From Problem Solvers to Problem Seekers: The Necessary Role of Tension in Engineering Education

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In this paper it is proposed that the current focus on problems in engineering education and technological literacy may be more constructively reframed by focusing on tensions. Priyan Dias claims engineering has an identity crisis that arises from tensions inherent in: 1) the influence of the profession on society, 2) the role engineers play, and 3) what constitutes valid knowledge in engineering. These are ethical, ontological, and epistemological tensions respectively, which Dias frames as a tension between identities of *homo sapiens* and *homo faber*. Beyond the tensions in engineering there are additional tensions that arise for engineering educators that impinge on identity, but derive from educators' beliefs about the aims of education and beliefs about teaching. With respect to the aims of engineering education the tension arises between utilitarian and humanistic aims and plays out through debates about the importance of diversity (inclusion vs. professionalization), discussion of which courses should be included in a curriculum, and the long simmering debate on four year vs. five year engineering degrees in the United States. Tensions that arise from beliefs about teaching are seen in the discussions on the relative merits of summative vs. formative assessment, student- vs. instructor-centered learning, and the relative merits of inquiry-based and active learning. Given that one aspect of the identity of an engineering education is being a problem solver, faculty may perceive these tensions as a problem or conflict to be solved. An alternative view is to see tensions as both necessary and generative. Tensions are necessary since they are a natural part of human affairs and generative in that tensions highlight dialectics from which new truths or perspectives emerge. From this viewpoint a key element of faculty development is developing a defensible personal philosophy that both lets one navigate and learn from the inevitable tensions that will arise in practice as well as contribute to larger dialogs from which new systems and forms of education emerge.

Introduction

In the United States there is a long history in engineering education of critical self-reflection and focusing on problems. This is not surprising because as early as the nineteenth century the United States possessed a Society for the Promotion of Engineering Education that had sponsored the first of these major reflections, and subsequently several more. Socially relevant issues in engineering education (and STEM education more generally) are often identified by nationally distributed reports from blue ribbon panels. In engineering these date back to the Mann report of 1918, through the 1923 Wickenden study, the 1940 Hammond Report, the 1955 Grinter Report, the *Goals of Engineering Education* report (1968), *Engineering Education and Practice in the United States* (1985), *The Engineer of 2020* (2004), to the more recent *Rising Above the Gathering Storm* reports to name a few. The fact that issues are perceived as problems may arise since these reports often use a tone of crisis as a literary device to help make the story more compelling to the intended audience of policy makers [1]. This tone of crisis is also to be found in several British reports relating to the status of the engineer [2], lack of able students presenting themselves for study in engineering departments [3, 4], and what to do about it [5, 6].

Furthermore when engineering faculty talk about what engineering is, problem solving is a key element of their narratives [7]. Sub-texts on problem solving center around problems as important, relevant, and societally defined. In other words one of the defining features of engineering faculty is their self-identification as people who value the ability to solve societally important problems.

In reading through the last century of reports on engineering education at first glance it seems that little has changed despite the intense focus on identifying problems. Many of the issues in the 1918 Mann report are still actively being discussed by the engineering education community today. While there have been major shifts [8] in engineering programs, the extent to which the field repeats its past is somewhat surprising. For example over a forty year period blue ribbon panels repeated the same six recommendations around diversity, yet the "problem" of diversity is still persists. Some of this sense of stasis may arise due to the self-reflective and risk adverse nature of engineering which has always been sensitive to social factors. However since the "problems" engineering education seeks to solve recur regularly and over the long term the overall impression is that little progress has been made. In this paper we explore whether the perceived inability to address longstanding issues in engineering education arises in part from framing them as problems and if a reframing from problems to tensions might allow more progress [9].

