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The Veiled Problem of "Problem Solution": Problem Definition as Necessary but not Sufficient*

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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

1. Introduction

Engineering students and educators alike identify becoming effective "problem solvers" as core to their engineering identity formation [1–3]; however, the type of problem solving practiced in most engineering undergraduate courses is highly simplified compared to real-world analogues, with many of the real-world complexities that are not amenable to engineering analysis stripped away. This reductionist approach to engineering problem solving has been widely identified as a barrier to students' engagement with real-world engineering complexities [4], ultimately hindering their development of the skills and judgment needed for professional practice. With other scholars, we find this misalignment between problem solving in engineering education and professional practice to be of general concern in terms of career preparedness of graduates [1]. That broader concern notwithstanding, this paper explores a particular dimension of the larger phenomenon, specifically how "problem solving" can be so thoroughly reductive and yet still so central to discourses surrounding engineering education's effectiveness and how students characterize their core expertise. We leverage this incongruity in the planning of our own academic programming and explore educational strategies for addressing engineering problem solving in ways that better prepare graduates for the complex entanglements of professional practice.

One prevalent response to reductionist problem solving among engineering educators is to teach students to engage earlier in the design process, specifically by adding "problem definition" to students' workflow prior to "problem solution." Problem definition is the design step through which unbounded real-world problems are translated into "engineering problems" – that is, problems amenable to engineering analysis. Adding problem definition to engineering problem solving is often referred to as "problem definition and solution" or PDS. PDS is intended to open students to considering a wider range of contextual factors that shape real-world problems prior to their simplification into engineering problems, hopefully

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informing the simplification process to achieve more impactful and intentional engineering interventions [2, 5].

This paper's authors are leaders in the development of a relatively new Design Engineering bachelor of science degree program at the Colorado School of Mines (Mines). Mines is a mid-sized public university that focuses almost exclusively on STEM undergraduate and graduate programs. One of the central motivations for creating the Design Engineering program was to provide a more expansive approach to engineering education than traditional engineering disciplinary program, thereby aligning better with engineering professional practice. A key mechanism we identified for achieving that expansion was delivering repeated exposure to problem definition along with problem solution. In this sense, we are advocates for PDS and draw explicitly on that framework in our coursework, highlighting for students the importance of the problem definition phase of design to engineering project success. Somewhat to our surprise, however, our curriculum-development experience – and in particular our engagement with ABET accreditation planning – has highlighted for us that PDS is inadequate to addressing the root cause of engineering education's narrow conception of problem solving. Specifically, we found ourselves returning repeatedly to ABET's Criterion 3.1 – "an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics" [6] – homing in on both "engineering problems" and "applying principles of engineering." How might we engage this key student outcome, and implicit assumptions surrounding both "engineering problems" and "engineering principles," while holding true to our program's goals built upon PDS and an expansive approach to engineering practice?

As we have built our program's educational foundation upon PDS, our biggest conceptual challenge has been grappling with *the highly circumscribed presumption of what constitutes an "engineering solution" to begin with* [7]. To our surprise, we have found this challenge to be independent of whether the respective problem-solving process was preceded by problem definition. Rather than merely inserting problem definition at the front end of an engineering problem-solving process that otherwise remains identical – resolving as it does into the same narrowly focused engineering "solution" as prescribed by Criterion 3.1 – we have sought to shift the entire "problem space" upstream by displacing the end-step of a traditional engineering problem solution with our expanded frame. Rather than conceiving a "solution" as a single, discrete number; an optimized model; or even a discrete design proposal, that is to say, a final answer enclosed within a box, our programming seeks to interrogate this very conception of an "engineering solution" as reduced exclusively to that which is amenable to engineering analysis. Hence, in addition to replacing problem solution with problem definition and solution, we go one step further to explore "problem framing" – which we conceptualize as the rich interplay among our epistemological predilections, what we interpret to be problems worth solving, and the problem-solving tools at our disposal. We argue that *engineering judgment* is needed to effectively navigate the richness of problem framing, to know what one knows and how to apply it as well as the limits and positionality of that knowledge and its potential application within a given problem space.

This paper explores engineering problem framing and engineering judgment by first considering relevant scholarship from engineering studies, the subfield of science and technology studies that focuses specifically on engineering knowledge and practice. Next, we review the development of our academic program, Design Engineering, where we have labored to overcome narrow conceptions of engineering solutions. The following section considers our findings and reflects on some of the practical and theoretical implications of our work. We then conclude the paper by returning to engineering judgment and the importance of situating engineering knowledge within complex problem-solving environments with differential perspectives and goals.

2. Engineering Studies Literature on Problem Solving

2.1 Engineers' Lost Claims of Jurisdiction over Technology

Anthropologist and science and technology studies (STS) scholar, Gary Downey, claims that engineers have increasingly "lost claim of jurisdiction" over technological development, stating that engineers (and their educators) face four challenges to their jurisdiction and, as a result, the defining features of their work. First, scientists have increased their claims to the "applied" dimensions of their practice as being mainstream to their work, thereby incorporating technology increasingly as part of scientists' purview [5, pp. 438–39]. Whereas previously science was described as "upstream" to engineering, the linear notion of a science-to-technology pipeline has been thoroughly blurred. This blurring is reflected in STS through the conceptualization and study of "technoscience" as an alternative to science and engineering as mutually exclusive domains of practice [8].

Second, Downey addresses the mass production of engineers *as technicians* around the world [2]. Downey points here to the work of historian Rosalind Williams [9], which describes the credentialing of engineering by written exam as one of the main factors that has distanced engineers from the material and object-oriented core of their professional practice, such as that described by scholars like Louis Bucciarelli [10]. Williams describes a credentialing process based more on digital fluency and rote, applications-based versions of engineers' former identities, describing academic engineering departments in the United States as increasingly akin to applied information technology. These transitions in modes of professional formation dilute engineers' ability to claim real and complex problem solving as core to their training.

