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Special Issue

**Clive L. Dym Mudd Design Workshop XIII
Collaborations in Student Design Experiences**

Guest Editor

Gordon G. Krauss – Harvey Mudd College, Claremont, CA, USA

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David Gray, Julia Devoy, Kathryn Wozniak, Tsailu Liu and Daniel Harding

While much focus has been placed on the student learning outcomes of interdisciplinary and human-centered design programs, there has been less investigation into the experiences and developmental outcomes of the instructors who deliver these programs. Specifically, important questions exist in relation to the potential of such experiences to foster instructor professional growth and meaningful development. Building off a model of instructor professional development that emphasizes the interconnectedness of growth mechanisms in courses led by a single instructor in a single program, this community analytic autoethnography explores instructor growth and development in an intercollegiate, interdisciplinary human-centered design program co-instructed by faculty from four institutions of higher education. Our qualitative study shows that in addition to interconnected instructor growth mechanisms within each faculty member involved, distributed growth mechanisms mediated by cross-instructor reflection open up additional multi directional pathways for professional growth and career development. Moreover, our group successfully fostered a culture and mindset of interdisciplinary appreciation and respect among the participating faculty, contributing to our own collective growth, enriching both individual experiences and the overall Design for Impact (DFI) program dynamics. This interdisciplinary culture and mindset not only enhanced the learning environment for participating students across multiple academic and professional majors at four universities, but also contributed to ongoing development of the DFI core faculty, as well as, faculty adjacent to those directly involved in DFI. However, despite this culture, growth mindset, and reflective practices employed, the basic limitations of time set aside for intentional, mutual reflection were inadequate to completely resolve reflective pathways for learning and growth. These incomplete collective reflection pathways underscore the ongoing need for dedicated time and embedded, structured processes to support comprehensive growth networks among instructors, especially in co-teaching contexts.

Keywords: interdisciplinary design; faculty development; interinstitutional; human-centered design

Unlocking the Secrets of Intuition Use: Evaluating Solutions and Predicting Outcomes During Engineering Problem Solving	1295–1312
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Intuition is a hidden problem-solving skill used in engineering and design. Engineering intuition has been specifically defined as subconsciously leveraging experience to evaluate a present situation or predict a future outcome. This paper uses the Predicting and Evaluating in Engineering Problem Solving (PEEPS) instrument to explore how students navigate problem solving. The instrument includes a mechanism to assess the effect of confidence on problem solving as well as the differences in approaches to solving prediction and evaluation problems. The aim of the measure is to better understand intuition use in engineering. We analyzed fixed item and open-ended responses from 271 participants. The base of PEEPS includes two problems paired with follow-up Likert scale and open-ended questions. The current problems presented in the PEEPS instrument are contextualized within statics. Quantitative data was analyzed through one-way ANOVA, independent samples t-test, correlation analysis, chi-squared tests, and Fisher's Exact test, while qualitative data was analyzed using a thematic analysis approach. We found that participants who answered the statics problems correctly were more likely to report higher confidence, have received better grades in statics, and use a combination of prior knowledge and conceptualization to solve the problems. Participants who were confident in their answers and participants who were high performers in statics appeared more comfortable with their answer when evaluating an existing answer rather than making a prediction. Our findings suggest that our sample population had high metacognition and that there may be a difference in how students approach prediction and evaluation problems. The emergent code of Instinct is most closely related to the colloquial definition of intuition and was not linked to the use of prior knowledge.

Keywords: problem solving; survey; mixed-methods research; expert-novice; metacognition

Use of Different Prototype Modalities for Design Communication in Industry-Sponsored, Interdisciplinary Capstone Design Teams during COVID-19	1313–1322
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Pablo Luna Falcon, Hannah Budinoff, Julia Kramer and Jannatul Bushra

