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Incorporating the Constraint-Source Model into the First-Year Design Experience

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Dr. Estell is active in the assessment community with his work in streamlining and standardizing the outcomes assessment process, and has been an invited presenter at the ABET Symposium. He is also active within the engineering education community, having served ASEE as an officer in the Computers in Education and First-Year Programs Divisions; he and his co-authors have received multiple Best Paper awards at the ASEE Annual Conference. His current research includes examining the nature of constraints in engineering design and providing service learning opportunities for first-year programming students through various K-12 educational activities. Dr. Estell is a Member-at-Large of the Executive Committee for the Computing Accreditation Commission of ABET, and also serves as a program evaluator for the Engineering Accreditation Commission. He is also a founding member and serves as Vice President of The Pledge of the Computing Professional, an organization dedicated to the promotion of ethics in the computing professions through a standardized rite-of-passage ceremony.

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Abstract - **The purpose of this workshop is to present the Constraint-Source Model (CSM) framework and preliminary evaluation data from an initial deployment of the CSM to the first-year engineering community for review, discussion, and refinement. The CSM is conceptually based on four characteristics traditionally associated with the entrepreneurial engineering mindset: technical fundamentals, customer needs, business acumen, and societal values. Our hypotheses are that, by categorizing constraints such that the source of a constraint is also included, an engineering student can (1) examine each constraint from the point of view of a stakeholder from that source area, thereby allowing for a greater perspective on how such constraints can affect the design, and (2) gain an appreciation for the general education courses that provide that perspective. Resources developed to date in support of this framework will be provided. Attendees will have opportunities to apply the CSM towards different design scenarios, to participate in evaluation of student submissions, and join in a facilitated discussion afterwards.**

Index Terms – First-year design, design process, evaluation metrics, constraints.

DESIGN PROJECTS IN THE FIRST YEAR

First-year engineering programs often include a design project within the curriculum. The introduction of the design project meets goals often mentioned in these programs: experiencing an engineering design process, incorporating some amount of hands-on experience (typically with a lower-fidelity proof of concept or prototype), and demonstrating that a design can meet the goals for some customer. These designs, like designs in the "real world," are constrained in many ways and must meet suitable evaluation metrics to prove their success to an acceptable level. However, the discussion of constraints and evaluation metrics is often limited in the first year curriculum; this can lead to a lack of appreciation for the consideration of realistic constraints and evaluation metrics within a design. Furthermore, evaluation metrics and realistic constraints are usually covered near the beginning of the first-year design process, and then no longer discussed. At best, students are asked to demonstrate that their design met the established evaluation metrics. The purpose of this workshop is to introduce a more robust and meaningful pedagogical approach towards realistic constraints, particularly in their introduction within the first year of engineering.

THE "ELITE EIGHT" ABET REALISTIC CONSTRAINTS

In the ABET Engineering Criteria (*Criteria*), Criterion 3 (Student Outcomes) states that engineering programs must have documented student outcomes, including:

(c) an ability to design a system, component, or process to meet desired needs within realistic constraints ***such as*** economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability (*emphasis added*). [1]

Although the phrase "such as" is present as a modifier indicating that the eight constraints that follow are to be treated as examples, many programs view this list – an "Elite Eight" of realistic constraints - to be exhaustive. By publishing this list in the *Criteria*, ABET has inadvertently created a two-tiered classification scheme that emphasizes the Elite Eight constraints to the exclusion of all other possible constraints. As a result, many instructors wind up "teaching to the test" by focusing only on the Elite Eight, and students (along with some faculty) mistakenly assume that these constraints are the only ones that matter with respect to engineering design. Additionally, by not providing an appropriate context, ABET inadvertently discounts the very nature of constraints: that, instead of being holistic entities, constraints emanate from the various direct and indirect stakeholders associated with a product and its design. It should be noted that ABET is considering a proposal that would relocate and modify the above language as part of the definition for engineering design. [2] To avoid the perception of an exhaustive list, the revised language states that "for illustrative purposes only, examples of possible constraints include accessibility, aesthetics, constructability, cost, ergonomics, functionality, interoperability, legal considerations, maintainability, manufacturability, policy, regulations, schedule, sustainability, or usability."