Third, engineers' jurisdiction over the development of technology is threatened by "the institutionalization of teamwork in industry" [2]. While many of the dominant images of engineering work in the 19th and 20th centuries were of single, individual inventors who worked by themselves, modern labor prioritizes teamwork. What follows is that engineers' lack of institutionalizing multidisciplinary participation leads to the distancing of relevant problem framing from engineers' purview. Below, we will describe teamwork as a productive opportunity space; however, in engineering programs and institutions where teamwork fails to incorporate participants from varied disciplinary perspectives, much of this potential is lost. These threats to the jurisdiction of engineering practice set the stage for Downey to claim that engineers must reposition themselves as problem definers as much as problem solvers. By taking greater ownership over which problems are theirs to solve and how those problems are operationalized so as to align with an expansive notion of engineering expertise, engineers can retain credibility as self-regulating, authoritative professionals and change makers.

2.2 Problem Definition and Solution

Downey established the problem-definition-and-solution (PDS) framework as a response to engineers' loss of jurisdiction over technology development [2]. Downey's construct of PDS provides a set of four practical strategies for engineering educators to apply in their classes and programs to address the challenges to legitimacy described above. First, engineers should be involved with early-stage problem defining so as not to be siloed as "purely technical" problem solvers (i.e., technicians). Too often in engineering education, the provided problem statement is so narrow and specific, so completely removed from any relatable context, that students can expertly solve the problem without understanding how or where such a solution might be relevant to "real-world" engineering practice [2]. Participating in problem definition allows engineers to develop a more holistic understanding of their work, including developing greater clarity on how it connects with users and other proximate stakeholders. As Downey states, "by successfully defining a problem one also takes possession of it, gaining control over what will count as a desirable outcome" (p. 446).

Downey's second strategy for deploying PDS is for engineering students to define problems alongside others who understand the problem space differently (pp. 446–47). As Downey claims, "Engineers trained in conventional problem solving know that the first step in solving an engineering problem is to draw a boundary around it so that it can be analyzed in mathematical terms." This approach makes problems uniquely amenable to engineers' expertise, and thereby separates engineering solutions from other disciplinary approaches and perspectives. While this process enhances the disciplinary authority of engineers – or at least their authority over problems framed by them for their expertise – it simultaneously isolates them from engaging in negotiations over the benefits, limitations, and implications of that expertise, negotiations that clarify one's positionality in complex knowledge ecosystems rife with power disparities and struggles over disciplinary legitimacy as described above. Downey argues that engineering students' engagement with divergent disciplinary perspectives, particularly during problem definition, can increase disciplinary awareness that enhances their legitimacy through engagement rather than retreat and isolation.

Not only should engineering students engage other disciplines in solving problems, but they should also consider their solutions from the perspective of other stakeholders, including users, according to Downey's third strategy for PDS (p. 448). Through diverse stakeholder engagements, engineers can learn to negotiate both the problem and solution spaces, as well as their interrelationships, with the possibility of challenging implicit power imbalances. For example, providing a technological solution to an ill-structured human problem likely increases the power and authority of engineers relative to other stakeholders, irrespective of the suitability of any derived solution otherwise; as STS scholars have long argued, technological interventions are inherently political [11]. Teaching robust stakeholder engagement provides students the ability to navigate the political implications of their epistemological commitments as they bump up against the perspectives and priorities of users and others impacted by their technologies. Humanitarian engineering, engineering for community development, and service-learning opportunities serve as educational sites for making these implications explicit; however, without simultaneously and decisively navigating the value-ladenness of engineering approaches, these initiatives risk providing the same, narrow engineering solutions, even if those solutions are more closely aligned with user needs [12], [13] as a result of stakeholder engagement. Additionally, even when such projects are scoped to serve the need of targeted users, student learning is consistently prioritized over community development [14].

Downey's final strategy for PDS extends the prior three, calling for engineers to serve as "technological mediators" and to consider such mediation as an important part of *engineering* work (pp. 448–9). This means that engineers should navigate the trade-offs associated with different solution pathways – not only the tradeoffs impacting themselves and their design solutions, but also tradeoffs arising from engagement with different stakeholders, different definitions of the problem, and different motivations for defining problems in various ways, including ways that challenge their own assumptions. In Downey's words, "engineers would continue seeking solutions to meet technical needs but also add the work of reconciling differences in defining them" (p. 448). In summary, Downey claims that PDS creates opportunities for a new type of engineering work, work that not only oversees the development of new technologies [15], but also navigates the political tradeoffs inherent in engineering, especially as they manifest through problem definition.

2.3 Object-Oriented Predilection, Pragmatism, and Approximation

Engineering studies scholars provide images of engineering practice that emphasize making and negotiating "things," through pragmatic and approximate decision making. Symmetrically, engineering faculty articulate engineering as the application of math and science, problem-solving, and making [16]. For example, Louis Bucciarelli describes an object-oriented worldview within engineering [10, 17], characterizing engineering design as a site where engineers' object-world epistemology meets with other perspectives [10], where differently situated participants speak different languages and mathematical, physical, and material as well as social, organizational, and political decision-making converge [17]. Describing an engineer's individual efforts in applying their expertise to the design process, Bucciarelli introduces the concept of "object worlds" to convey how engineers carry out their work using the appropriate disciplinary tools, language, and skills to design and build "things." According to this framework, the engineer sees and works with an object *individually* because of their own positionality, experience, skills, and expertise [10]. Each engineer inhabits a unique object world. It is in the meeting of object worlds that allow the design of objects, but it is engineers' unique individual training and past that allows them to see objects differently from other disciplines but also even from one another. And it is the *thing*ness of engineers' object worlds that enable them to preconceive appropriate solutions (and problem definitions) as artifacts even before they are designed. In other words, engineers are trained, conceptually and in terms of their tool sets, to perceive technologies, and particularly technological artifacts, as solutions to diverse human problems.