Students' participation in a culminating engineering design experience is an important element of many undergraduate engineering programs. A typical outcome of this experience is for students to communicate a clear understanding of the design problem and associated constraints, describe their design process, and illustrate that their final design meets its requirements. Effective communication skills are an influential factor for success and are considered a critical learning objective for capstone engineering courses. Even though visual media such as sketches and prototypes are an essential means of communication, little work has been done analyzing their use in students' design communication. In this study, we seek to identify and compare prototype usage of

different modalities among student design teams. Data was collected from approximately 8-minute video presentations that served as a final deliverable in an interdisciplinary capstone course during the 2019–2020 academic year, which was interrupted by the COVID-19 pandemic. Prototypes shown in the videos were classified by prototype category and the duration of prototypes presented in each video was recorded. We sought to understand how prototype usage varied between teams who were given awards from panels of judges and to identify patterns in prototyping among teams with different compositions of student majors. The results indicated that a larger proportion of prototypes were displayed by awarded teams compared to teams who did not win an award. Several differences in digital and physical prototype usage were seen among engineering disciplines. Across all teams, a higher use of digital prototypes was identified when compared to physical prototypes. Mechanical teams showed the highest proportion of physical prototypes, while interdisciplinary and chemical engineering teams showed the least. This study contributes to the understanding of visual artifacts and prototypes as means of communication (especially virtual communication) and provides guidance for student designers for effective demonstration of engineering projects.

Keywords: prototyping; capstone design; virtual prototyping

A Collaborative Inquiry into Tensions between Empathy and Engineering Design

1323–1338

Corey Schimpf, Nicholas D. Fila, Justin Hess, Allison Godwin, Elizabeth Sanders, Kirsten H. Dodson, Molly H. Goldstein and Rob Sleezer

Empathy has received increased attention for its role in engineering design. While research on empathy in engineering and engineering design is still relatively new, there are already several definitions or models of empathic design for engineers. Moreover, there are a variety of ways that scholars have integrated empathy into engineering design curricula. In this study, to better understand how instructors can integrate empathy into engineering design curricula and unveil the benefits, opportunities, and challenges of its integration, eight engineering design instructors formed a collaborative inquiry (CI) group. In CI, members act as researchers and participants to collectively explore their experiences with a topic of interest. The participant-researchers of the CI group for this study formed out of a larger project that seeks to create a model of empathy in engineering design and instrumentation to assess the model's manifestation in students' engineering design experiences. In this larger project, several tensions emerged related to empathy's integration into engineering design education. In response, we formed the CI group to address the question, "What tensions are experienced by engineering design researchers and educators regarding the construct of empathy in our educational practice?" Tensions recognize that problems or challenges may have two or more responses. The CI team met six times to identify tensions regarding empathy in engineering design as experienced in their teaching practice. Through our collaborative inquiry, we generated a model that represents our understanding of these tensions. The model included ten themes, which included four empathy frames (definition, value, manifestation, and pragmatics) and six intersections between these frames. Our results share insights from our discussion on five of the ten themes. We close the paper by reflecting on the model and the process of building the model. We offer that the model can be useful for other design instructors to integrate empathy into their curriculum and practices for thoughtfully responding to these tensions. We hope this work can help extend and facilitate ongoing research on empathy in engineering design.

Keywords: engineering design; empathy; collaborative inquiry; tensions framework

Collaboration, Professional Preparation, and Personal Growth: Alum Validation of Capstone Design Outcomes

1339–1349

Susannah Howe

Capstone design courses serve a dual role of synthesizing the undergraduate engineering experience and supporting student transition to life and work after graduation. Alum voices are an especially important, but underutilized, resource in affirming the outcomes of capstone design courses. This paper focuses on a set of ten podcast episodes featuring interviews with alum teams from the Smith College capstone course, Design Clinic. The alums graduated between 2006 and 2022 and collaborated on Design Clinic projects with different sponsoring organizations. Their responses regarding their Design Clinic experiences, transferable skills, role of Design Clinic in their undergraduate experience, and advice to future Design Clinic students revealed a number of common themes that can be organized into three primary categories: collaboration, professional preparation, and personal growth. The alum perspectives serve as a validation of the intended Design Clinic outcomes and also as a pedagogical tool to motivate current and future students.