Typical industrial designs involve far more constraints than just the Elite Eight presented in the *Criteria*, and the analysis is often more nuanced, such as making a distinction between the impact that the accuracy and the precision of a particular component can have on a design. Additionally, a constraint can take on multiple roles based on the point of view, or source, from which the constraint emanates: for example, the set of environmental constraints for an automobile includes not only how the design can affect the environment (such as the societal impact of carbon emissions), but how the environment can affect the design (such as the corrosive effects of road salt used for deicing roads).

INTENT OF THE WORKSHOP

In a speech given in 1976, the industrial designer Dieter Rams expressed several of his core beliefs, including:

> "*You cannot understand design if you do not understand people; design is made for people.*" [3]

Taken more broadly, the ramifications of engineering design span the disciplines – impacting the people, places, environment, and businesses that the product or system touches throughout its lifecycle. Accordingly, to become good at design, a designer must become at least familiar with the various aspects of the human condition as experienced through the study of the humanities, the environment through the study of the natural sciences, and the mechanisms of the economy through the study of business. Engineering students require a broad-based education, grounded not only in STEM (science, technology, engineering, and math) related topics, but also in the liberal arts and in business. This, therefore, is the underlying rationale for engineering majors to take general education courses.

The Constraint-Source Model (CSM) builds upon this educational framework by assuming that each constraint affecting a design can be modeled as an attribute derived from one of four possible source classification areas: business-driven, customer-driven, society-driven, and technically-driven. This assumption is conceptually based on the four identified characteristics of the entrepreneurial engineer as stated in 2010 by the Kern Engineering Entrepreneurship Network (KEEN) [4]:

- An understanding of the **technical** fundamentals of engineering,
- An understanding of **customers**,
- An understanding of **business** to support the organizations in which they work, and
- An understanding of **societal** values.

The Constraint-Source Model provides eliciting quantitative and qualitative questions for a set of 39 commonly experienced design attributes (please see Table I for the list of current attributes), allowing one to categorize the level to which each attribute serves to constrain the solution space for the problem being addressed.

The CSM will be explored in the workshop through planned activity sessions, including application of the guiding questions, evaluation of student responses, and application of a proposed expansion of the framework regarding relative importance of various attributes. The activity sessions will be followed by facilitated discussion sessions. Workshop leaders include an ABET expert with both program evaluator and commissioner experience, and a coordinator of a first-year engineering program with research experience in pedagogical development and studying student success.

BACKGROUND

For many years, students in the first-year introduction to engineering course sequence at Ohio Northern University have used poverty alleviation in developing countries as a theme for their culminating design experience. [5, 6] However, the results of course assessments indicated that students had difficulty in understanding how the real world can influence and thereby constrain design. The CSM was subsequently developed as a tool for exposing students to potential sources of design constraints and shared last year with the first-year and design communities. [7, 8]

In the fall of 2016 a study was conducted to evaluate how engineers at various experience levels – first-year, seniors, and practicing professionals – use this tool to perform constraint analysis. [9] For this research, a subset of 15 design attributes (shown as shaded attributes within Table I) was used, so as to not overwhelm the first-year students serving as the baseline for this study. Participants in the study were presented with a problem of someone wanting an easier way to haul Christmas holiday items in and out of an existing household attic located above the garage, along with instructions for using the Constraint-Source Model to perform the constraint analysis.

TABLE I
LIST OF CSM DESIGN ATTRIBUTES
ATTRIBUTES USED IN PILOT STUDY ARE HIGHLIGHTED

Design Attributes **Organized by Constraint-Source Area**	
Business	**Society**
Competition	Affordability
Ethical	Customs/Traditions
Labor	Environmental
Liability	Health
Manufacturability	Manufacturability
Regulatory	Policy
Schedule	Regulatory
Supply Chain	Safety
Sustainability	Sustainability
Technical	**Customer**
Accuracy	Accessibility
Capacity	Aesthetics
Electrical	Efficiency
Environmental	Ergonomic
Manufacturability	Health
Mechanical	Learnability
Physical	Maintainability
Precision	Physical
Reliability	Risks
Size	Safety
Thermal	

For each attribute, a question was posed consisting of five quantitative responses ("definitely", "probably", "maybe", "probably not", and "definitely not") and one qualitative response area for explaining the chosen quantitative response. For this study, no further definition of the design attributes was provided aside from the context of the question. To present an example of the benefits of the CSM, note that both the Society and the Technical Constraint-Source areas present "Environmental" as an attribute. Environmental is listed as one of the "Elite Eight" realistic constraints, but its listing within the CSM draws the following distinctions based on the source, where "T-4" is the code for the technically-sourced attribute, and "S-3" is the code for the societally-sourced attribute:

- [T-4. Environmental] Can the operational environment negatively impact the product through normal use?
- [S-3. Environmental] Is it probable that the regular use of this type of product might have a potentially negative impact on the environment?