Additionally, engineering practice prioritizes socially constructed pragmatism. This pragmatism recognizes distinct priorities (to employer, environment, individual values) which all can somehow be mutually accomplished, even if at first they seem distinct and counterproductive to one another. As anthropologist Jessica Smith describes, engineers exhibit a solutionism that prioritizes benefits for all, or "win-win" scenarios that reconcile their distinct accountabilities [18]. Smith's detailed work describes engineers' desired wins for their corporate employer and a wins for the communities that their designs will impact – or at the very least a minimization or reduction of negative impact. It is through this pragmatic framing that problem definition occurs [19], providing a grounded example of Downey's vision of technological mediation, allowing engineers to respond to their employer's needs while also looking beyond them. Still, engineers' pragmatist view of their employment often supersedes this idealized view of trade-offs [20].

Beyond pragmatism, engineers prioritize approximation. In anthropologist Elizabeth Reddy's account of the group of engineers who built Mexico's earthquake early alert system, she describes the pride those engineers took in approximating reality to produce a particular conception of utility [21]. For these engineers, it was the art of approximation – knowing what to simplify and how – that set engineering practice apart from scientific inquiry. In fact, it was through imprecision that the engineers' work was deemed useful in practice. In combination with the pragmatism described above, engineering solutions are designed to serve a purpose, and through PDS, engineers will define problems that are solvable through object-oriented design, an eye towards pragmatism that prioritizes "we all win" outcomes, and a form of approximation that is embedded into their problem definition

Table 1. EDS Department Faculty Profile (n = 20)

Most-advanced degree				Men/women identifying	Teaching track/ tenure track
Social science	Engineering/ Science	Engineering education	Design		
8	8	3	1	12/8	14/6

and solution making. These three features of engineering practice are not problems in and of themselves, but they provide a pervasive backdrop to how engineers go about reducing real-world complexities and divergent needs and goals into the kinds of problems engineers pursue.

3. Design Engineering Program Development

3.1 Design Engineering Program Overview

The Design Engineering program at the STEM-focused Colorado School of Mines is offered by a broadly interdisciplinary academic department called Engineering, Design, and Society (EDS). EDS faculty span academic disciplines in social sciences, engineering and natural sciences, engineering education, and design, with most faculty educated in two or more disciplines and numerous faculty with professional engineering career experience. Table 1 provides a snapshot of EDS's faculty.

Drawing on EDS's disciplinary breadth, Design Engineering combines: (1) a "design spine" of interdisciplinary, open-ended design coursework offered exclusively by our department; (2) traditional math, science, and engineering coursework offered outside our department; (3) focus area electives offered within and outside our department, where students can apply their design and engineering analysis skills to an area of individual interest and career aspiration, and (4) our university's general education requirements in the areas of: (a) culture and society, (b) wellbeing, and (c) unrestricted electives. Fig. 1 provides a simplified schematic of the Design Engineering program's curricular structure.

The design spine is the program's hallmark and includes our department's "bookend design" courses that are also offered to the wider

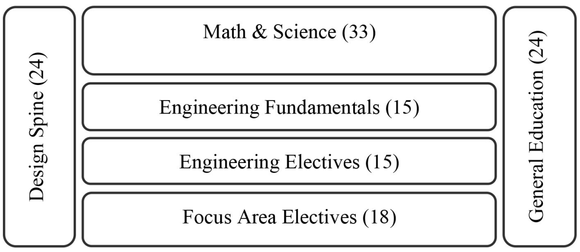

Fig. 1. Design Engineering Curricular Structure (credit hours in parentheses).

campus – Cornerstone Design as a first-year introduction to engineering design, design thinking, and stakeholder engagement and Capstone Design as a two-course senior-year sequence, where students work with external clients on their real-world design challenges. Between these bookend design experiences, the Design Engineering curriculum provides a unique sequence of "integrative design studios," which serve Design Engineering students exclusively. Through these studios, students explore complex, real-world problems, where they are charged with defining, examining, and assessing the tradeoffs surrounding multiple solution approaches, identifying and weighing a variety of assumptions in context, including the assumption that the problem identified is even amenable to a discrete technological solution arrived at via traditional engineering analysis. The integrative design studios are informed by diverse disciplinary perspectives from engineering, the social sciences, and human-centered design as conveyed by the EDS faculty's diverse academic and professional expertise. The integrative design studios have been designed and are instructed largely, but not exclusively, but the authors.

The full design spine includes the following courses:

- *Cornerstone Design* – An introduction to engineering design serving the entire campus community, including Design Engineering.
- *Introduction to Design Engineering* – An introduction to integrative design at the intersection of engineering design, design communication and visualization, and social sciences perspectives.
- *Design Unleashed* – An open-ended design courses that permits students to identify and pursue individualized design learning, structured via an iterative prototyping process.
- *Design for a Globalized World* – A systems thinking and design course exploring global interdependencies surrounding social and environmental systems.
- *Design and Modeling of Integrated Systems* – A systems modeling course that enables students to characterize and formalize component relationships to inform design in response to complex sociotechnical systems.
- *Design Engineering Applications* – A career-focused distillation of student competencies and designer identities.

- *Capstone Design I & II* – An interdepartmental collaboration offering client-sponsored projects spanning Design, Civil, Electrical, Environmental, and Mechanical Engineering programs.

The pairing of traditional engineering coursework, including Cornerstone and Capstone Design, with our integrative design studios allows students to understand a broad sweep of sociotechnical systems concepts, while also making connections among them. Navigating and addressing this translation process develops a breadth of engineering judgment not typically required in traditional engineering programs. This judgment demands both knowing what one knows and how to apply it in context as well as the limits and positionality of that knowledge and its application. While other observers may interpret this approach as engaging *non-engineering* disciplines, we assess it as integral to engineering insofar as real-world engineering design always involves differently situated participants and their distinct perspectives. Engineering students then can also begin to see themselves as technical mediators in other venues, translating what they know of their traditional engineering coursework into design settings.

3.2 Problem Definition and Solution as Foundational to Design Engineering

PDS serves as an explicit pedagogical foundation for our program, and this section provides a brief overview of how we implement PDS. Table 2 summarizes Downey's four strategies for practicing PDS as well as their implementation in Design Engineering. Each of our implementation strategies will then be described in greater detail.