Keywords: capstone design; learning outcomes; alum feedback; podcast

The Students Are Doing The Best They Can: Reframing Why Inequitable Community Engagement Happens in Engineering Design Higher Education

1350–1369

Kaylla Cantilina and Robert P. Loweth

Community engagement is a core part of socially engaged engineering work, and undergraduate engineering programs are increasingly providing curricular and co-curricular opportunities for students to develop community engagement skills. However, if not conducted and managed with an intentional focus on equity, these opportunities risk exploiting communities and exacerbating existing problems regardless of student efforts or skill level. While prior research has mainly explored students' skills and mindsets related to community engagement, this study uses an agentic framework, combined with Domains of Power, to investigate how factors beyond students' control – i.e., external factors – impact the equitable nature and outcomes of students' community engagement experiences. Using data-driven composite counter-storytelling, the researchers present a semi-fictional, transferable narrative grounded in data from their own and their participants' community engaged experiences to explore how external factors influence engineering students' stakeholder engagement activities and outcomes in curricular and co-curricular design project contexts. The data-driven composite narrative describes the experiences of a student, Ash, during two pivotal stakeholder engagement opportunities: a design project during their first-year Introduction to Engineering course, and a co-curricular community-based service-learning project. Analysis of Ash's narrative highlights how external factors, including interpersonal, curricular, institutional, and societal factors, impact the equitability of engineering students' stakeholder engagements. The outcomes of the analysis suggest different ways that faculty and administrators can support students, in addition to developing new stakeholder engagement pedagogies.

Keywords: agency; Domains of Power; composite counterstory; community engagement; engineering students; equity

Assistive Technology and Human-Centered Engineering Design: Partnership between a School that Serves Students with Extensive Support Needs and a Human-Centered Engineering Program

1370–1377

Avneet Hira, Jennifer Gemski and Justin Henriques

In this paper, an Assistive Technology Professional (ATP) and two engineering instructors share how an engineering program and a school that serves students with extensive support need develop a partnership based on engineering design and the development of assistive technologies. We use a qualitative cross-case analysis approach to understand and share the development of the partnership over three sequential courses, each of which we frame as a case. While there are differences in the cases informed by the time in the partnership they took place, prioritizing front-end design vs. prototyping activities, and different learning outcomes for the courses, some strong themes to understand key aspects that inform the partnership emerge. These themes include building sustainable partnerships of trust, the role of people as connection agents, centering issues of power and justice, and engineering design as a medium to support partnerships.

Keywords: assistive technology; authentic partnerships; design justice; human-centered engineering

Laura R. Murphy, Thanina Makhoul, Shanna R. Daly and Colleen M. Seifert

Engaging stakeholders is a key part of successful engineering design projects. The set of stakeholders with whom engineers engage influences engineering outcomes, where divergent thinking can support a collection of broad perspectives to guide the work. In design processes, divergent thinking is used to consider a variety of solutions, problem understandings, and process pathways, as well as a variety of perspectives of both internal and external stakeholders. Business management literature describes stakeholder identification methods and engineering literature describes stakeholder engagement approaches, yet engineering literature has not addressed barriers to and supports of divergent thinking about potential stakeholders within practitioners' disciplinary, work, and personal contexts. As part of a larger project on divergent thinking, this paper focuses on engineering practitioner barriers to and facilitators of divergent exploration of stakeholders. In our study, we interviewed twenty professional engineers about their divergent thinking about stakeholder perspectives in one of their engineering projects. The data revealed eleven barriers to and eight facilitators of divergent exploration of stakeholders as well as reasons the practitioners valued stakeholders. Our findings advance research on engineers' experiences with divergent thinking about stakeholders and suggest ways to leverage professionals' experiences in early-career design education to assist engineers as they learn to consider and collect stakeholder perspectives.

Keywords: divergent thinking; stakeholder exploration; engineering practitioners

Joshua D. Summers, Apurva Patel and Marissa L. Shuffler-Porter

Teamwork is a 21st Century Skill that is recognized as critical for engineering student development. The primary approach to develop this skill in engineering curricular is through team project work. Assessing the teamwork skills has primarily been through peer evaluation, direct observation, and student contribution essays. The faculty who are typically charged with assessing the collaboration and teamwork skills of students are often not well versed in the socio-psycho metrics associated with team science. Thus, it is important that a teamwork skill development assessment mechanism be offered that is easy to use, objective, and meaningful. This paper presents a discussion and proposal for using scenario building and heuristic authoring as a pre- and post-test instrument to evaluate student growth in teamwork. The equivalency of these scenarios is an important consideration. Additionally, a heuristic evaluation protocol is presented. This work still requires detailed validation in the classroom with triangulation against other more traditional means.