The aggregate quantitative responses for these two questions are presented in Table II, where the data columns represent the tallies from the first-year engineering students for definitely, probably, maybe, probably not, and definitely not.

TABLE II
RESPONSE TO T-4 AND S-3 ENVIRONMENTAL QUESTIONS

Attribute	D	P	M	PN	DN
T-4 Environmental	19	22	27	20	8
S-3 Environmental	5	10	26	36	17

These results indicate that many students are able to differentiate the technical and societal aspects of the environmental attribute. However, deeper analysis of justifications would be needed to explore the validity of these identifications. Overall, the responses raise interesting questions regarding how to best approach introducing first-year engineering students to the various aspects of engineering design.

FUTURE WORK

Future research includes the study of (at least) three research questions evolving from the realistic coverage of constraints through the CSM:

1. *Does covering realistic constraints through a model that ties a design attribute to its stakeholder-oriented source lead to a better appreciation of General Education courses?* The authors hypothesize that, by presenting the CSM and related supplemental information in the first year, the coverage of realistic constraints will help students make a stronger connection to their general education courses. Through a greater emphasis on the nature of realistic constraints, students are being given a reason grounded in reality to consider their general education courses as important to their future careers as engineers.
2. *Does the CSM provide a functional means of assessing student thinking about the possible limitations present in an engineering design?* The authors hypothesize that, through expansion of the framework to include judgement about relative importance of potential sources as well as refinement and calibration of the assessment approach, the CSM will provide such a tool.
3. *Does the early emphasis of constraints in a realistic framework lead to increased attention to such detail in the engineering design projects in future years?* The authors hypothesize that the early introduction of these concepts will have a lasting affect throughout the remaining years of the student's engineering program.

REFERENCES

[1] ABET Engineering Accreditation Commission, "Criteria for Accrediting Engineering Programs: Effective for Reviews During the 2015-2016 Review Cycle," 2014. Accessed online: http://www.abet.org/wp-content/uploads/2015/05/E001-15-16-EAC-Criteria-03-10-15.pdf, 5/18/2016.

[2] ABET Engineering Accreditation Commission, "Comparison of Proposal Submitted in 2015 to Proposal Submitted in 2016," 2016. Accessed online: http://www.abet.org/wp-content/uploads/2016/08/EAC-Side-By-Side-Criteria.pdf, 4/2/2017.

[3] Dieter Rams, "Design by Vitsoe," 1976. Accessed online: https://www.vitsoe.com/files/assets/1000/17/VITSOE_Dieter_Rams_speech.pdf, 5/22/2016.

[4] Timothy J. Kriewall and Kristen Mekemson, "Instilling the Entrepreneurial Mindset into Engineering Undergraduates", J. Engineering Entrepreneurship, vol. 1, no. 1 (July 2010), pp. 5-19. Online: http://www.jeenonline.com/Vol1/Num1/Vol1No1P1.pdf

[5] John K. Estell, Kenneth J. Reid and Jed Marquart, "Addressing Third-World Poverty in First-Year Capstone Projects," *American Society for Engineering Education Annual Conference Proceedings (K-12 Division)*, June 2010.

[6] Kenneth J. Reid and John K. Estell, "Incorporation of Poverty Alleviation in Third World Countries in a First-Year Engineering Capstone Course," *International Journal of Engineering Education*, vol. 26, no. 6, 2011, pp. 1273-1280.

[7] John K. Estell and Kenneth J. Reid, "Workshop: Incorporating Realistic Constraints into the First-Year Design Experience," 8th First-Year Engineering Experience Conference, Columbus, OH, August 1, 2016.

[8] John K. Estell and Kenneth J. Reid, "Incorporating Realistic Constraints into the First-Year Design Experience," Proceedings of the 8th First-Year Engineering Experience Conference. Available online: http://fyee.asee.org/FYEE2016/papers/M7.pdf

[9] J. Blake Hylton, John K. Estell, Todd France, and Louis A. DiBerardino III, "Work in Progress: Do Students Really Understand Design Constraints? A Baseline Study," *American Society for Engineering Education Annual Conference Proceedings (Design in Engineering Education Division)*, June 2017.

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