PDS Practice 1: *Early involvement in problem definition*

This is core to our engineering design programming, serving as the basis for the design process executed in several of our core-curriculum courses, starting with our first-year Cornerstone Design, where all Mines students engage with a broad, common theme described in a short call for proposals and project brief. Themes in the past have included designing to support aging in place, responding to natural hazards and derived risks, and reusing urban waste. These open-ended calls provide students a common theme around which all projects revolve, while simultaneously allowing teams considerable flexibility to craft their own problem definition with distinct targeted users. This practice allows students to engage with a loosely bounded problem space, which in turn requires them to conduct significant background research to create a more specific problem definition that will then guide their solution-generation process.

PDS Practice 2: *Collaborate with diverse problem definers*

We do our best to encourage our students to work with others who define problems differently – and Design Engineering students tend to take a broader approach to problem definition than their disciplinary engineering student peers. However, we are situated within a STEM institution, whose student body overwhelmingly consists of STEM students, with only a small handful studying engineering economics, technology management, and natural resource policy, so even our non-STEM students focus on STEM-related applications. Hence, while there may be a number of engineering students from various majors present on a given team, and while Design Engineering student focus areas are broad and diverse, almost all students pursue engineering or science. In the face of this limitation, we do our best to encourage our students to think beyond traditional STEM perspectives, even as it is difficult at Mines to assemble broadly interdisciplinary design project teams.

PDS Practice 3: *Assess implications for a variety of stakeholders*

From their very first design experience in Cornerstone Design, our students are required to pursue pointed stakeholder engagement, with specific learning outcomes, supportive methods instruction,

Table 2. PDS Practices and Generalized Implementation Strategies in Design Engineering

PDS Practice	Implementation
1. Early involvement in problem definition	Emphasis on problem definition over solution, especially at the early stages of major design projects; solution posing over solution specification.
2. Collaborate with diverse problem definers	Extensive stakeholder engagement and background research into the problem space; project groups entail students with diverse focus areas.
3. Assess implications for a variety of stakeholders	Consideration of a variety of stakeholders, including targeted users and the design sponsor/firm, but also extending to include adjacent stakeholders; deployment of risk-assessment tools applied specifically to stakeholder interests.
4. Recognize technical mediation as a component of engineering work	Analysis of complex sociotechnical systems at different levels, including considering the problem/solution from disciplinary perspectives of engineering, design fields, and the social sciences.

and instructor follow-up to ensure teams remain grounded in stakeholder needs. Cornerstone Design specifically requires students to identify and then engage focused targeted user groups as well as subject-matter experts who can help student understand better both the context of the problem and state-of-the-art solutions applied within that context. These engagements are intended to validate "How might we?" problem statements for the teams. The Cornerstone Design program leadership identifies subject-matter experts for each semester's theme who have a big-picture understanding of the problem area, instead of experts in one solution area or technology or disciplinary approach. Student teams must identify for themselves technology domain experts only after having defined their individual problem statements. As with PDS practice 2, we do our best to counteract students' tendency to lock-in prematurely on a particular solution or solution domain by introducing stakeholder perspectives they would otherwise not have access to given the educational resources at hand overwhelmingly favor engineering perspectives.

PDS Practice 4: *Recognize technical mediation as a component of engineering work*

Design Engineering students are taught to consider stakeholder situatedness and perspective from the beginning, and they are provided with concepts and terminology to support inquiry into how perspective is shaped by one's situation, context, education, etc. Importantly, this includes "sociotechnical" frameworks that complicate the facile demarcation between social and technical dimensions of engineering practice. This focus on engaging, learning about, and representing diverse perspectives provides fundamental skills in technical mediation for our students. Additionally, we return repeatedly to the departmental configuration of Design Engineering's host academic department, Engineering, Design, and Society, which exists at the intersection of engineering/STEM disciplines, design disciplines, and the social sciences and humanities. We believe that a prerequisite for engineering students to become effective technical mediators is recognition of distinct, and in some ways divergent, worldviews across stakeholder groups. Such distinctions cannot be resolved through analysis or expert authority but must be mediated via situated dialogue in context over time, which is to say, technical mediation.

3.3 DE Program Assessment

While we were more or less content with the overall standing of our program's curriculum, and in particular proud of our achievements integrating social dimensions of engineering practice into students' design activities, our planning for ABET accreditation exposed to us a series of progressively more nuanced challenges associated with our sociotechnical integration efforts. For accreditation, we set for ourselves the ambitious goal of relying exclusively on our design spine coursework for accreditation assessment. The implication of this decision was that all ABET student learning outcomes would be assessed exclusively within our design coursework, leaving the larger fraction of the curriculum's traditional engineering coursework – including both engineering fundamentals and engineering electives courses – not to mention the larger-still component of basic math and science courses, wholly outside of our assessment regime. Our programming decision of rejecting tidy problem solutions as part of our design spine meant we could not rely on discrete solutions to engineering problems, say calculating resultant forces on a free-body diagram, to demonstrate our students' engineering learning outcomes. We embarked upon a months-long effort to craft an alternative approach to outcomes assessment.

With each of our program's educational objectives, we took time to research, deliberate, and reframe typical approaches to outcomes assessment in alignment with our program's unique goals. A post facto characterization of our process includes four broad phases. First, we sought to clarify our program's unique educational achievements. To do this, we explored how student achievement of a traditional engineering skills (throughout history and across disciplinary and institutional contexts) was reflected in other engineering programs' assessment frameworks and then characterized the limitations of these approaches with respect to our educational goals. Second, we sought to identify our unique strengths in problem framing, design-process navigation, solution concept exploration, and identify formation [1] among our students. This step led to a revised set of program learning outcomes, which are enumerated in Table 3.