Keywords: teamwork; collaborative design; heuristics modeling; capstone design; design research

Grace Bursleson, Kentaro Toyama and Kathleen H. Sienko

Incorporating contextual factors throughout a design process is necessary for successful outcomes in global health settings. However, additional tools are needed to equip engineering students with skills to investigate and incorporate contextual factors into their design processes. We developed in-depth narratives from three real design experiences to demonstrate how design practitioners incorporate a broad range of contextual factors into their global health solutions. Since incorporating context is not yet systematized in engineering design work, narratives provide necessary nuance and exposure to the concepts and approaches used by experienced designers. Our findings highlighted several ways engineering design practitioners incorporated contextual factors into their design processes, including regularly conducting first-hand observations, developing meaningful relationships with stakeholders, and using iterative and adaptive design approaches that allow for contextual factors to emerge throughout a design process. Ultimately, we recommend engineering educators encourage more consideration and incorporation of contextual factors into engineering design processes, particularly in global health settings. These narratives can be used in engineering classrooms to support novice designers' acquisition of skills related to incorporating contextual factors into engineering design processes.

Keywords: design practice; global health; contextual factors; narratives; engineering education

Nick D. Moses, Shanna R. Daly, Jacqueline Handley and Kathleen H. Sienko

Collaborations within engineering student teams and among student teams and community partners, end users, and other stakeholders are an integral part of design projects that can support positive social impact. Engineering programs and experiential learning opportunities that emphasize positive social impact are becoming increasingly popular. These programs, focused on what we collectively call "design for social good," often lack explicit consideration of the role of positionality, which can be defined as the ways an engineer's and other stakeholders' identities shape relative social and political position in a specific design context. Without sufficient consideration of positionality, engineering students are not likely to fully recognize and reflect on broad problem contexts, diverse perspectives, or power dynamics among themselves and other stakeholders, nor understand how personal values and biases influence design decisions, ultimately affecting the effectiveness of design solutions. Moreover, empirically-based pedagogy on the consideration of positionality in engineering design work is lacking. To support the exploration of the effects of positionality in engineering design, this research characterized the ways engineering student designers conceptualized their positionalities in early-stage design for social good projects. A written reflection activity, followed by a semi-structured interview, was conducted with five engineering students engaged in design for social good projects. Key findings included (1) connections between participants' own minority identities, related life experiences, and conceptions of positionality in engineering design, (2) a range of the types of conceptions related to positionality across participants, and (3) characterization of the ways in which participants' conceptions changed as a result of participation in this research. We end with recommendations for the development of engineering design education strategies to improve the consideration of positionality for engineering students engaged in design for social good projects, with implications for stakeholder engagement and partnership-building skill sets.

Keywords: design; positionality; identity; student; engineering; education

Haley Cutler, Jorge Martinez, William C. Oakes, Andrew Pierce and Robin Terwilliger

Situating design experiences within the context of addressing human, community or environmental needs has many benefits to enhance the student experience. It provides meaning to the design work that can increase motivation and student interest. The broader context of making a positive impact on people and the environment aligns with research on diversity in engineering. These contexts also provide platforms for students to explore broader issues within our societies that include societal, cultural and policy dimensions from a personal and professional perspective. Partnerships are central to community engaged learning and take many forms. Community partners are critical as they provide the context and real stakeholders that interact with the students. They are the recipients and stewards of the results of the designs. They can be an actual community, leaders from government, non-profits, or non-governmental organizations (NGO's), schools or other organizations that work with people or the environment. The EPICS Program at Purdue University has engaged undergraduates with local and global community partners for 28 years and this paper describes how partnerships are established and nurtured within the program as it has scaled to more than 50 partnerships and 1300 students per year. 40% of the partners have worked with the program for more than 10 years and 84% for more than their original commitment of five years. Lessons learned are shared from the perspective of the program leaders as well as voices from the partners themselves.