The third phase of our assessment planning process was likely the most consequential in terms of aligning accreditation with our educational aspirations. Via several rounds of iteration as a group, we crafted performance indicators that simultaneously deconstructed traditional engineering student competency assessment and reconstructed components of our program's unique approaches to design education. This critical step aligned our ABET assessment practices (and hence our continuous improvement processes) with our program's atypical engineering learning outcomes, generating the necessary latitude for educating a more holistic engineer. This step also aligned our assessment practices with our and our students'

Table 3. Design Engineering Program Educational Objectives

The objectives of the Engineering, Design, & Society's Bachelor of Science in Design Engineering program are to produce graduates who, within five years of graduation, will: • Creatively interpret complex problems and propose novel solution concepts contextualized within unique social, technical, ethical and environmental constraints. • Serve as solution innovators, bridging the gap between social, technical and creative design disciplinary teams, all while demonstrating high levels of ethical standards, social consciousness and technical expertise. • Contribute to interdisciplinary problem-solving endeavors and establish positions of leadership in their careers and through service activities within their profession or community. • Embrace expansive lifelong learning, demonstrating continuous professional growth.

motivation to engage the broader contexts shaping expectations of our students, their particular competencies, and their ability to demonstrate those competencies in useful and meaningful ways through their education, careers, and personal lives.

Finally, our fourth step was to moderate our own expectations by recognizing the limitations of our fundamental educational transformation initiative given the over-determined nature of educational and professional institutions, the epistemological conservativism of disciplinary reproduction, and reality of educating diverse students with diverse individual educational goals with our limited resources and limited time with our students relative to the vast majority of their other coursework.

Table 4. ABET Criterion 3 Student Outcomes (1–7) and Program-Specific Performance Indicators (PI)

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics. PI-1.1: Determine appropriate boundary conditions to support problem definition. PI-1.2: Identify appropriate engineering, science, and math principles to inform problem solution. PI-1.3: Calculate solution components using suitable steps. PI-1.4: Assess alternative solutions with respect to engineering, science, and mathematics principles.
2. An ability to apply engineering design methods to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors. PI-2.1: Execute robust design problem framing through needs identification, problem definition, research and alternative solution approach exploration. PI-2.2: Synthesize social and technical design decisions throughout the design process. PI-2.3: Compare alternative design solution approaches and their impact on social "goods" (public health, safety, and welfare). PI2.4: Validate optimum design solution considering global, cultural, societal, environmental and economic factors.
3. An ability to communicate effectively with a range of audiences. PI-3.1: Identify and deploy appropriate communication strategies based on intended purpose for differing audiences. PI-3.2: Organize communications content in logical and effective manner with supporting information (e.g., data, evidence, references, reason). PI-3.3: Receive and document in-process feedback and apply it to future design iterations. PI-3.4: Communicate using written, oral, and/or visual modalities in a way that is effective with target audience.
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts. PI-4.1: Identify and describe salient mutual impacts between engineering designs and global, economic, environmental or social contexts. PI-4.2: Anticipate and describe the likely impacts of proposed solutions on global, economic, environmental and social contexts. PI-4.3: Contextualize ethical design principles according to specific users and use settings. PI-4.4: Adapt ethical solution requirements to variable contexts (e.g., user empathy, professional responsibility, pattern recognition).
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives. PI-5.1: Collaborate with teammates to create shared team goals and peer expectations. PI-5.2: Enact a variety of project management skills, including delegation, distribution of responsibilities, integration of individual work output, cultivation of accountability, and assessing output according to agreed-upon goals. PI-5.3: Provide and receive constructive feedback to foster an inclusive team environment. PI-5.4: Serve in a variety of roles on a team.
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions. PI-6.1: Identify and examine key variables informing engineering decisions. PI-6.2: Identify appropriate measurement tools, methods or constraints for variables of interest. PI-6.3: Analyze data to identify noteworthy patterns. PI-6.4: Apply engineering judgment to make relevant, appropriate and justified decisions.
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies. PI-7.1: Identify salient knowledge that is absent but is needed to address problem. PI-7.2: Establish strategy to acquire and validate knowledge. PI-7.3: Apply new knowledge to solution generation and validation. PI-7.4: Demonstrate how acquired knowledge informed the design solution.

In building out performance indicators, the author team aimed to utilize our programmatic strengths – such as interdisciplinary faculty, a passionate and highly-engaged student body, and a willingness to wrestle with ambiguous problem spaces – while continuously being circumspect of what we included within engineers' jurisdiction. As we drafted our performance indicators – which articulated how our students should produce solutions, design experiments, and make ethical decisions – we considered the broader purposes of each ABET student outcome and the degree of flexibility in how it could be assessed through thoughtful curriculum building. Table 4 provides the list of ABET 2024-2025 Criterion 3 Student Outcomes for Engineering Programs (1–7), along with our program's unique performance indicators for each sub-criterion delineated.

Our hope and intention with this set of performance indicators is that they support our development of holistic problem framing among our students. For example, achieving and assessing PI-2.3: *Compare alternative design solution approaches and their impact on social "goods" (public health, safety, and welfare)* relies on students' ability to contextualize how different stakeholders define this social good and assessing their proposed design solutions accordingly. Through project-based coursework in Design Engineering Applications, students are asked to produce a public-service announcement describing the benefits of their design interventions, which develops their ability to speak to target audiences about benefits and limitations/potential risks associated with their solutions, both to intended audiences and the public broadly.

Another example of how our performance indicators advance students' development of holistic problem solving is PI-4.4: *Adapt ethical solution requirements to variable contexts (e.g., user empathy, professional responsibility, pattern recognition)*. This performance indicator provides the capacity to "count" students' ability to assess the role of specific contexts in determining appropriate ethical dimensions of a proposed design solution. Recognizing context as an important dimension of ethical decision making is unique relative to typical engineering ethics education. Instead of claiming *either* universal ethics framings or entirely situational decision making, this performance indicator accounts for recognizing and reading context as a component of engineering decision making.

Our efforts build upon and expand the PDS approach by systematically exploring "problem framing" as an equal dimension of engineering education alongside "problem solving." However, our approach to problem framing goes beyond simply adding problem definition to the traditional engineering problem-solving process. It engages students in translating real-world problems into engineering problems (problem definition), but it also engages them in understanding the wide-ranging conditions that demarcate an acceptable engineering problem statement and, hence, implicitly, an acceptable engineering solution. Shifting focus from problem solution to problem framing allows students to move between (traditional) engineering and alternative perspectives on the problem at hand, implicitly determining what potential solutions are considered sensible [22].

4. Discussion: The Problem with Problems

Having reviewed our efforts to operationalize "problem framing" as a core engineering skillset via our ABET assessment practices, we now return to some of our concerns regarding "problems" as the primary unit of engineering design inquiry. First, the problems that engineering students are typically asked to solve – across the majority of their engineering coursework – are very different than the problems they define and solve in their design courses. We believe this gap is of essential importance, and students require curricular space and scaffolding to explore the reasons behind the gap and its significance to their education. Second, in most engineering design courses, whether at STEM-focused universities such as our own or at comprehensive or liberal arts-focused universities, rarely are non-engineering students participants in the courses or on the design teams. As a result, faculty and students alike are permitted to approach problem defining through a closely aligned, if not singular, disciplinary lens, leading to overemphasis on the engineer's pragmatism, the predilection towards objects and the building of things, and thinking about approximation as central to their work.

4.1 False Equivalency of Problem Solving

Like their students, engineering faculty members often include "problem solving" in their universalized narratives of engineering practice [16]. This terminology and its underlying attitude provide substantial yet arbitrary limits on which (human) problems are considered to be (engineering) problems and how those problems are to be scoped in order to be manageable for an individual or small team of engineers to attempt to solve. A majority of the engineering sciences, considered to be the "sacred cows" of engineering education [23], provide "problems" that engineering students are expected to be able to solve, often quickly, through the correct matching of a provided problem with a derived equation and flawless algebraic manipulation to arrive at a single, numeric "solution." This is the answer enclosed within a box referred to in the introduction.

Insofar as these types of problems are considered to be "sacred" in engineering education, it constrains how design educators can make jurisdictional claims surrounding educating students in problem solution: The "problem solving" processes in engineering sciences and engineering design clearly are not equivalent. They are not even conceptualized as nested problems; that is to say, problems from the engineering sciences are not typically taught as *tools* for larger solution development in more comprehensive design courses. Instead, they embody the "engineering problem" and solution unto themselves. It is rare, and typically not until senior design, that design-informed approaches are applied to problem solving, where students participate in problem definition, at least in terms of establishing design requirements and constraints. In contrast, introductory design course students typically are not expected to provide thorough quantitative engineering analysis, because they have not yet taken the relevant engineering science courses that are prerequisite to such analysis. As reasonable as the prerequisite logic appears, the converse is not also true: That once students have gained decontextualized engineering analysis skills, they are then provided ample opportunities to apply those skills – and importantly to determine when and how to apply them – to widely open-ended design projects. Our approach attempts to address this challenge by teaching our students to define problems with a clear understanding of their own skills, the limits of these skills, where these skills fit relative to others' skills (particularly the skills of other engineers), and how to align all this with the perspectives and expectations of differently situated stakeholders surrounding the problem.

4.2 Interdisciplinarity at an Engineering University?

Together the second and third PDS practices emphasize interdisciplinarity in terms of how engineers ought to engage with problem definition and with stakeholders, yet interdisciplinary problem solving is context specific [24]. Because of the Mines student body's disciplinary make-up, problem-solving activities are carried out by teams made up almost exclusively of engineering and applied science majors. While Design Engineering students and other majors in our courses are consistently expected to engage in background research and stakeholder interviews and feedback to broaden the range of input to their solution generation processes, it is still engineering student teams that ultimately define their design problems. In other words, the student teams are expected to complete both problem definition and solution, with the expectation that they will summarize, synthesize, and implement external feedback, with limited ability to consistently engage across disciplines on campus. Collaborating in problem definition with those that define problems differently can be difficult in an engineering university, even for Design Engineering students whose departmental faculty embody such interdisciplinarity.

The practical limits around forming interdisciplinary teams at a STEM university notwithstanding, we suspect that even broadly interdisciplinary teams might not be enough to address the challenge of inclusive problem definition as envisioned by Downey with PDS. As mentioned above, engineers historically have enjoyed jurisdiction over "problem solving" [16], which we believe to be a part of the challenge. With PDS and other design education initiatives we promote, non-engineers – whether they be other disciplinary representatives or lay (non-expert) stakeholders – are being invited to *engineers'* problem-definition practice, where engineers can continue to center their expertise. So even with interdisciplinary participation in problem definition, engineers exercise ownership of the overarching solution-generation process. At the very least, there is a significant mismatch between engineering problem sets and "solving" design problems; however, without much consideration of the differences, engineering students are expected to demonstrate competencies in both. Further, describing engineering students as "problem solvers," while allowing those problems to be framed solely through an engineering lens creates a false sense of broad problem-solving competence that fails to prepare students adequately for real-world problem solving in professional pursuits.

As evidenced by our efforts with ABET student outcome performance indicators, we have sought to address the disparity of complexity between engineering science course problem solving and open-ended design directly, even if we do not enjoy the benefits of collaboration with non-engineering students in the process. Instead, we require Design Engineering students to respond to complex, unbounded, sociotechnical problems without first stripping out the contextual specificity, divergent perspectives on the problem, or the need to justify one's solution approach in both engineering and non-engineering terms. Of course, we recognize that sociotechnical systems and their problems have always been "wicked," but we are asking our students to respond differently: by engaging with the complexity, with contextual specificity, with interdisciplinarity and multiplicity of perspective, and with the formulation of their own expertise.

4.3 Problem Framing as Reframing Engineers' Jurisdiction

Considering all the opportunities and productive tensions surrounding PDS in engineering education, we offer a nuance on Downey's approach to engineers' loss of jurisdiction over technology development trajectories. We argue not simply for reclaiming that jurisdiction, but for *reframing* it. In alignment with PDS, we agree that engineers should be more systematically involved in problem definition than what is allowed for in most engineering curricula. But we find greater opportunity in confronting the gap between two incongruous approaches to problem solution: that provided in most engineering science courses and the open-ended problem definition encouraged in engineering design courses. Clearly characterizing this gap is to contextualize not only potential engineering problems to be solved through PDS practices, but it addresses the core deficiency in how engineers are encouraged to identify as "problem solvers" despite a legacy of problem solving that is overly narrow and often centered on developing technologies over people's engagement with those technologies.