Keywords: community engagement; partnerships; reciprocity; service-learning

Marie Stettler Kleine, Dean Nieuwma, Chelsea Salinas and Aubrey Wigner

In this paper, we provoke a discussion regarding how engineering educators perceive and frame engineering problem solving and its central role in engineer education’s pervasive narrowing of perspectives. We catalyze dialogue about equipping our students with the engineering judgment necessary to assess their institutional, professional, and epistemological positionality. We aim to empower students to open the black box of problem definition, yes, but we also want them to be attuned to the power and limits of traditional engineering problem solving as such, so they can effectively deploy traditional engineering methods when generative and, when too restrictive, move beyond them. The paper draws attention to engineers’ predilection for objects/artifacts, pragmatism, and quantitative approximation as specific examples that frame what engineering work has been, hoping that engineers (as counter examples) can expand beyond these traditional conceptions of technical work. The authors, critical participants in forming a new degree program in Design Engineering, first describe what is at stake if engineers focus too narrowly. Next, literature from engineering studies, a subfield of science and technology studies, contextualizes how an expansion of engineering jurisdiction is appropriate. This jurisdiction expansion is described by moving from simple problem solving to problem definition and solution, to further include “problem framing.” This paper then details our academic program, Design Engineering at Colorado School of Mines, where we have attempted to overcome narrowly defined conceptions of engineering work through problem framing. We reflect on our curriculum and program building as a generative site for defining what engineering judgment is and ought to be. Rather than attempting to provide a series of best practices, this provocation seeks to promote a deeper conversation on how we frame engineering work. Intermittent attention to problem definition, however effectively executed, is not adequate to the task of challenging narrow techno-solutionist educational frameworks. We aim to spark conversations about the solutionism embedded into engineering, questioning engineers’ limitations and opportunities for growth in key areas, including learning how to implement problem definition and solution while simultaneously critiquing its boundaries and expanding its utility.

Keywords: problem solving; problem definition and solution (PDS); problem framing; engineering judgment

Society Centered Learning: Approaching Society as a Complex System with Diverse Stakeholders

1457–1466

Elizabeth M. Gerber and Amy O’Keefe

Building on the increasing interest in designing in complex systems, Society-Centered Learning (SCL) is an emergent pedagogical approach that approaches society as a complex system and allows students to work on discrete aspects of the system. This autoethnography explores the role of a broad set of dynamic stakeholders and how students collaborate with them. We investigate the unique benefits and challenges of coordinating, planning, and teaching this approach in the classroom and communicating and managing relationships with stakeholders before, during, and after the course. Observations are based on our experience working with nine distinct sets of stakeholders in graduate-level studio-based service design courses over a ten-year period. In addition to contributing a model of Society Centered Learning to design education, we outline future research and practice.

Keywords: systems design; complex systems; stakeholders; society centered learning

Enhancing the Value Co-Creation in Student Team Project among the School of Design and the Department of Mechanical Engineering through Interdisciplinary Pedagogical Approach

1467–1478

Luqian Wang and Yi-Teng Shih

Within the ever-changing world, it is recognised that specialized disciplinary skills are limited in their ability to deal with complex real-world problems. This recognition has spurred the proliferation of various interdisciplinary pedagogical approaches aimed at equipping students with a more comprehensive skill set. In this backdrop, a pilot co-teaching curriculum was developed and implemented to foster interdisciplinary collaboration between the School of Design (SD) and the Department of Mechanical Engineering (ME) at The Hong Kong Polytechnic University. Seven final-year undergraduates from SD and ME were grouped to collectively embarked on graduation projects centred around the pertinent issue of air quality during the pandemic. The curriculum design and delivery were steered by the action research model, enabling a reflective process of curricular refinement and innovation. To evaluate the implication of this pilot curriculum, pre- and post- self-assessment questionnaires were administered to measure competencies in creativity, critical thinking, communication, and teamwork. The findings revealed enhancements across all assessed competencies, underscoring the effectiveness in fostering essential soft skills. However, only design students demonstrated statistically considerable improvements in communication and teamwork skills, which potentially attributes to bias caused by the limited sample size. Additionally, thematic analysis of students’ self-reflection reports uniformly highlighted the distinct mindsets in problem-solving process between SD and ME students. Students reflected that the interdisciplinary collaboration was largely expand problem exploration spaces, promoting value co-creation, learning experience and outcome. This study suggested the effectiveness of interdisciplinary pedagogy at the levels of curricula, which is potentially replicable across other disciplines.