Here again we have attempted to operationalize our insights around problem framing as a core educational outcome through our performance indicators. We recognize that implementing this particular approach is an interdisciplinary move in and of itself, as contextualizing engineering pedagogy and practice for our students requires skills and expertise derived outside of engineering and science disciplines [4] or their approaches to education. We are able to achieve this goal through our faculty's diverse disciplinary expertise, which can both contextualize engineering educational assumptions, approaches, and epistemological foundations and teach students how to understand their own problem definition and solution making expertise, opportunities, and limitations. We aim for our students to be able to talk about their education at a systems level.

We also want to encourage our students to be able to analyze when they are assuming that engineering ways of knowing make for the best solutions. Recognizing their predilection for object-oriented solutions, utility, and particular forms of approximation allow us to help them move beyond traditional forms of engineering problem definition. If they can interrogate their own desires to build a prototype in an effort to solve a problem, for example, they can begin to differentiate the engineering judgment needed to provide what is needed versus their reasonable attraction to solutions that extend from the skills they have to produce a solution. These moments allow for expansive problem reframing, encouraging students to think more about how their skills can be used to address these problems and/or who they can enroll in their solution processes that extend beyond their capacities.

Centering complex systems in areas of healthcare, transportation, energy distribution, communication and more in our coursework allows for sociotechnical integration to be core to our students' approach to engineering work and systems thinking. Students developing an understanding of complex systems thinking as a holistic context for their problem framing drives discovery and generates more broadly informed decision-making. Engaging with systems thinking in a way that recognizes the 'whole' of the problem allows for deeper understanding of interrelationships, attributes, and effects. Further, reflectively applying this process to our own design work, we seek to enable students to dissect and critique Design Engineering's educational experience, all while they co-construct its future. We argue that learning this skill – of framing one's own disciplinary jurisdiction, all while being both generous about and critical of its core features – will empower students as they pursue their careers, professional development, and personal lives.

4.4 Rethinking Engineering Judgment

Real-world engineering design always involves differently situated participants with their distinct perspectives and differential experiences. Judgment is needed to navigate such spaces, where analysis alone cannot eliminate uncertainties, disagreements, or incommensurabilities. While the authors are early in our efforts to frame our educational interventions in terms of enhanced engineering judgment, our ABET accreditation preparation activities have advanced our thinking in this area as well. ABET's student outcomes call for engineering students to exhibit judgment through two of seven student outcomes. These student outcomes highlight the importance of judgment in considering both (1) wide-ranging societal contexts and (2) design of experiments and data interpretation. We interpret these dimensions of engineering judgment to pull in opposite directions – one grappling with the expansive contextual conditions impinging on engineering and the other drilling down to foster more robust data generation and date-informed decision-making – thereby allowing for expansive, pedagogical application. Others have explored the interpretive flexibility engineering judgment as connected to critical thinking [30] and identity and decision making [31], and we assess there to be considerable opportunity for critical explorations into engineering judgment as a lever for educational reform.

Opening engineering's jurisdiction beyond the utility and usefulness (pragmatism and approximation) of technology (artifacts) provides flexibility for engineering education reform. Framing engineers' aptitudes and limitations to engage in PDS provides a forum for engineering students and faculty to participate in more complicated visions of technological design, development, and implementation. But simply adding these extra skills – problem definition and framing – does not elevate engineering education as much as we seek. Instead, students can be prepared to navigate these expanding jurisdictions to more effectively negotiate the classroom, the engineering workplace, or even personal passion projects in their futures. Using problem reframing to navigate these complicated relationships within technology and design requires engineering judgment of a sort imperfectly conveyed in traditional engineering coursework, whether engineering science or design courses.

5. Conclusions

This paper has sought to reignite a conversation about engineering's jurisdiction and build upon foundations provided by engineering studies scholars in describing and theorizing what engineering practice is as well as proposing what it ought to be (c.f., [25–28]). Recognizing Downey's influential framing, we have explored whether PDS is sufficient, specifically whether it is sufficient simply to teach our students to engage more in problem definition, without also contextualizing engineers' past, current, and potential domains. Our students are often ambitious, creative problem solvers, but we hope that our contextualization of the structures in which they learn and work will allow for more flexibility and promote more humility, while also producing greater impact across their careers. Critiquing how and why engineers have been given the jurisdiction of ''problem solver'' and, more recently, ''problem definer'' opens dialogue about individual and disciplinary opportunities and limitations. We hope that framing PDS with our faculty and students will provide fodder for thoughtful engineering education reform.

Our reform efforts ultimately aim to reconsider what engineering judgment could be by expanding engineers' jurisdiction from problem definition to problem framing. By drawing attention to engineering's particularities – including but not limited to a preoccupation with objects/artifacts, specific forms of pragmatism, and quantitative approximation – our programming allows for engineering decision-making to follow a more holistic approach. If engineers are aware of how traditional disciplines frame and approach problem solving, they might just be able to circumvent tired problem definitions and solutions, making way for true innovation in engineering work and more holistic forms of understanding engineering problems. By exposing our students to how traditional forms of problem definition and solution have fallen short, we seek to inspire and empower them to reimagine new futures.

Similarly, we see ourselves as critical participants in engineering education reform through program building ([29], pp. 219–43), yet at the same time, we boast a department with the highest density of engineering studies scholars anywhere [15]. This combination leads us to argue that thoughtful program building that is engaged with scholarly debate is itself a form of scholarship. We aim to empower other program faculty and staff to see their work as critical participation in STS, engineering education research, and/or an act of engaged scholarship in their own disciplines.

Future work by this author team will consider engineering judgment's interpretive flexibility as it enables actionable change in curricular development and assessment opportunities, which will also highlight the judgment required for teaching and assessing problem framing and the implications of various problem definitions and solutions. Our conceptual engagement with engineering judgment, paired with our roles as critical participants in engineering education reform, has reaffirmed our commitments to sociotechnical integration, design-based pedagogies, and educational interventions in engineering and beyond. This expansion of engineers' formation, knowledge, and expertise can have generative and humbling effects on future generations of engineers.