Keywords: interdisciplinary pedagogy; co-teaching; pedagogical innovation; collaboration; value co-creation

Teaching Engineering Design With People, Problems, and Prototypes

1479–1498

Desen S. Özkan and Nicole Batrouny

Modern professional engineering has the impression of being about solving grand, global problems through an emphasis on technical skills and knowledge. However, many liberal arts students perceive engineering as an intimidating field that is hard to understand and gain entry to. In this paper, we describe a new, nontraditional course for non-engineering majors developed to introduce liberal arts students to engineering decision-making and ways of thinking. Through analysis of our own experience designing and teaching the course, paired with students’ class artifacts, reflections, and retrospective interviews, we examine the reflections and insights from two focal students constructing and deconstructing their own understandings of engineering as they address a local infrastructure problem. This process unfolded in relation to particular course design elements: interdisciplinary readings and reflective discussion; focusing on decision-making in engineering; and group project collaborations. We contend that critique and design are complementary, and that critique offers entry points for liberal arts students to bridge their ways of thinking to engineering decision-making. Ultimately, this course was positioned to open up the black box that can be engineering as a way to seed future interdisciplinarity across engineering and the liberal arts.

Keywords: non-engineers; engineering design; interdisciplinarity; qualitative research

Learning Through Product-Based Learning with Emphasis of People, Process, and Product Across Multi-Disciplinary Courses

1499–1506

Micah Lande

This research paper extends the frameworks of PBL as project-based learning to describe a concept of “product”-based learning – learning experiences that focus on the deliberate design and making of tangible products with some engineering complexity as the learning goal of a course. A multiple case-study approach is used to apply and illustrate a “product”-based learning framework to multiple multi-disciplinary courses: a global design innovation course with corporate project sponsors, and a mechatronic (smart products) design course. We develop and describe three dimensions for considering the pedagogical intent of such courses along axes of people-focused, product-focused, and process-focused in their efforts to give students practice as engineers and engage in industry and partner projects.

Keywords: design education; pedagogy; product-based learning; project-based learning; multi-disciplinary learning

To better serve the evolving needs of society through responsible design, we must better educate the next generation of engineers to continue innovating and advancing technological solutions for the betterment of humanity. Wake Forest Engineering was built on the mission to Educate the Whole Engineer with a vision for our graduates to make positive societal impact (For Humanity). In educating the whole engineer, we must recognize that the complexities of engineering practice involve not only technical domains of learning (e.g., technical engineering knowledge, processes and thinking, fundamental principles, advanced technological methods and tools, prototyping, testing) but also non-technical domains of learning (e.g., collaboration and teamwork, engagement with stakeholders, effective communication, project management, ethical decision making, entrepreneurial mindset, professionalism, character development, etc.). The closest we come to engineering practice within undergraduate education is capstone design project experiences typically found in the senior year. Like engineering practice, engineering design involves not only technical domains of learning (e.g., design process and thinking, design principles, design methods and tools, prototyping, testing) but also non-technical domains of learning (e.g., collaboration and teamwork, engagement with stakeholders, effective communication, project management, ethical decision making, entrepreneurial mindset, etc.). It is thus imperative for engineering educators to use appropriate pedagogical approaches to prepare engineering graduates for the complexities associated with real-world engineering practice and this can happen during capstone design experiences. Because both technical and non-technical domains of learning involve cognitive development for the learner, this paper connects engineering design, in the context of capstone design experiences, with a cognitive learning theory that is appropriate for engineering practice and engineering education – cognitive apprenticeship. The purpose of this paper is to reflect on the appropriateness of cognitive apprenticeship as a model to support pedagogical approaches and innovations in engineering design education via capstone design experiences. Applied to both technical and non-technical domains of learning within capstone design at Wake Forest University, we have discovered that cognitive apprenticeship can offer a meaningful way to develop and reflect on pedagogical features that can support engineering student development. Cognitive apprenticeship is grounded on six phases of learning – modeling, coaching, scaffolding, articulation, reflection, and exploration – and all these phases are important to the learning complexities of engineering design. While capstone design faculty may be better at scaffolding and articulation, we found that improvements could be made in regard to modeling, coaching, reflection, and exploration so that students can better cultivate engineering design competencies as well as entrepreneurial mindset and character development. We also found that while capstone design faculty may be more innately prepared to cultivate engineering design competencies and team effectiveness, more intentionality is needed with competencies like entrepreneurial mindset and character development. Knowledge gains at Wake Forest Engineering have significant potential for transferability to other engineering programs. Many opportunities for future work (research, pedagogy, and assessment) exist.