References

1. G. L. Downey, Opening up engineering formation, *Eng. Stud.*, **7**(2–3), pp. 217–220, 2015.
2. G. Downey, PDS: Engineering as Problem Definition and Solution, in *International Perspectives on Engineering Education*, B. Newberry, C. Mitcham, M. Meganck, A. Jamison, C. Didier and S. H. Christensen, Eds., Springer Verlag, 2015.
3. G. Downey, The (Professional) formation of engineers, Keynote delivered at NSF EEC Engineering Education Awardees' Meeting.
4. M. S. Kleine, K. Zacharias and D. Ozkan, Contextualization as Virtue in Engineering Education, in *2021 ASEE Virtual Annual Conference Content Access Proceedings*, Virtual Conference: ASEE Conferences, p. 36844, Jul. 2021

5. G. Downey, Are engineers losing control of technology?: From 'problem solving' to 'problem definition and solution' in engineering education, *Chem. Eng. Res. Des.*, **83**(A8), pp. 1–12, 2005.
6. ABET, ABET Accreditation. [Online]. Available: https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2024–2025/
7. D. Nieusma and X. Tang, The Unbalanced Equation: Technical Opportunities and Social Barriers in the NAE Grand Challenges and Beyond, *Int. J. Eng. Soc. Justice Peace*, **1**(2), 2012.
8. B. Latour, *Science in action: how to follow scientists and engineers through society*, [Nachdr.]. Cambridge, Mass.: Harvard Univ. Press, 2015.
9. R. H. Williams, *Retooling: a historian confronts technological change*, Cambridge, Mass: MIT Press, 2002.
10. L. L. Bucciarelli, *Designing engineers*, First MIT paperback edition, Cambridge, Mass.: MIT Press, 1996.
11. L. Winner, Do Artifacts Have Politics?, *Daedalus*, **109**(1), pp. 121–136, 1980.
12. D. Nieusma and D. Riley, Designs on development: engineering, globalization, and social justice, *Eng. Stud.*, **2**(1), pp. 29–59, 2010.
13. L. Wang, T. K. Carroll and D. A. Delaine, A Pilot Study of the Development of Empathy within a Service-learning Trip from a Qualitative Perspective, presented at the 2018 ASEE Annual Conference & Exposition, Jun. 2018. Accessed: May 22, 2022. [Online]. Available: https://peer.asee.org/a-pilot-study-of-the-development-of-empathy-within-a-service-learning-trip-from-a-qualitative-perspective
14. D. LaPorte, E. Kim and J. Smith, Engineering to Help Communities or Students' Development? An ethnographic case study of an engineering-to-help student organization, *Int. J. Serv. Learn. Eng.*, **12**(2), pp. 103–117, 2017.
15. G. L. Downey, What is engineering studies for? Dominant practices and scalable scholarship, *Eng. Stud.*, **1**(1), pp. 55–76, 2009.
16. A. L. Pawley, Universalized Narratives: Patterns in How Faculty Members Define 'Engineering,' *J. Eng. Educ.*, **98**(4), pp. 309–319, 2009.
17. L. L. Bucciarelli, Between thought and object in engineering design, *Des. Stud.*, **23**(3), pp. 219–231, 2002.
18. J. M. Smith, *Extracting accountability: engineers and corporate social responsibility*, in Engineering studies, Cambridge, Massachusetts: The MIT Press, 2021.
19. D. Nieusma, Conducting the instrumentalists: a framework for engineering liberal education, *Eng. Stud.*, **7**(2–3), pp. 159–163, 2015.
20. D. F. Noble, *America by design: science, technology and the rise of corporate capitalism*, Oxford New York Toronto: Oxford University Press, 1979.
21. E. Reddy, *'Alerta' engineering on shaky ground*, in Engineering studies, Cambridge, Massachusetts: The MIT Press, 2023.
22. D. Nieusma, Engineering/Design Frictions: Exploring Competing Knowledge Systems via Efforts to Integrate Design Principles into Engineering Education, presented at the 2018 ASEE Annual Conference & Exposition, Jun. 2018. Accessed: May 19, 2022. [Online]. Available: https://peer.asee.org/engineering-design-frictions-exploring-competing-knowledge-systems-via-efforts-to-integrate-design-principles-into-engineering-education
23. J. Lucena and J. Leydens, From Sacred Cow to Dairy Cow: Challenges and Opportunities in Integrating of Social Justice in Engineering Science Courses, in *2015 ASEE Annual Conference and Exposition Proceedings*, Seattle, Washington: ASEE Conferences, pp. 26.806.1–26.806.19, Jun. 2015
24. K. Zacharias, *The Transdisciplinary Dilemma: Making SEAD in the Contemporary Research University*, Virginia Tech, 2018.
25. W. G. Vincenti, *What engineers know and how they know it: analytical studies from aeronautical history*, in Johns Hopkins studies in the history of technology, Baltimore London: Johns Hopkins university press, 1993.
26. D. Vinck, Ed., *Everyday Engineering: An Ethnography of Design and Innovation*, The MIT Press, 2003.
27. D. Vaughan, *The Challenger launch decision: risky technology, culture and deviance at NASA*, Chicago: University of Chicago Press, 1996.
28. D. Riley, *Engineering and social justice*, Cham, Switzerland: Springer, 2008.
29. G. L. Downey and T. Zuiderent-Jerak, Eds., *Making & Doing: Activating STS through Knowledge Expression and Travel*, The MIT Press, 2021.
30. H. G. Giuliano, L. A. Giri, F. G. Nicchi, W. M. Weyerstall, L. F. Ferreira Aicardi, M. Parselis and F. Vasen, Critical Thinking and Judgment on Engineer's Work: Its Integration in Engineering Education, *Eng. Stud.*, **14**(1), pp. 6–16, 2022.
31. R. A. Francis, M. C. Paretti and R. Riedner, Theorizing Engineering Judgment at the Intersection of Decision Making and Identity, *Stud. Eng. Educ.*, **3**(1), pp. 79–98, 2022.

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