Keywords: capstone design; cognitive apprenticeship; coaching; engineering design; character; entrepreneurial mindset; educate the whole engineer

Assessing Divergence and Convergence in the Design Process: Results from Two Experiments 1531–1538
Arlindo Silva, Tamas Makany and Matt Chiu

It is often assumed that the design process comprises divergent and convergent thinking cycles. Although many authors studied the design process in depth, a quantification of divergence and convergence is yet to be established. This paper attempts to quantify divergence and convergence in the design process for teams of design students. Student submissions from two independent design-related courses from two Universities are analysed for divergent and convergent thinking. Such an approach uses Natural Language Processing to harvest existing student submissions in written documents and converts them into a ‘real-time’ dashboard for feedback that can be used in multiple ways: searching for a signature process for good design or as a feedback tool for both students and instructors. A specific universal pattern for “good design thinking” was not found in the experiment. However, several parameters often obscured by the lack of quantitative data about levels of divergence and convergence were uncovered. Future work must explore other patterns or factors relevant to instructors and students.

Keywords: divergence and convergence; natural language processing; design education

Strengthening the Link between Latine Communities and Engineering: Multicompetent Learners’ Expansive Design Perspectives 1539–1551
Greses Pérez and Sheri Sheppard

Every day engineers are tasked with developing solutions for an increasingly diverse population, which demands an understanding of social and technical dimensions of real-world complexity. Yet rarely are engineers trained to consider their own background in tandem with the language and cultural practices of the communities they are designing with and for when reflecting about the problems that get solved and the approaches they take to solve them. In this paper, we present exploratory work to characterize students’ responses to an engineering design task where participants were primed to incorporate communities’ ways of knowing and speaking through language and cultural cues. Specifically, we present measures that quantify the number and type of feature ideas a participant considers during the engineering design task. The results of our study suggest that Latina/o/x/e students who grew up in Spanish-speaking neighborhoods in the United States will offer more insightful features when the design task is presented bilingually by a Latina speaker relative to when is presented only in English by a white man. This work has implications for how we consider community resources in engineering design research and in reimagining engineering learning environments.

Keywords: design; Latine communities; engineering education research; multicompetent learners; bilingual design; undergraduate

Collaborative Project-Based Service Learning: What Motivates Students to Participate and What Do They Value After? 1552–1567
Deniz Dogruer, Vivek Rao and Alice Merner Agogino

Engineering design pedagogy has increasingly integrated project-based service learning (PBSL) across the curriculum for its promise of greater engagement of students, transfer of desirable skills, and improved student retention and persistence in STEM. However, little is understood about how student motivation for engaging in PBSL aligns with the actual perceived value that students derive from PBSL experiences. In this work, we examine three years of an engineering design course integrating a core PBSL element representing 70 participants and 17 projects, using a mixed-methods qualitative approach to ascertain student motivation, goals, and perceived value at four junctures before, during, immediately after, and 1–3 years after the PBSL experience. Our findings indicate that while students appear motivated to pursue PBSL experiences because of their desire to create positive impact, the sustained value they derive from PBSL experiences is primarily about career clarity and design process understanding. These results have important implications for how engineering educators present PBSL experiences to students, how they are positioned in a curriculum, and how they operate in conjunction with other efforts to promote retention and persistence in STEM.

Keywords: design pedagogy; Project-based service learning (PBSL); experiential learning; social impact; student motivation; perceived value