At some level calling problems tensions may be perceived to be merely playing with words. For this reason this paper will attempt to draw distinctions between problems and tensions that distinguish the two concepts as well as understand where the two overlap. The rational for exploring the distinction between problems and tensions is based on the sociological theory of the double hermeneutic [10]. In brief this theory states that objective theorizing as used in the physical sciences does not have the same results in the social sciences. While physical phenomena under study are not affected by the theories we make of their behavior, due to open communication and the science press, social science theories can impact the construction of social systems and thus how people behave. In other words social science theories can become self-fulfilling since an observer can influence the outcomes [1]. This the "double" part of interpretation- how a society understands itself through social sciences is as real as how the social sciences understand society. Thus engineering education's framing of issues as problems may serve to create an engineering education system that gives rise to, or exacerbates, those perceived problems. For example if it is widely believed there is a significant retention problem in engineering a possible solution would be to create a new first year course to better prepare

[1] In the late 1920's a group of investigators from Harvard University were able to observe people at work in the Westinghouse Electrical Company's works in Chicago. It was found that productivity increased among some workers when the conditions of work had been changed for the worse with the expectation that productivity would decline. The increase in productivity was accounted for by the fact that the workers wished to please the observers. This effect was given the name 'Hawthorne' after the name of the works in which it was found.

students for the subsequent years. However if the reality is a tension between student willingness to commit to a degree program and the perceived effort obtaining the degree requires, then adding more requirements might negatively impact how willing students are to stay in the program.

Framing issues in engineering education as tensions rather than problems has some support in the larger literature. In education Kezar [11] has reviewed models and processes of change in higher education. Higher education organizations differ from government and commercial enterprises in that they are interdependent yet relatively insulated from the external environment; have a unique culture and values; manifest a diffuse, loosely coupled, and often parallel decision making structures with shared governance; often have ambiguous goals; and are image and status rather than financially driven. She finds that in this environment, as opposed to commercial organizations which are more hierarchical and driven by the bottom line, dialectic change models can explain many attributes of change that are at first glance non-rational and nonlinear. In other words when universities seek to deal with challenging issues the pathway is rarely straight or given by top-down mandates, but can be explained by the ebb and flow of power between two or more points of view.

A review of developments in Europe seems to support this view [12]. Their focus is on the autonomy of flagship universities in continental Europe. They suggest that reforms of university autonomy to enhance it within universities are necessary for the reform of the university. But accompanying the trend in autonomy has been a trend to accountability. This has had the effect of moving autonomy away from its academic dimension to its organizational dimension. These writers suggest that these reforms have led to the creation of an executive structure at a distance from the traditional academic domain which have their own norms, values and practices. Fumasoli, Gornitzka and Maassen [12] conclude that in the modern European flagship of the university the tensions between these two components "can be interpreted from an institutional perspective as tensions between two institutions". One of us observes that this seems to be the way universities are moving in the UK and the Republic of Ireland.

Tensions have also been used to describe engineering. Priyan Dias [13] explores some of the tensions inherent to engineering and claims that engineering has an identity crisis that arises from three sets of tensions that are ethical, ontological, and epistemological in origin. The first tension identified by Dias is an ethical one that questions whether the influence of the engineering profession on society is, on the whole, positive or negative. While most engineers would believe the impact is positive Dias points to looming climate crises, environmental degradation, and social upheaval as negative consequences of our engineered world. The second tension revolves around what role engineers play, as primarily scientists or primarily managers. While engineering is based on a scientific understanding of the world, to make action happen engineers must manage processes, materials, and people which is the role of a manager. Finally there is a tension around whether theoretical or practical knowledge forms the basis of engineering work. This tension is important because an engineer differs from both the mathematician and the craftsman. Dias frames these ethical, ontological, and epistemological tensions more globally as a tension between identities of *homo sapiens* (rational man) and *homo faber* (making man); i.e. between understanding and transforming. This tension is inherent in the etymological origin of science and engineer where science is derived from the Latin *scire* or "know" while engineer is derived from the Latin *ingeniare* or "contrive".

Tensions vs. Problems

In both Kezar's summary of the importance of dialectical models in higher education change management and Dias' reflection on the tensions inherent to the engineering profession the interplay of ideas from two perspectives is seen as generative, or capable of production of new ideas or modalities of thinking. Educators have long distinguished between problem solving and problem finding [14]. Problems have also been identified as a source of creativity [15]. For example among innovators there is a creative method called "painstorming" which identifies problems by determining which are causing clients or participants the most trouble. We propose, however, that there is a key difference between tensions and problems that stems from the purpose for which such creativity is manifested. The ideas generated in solving problems serve to eliminate or mitigate the problems which is a dynamic process causing a change of state. Tensions, although often seen as inimical to harmony within organizations, exist because of a long standing static state of affairs characterized by a difference in perspectives or values. A tension can then be characterizes as an acknowledgment of an existing state of being without the imperative for change. A tension is not necessarily static but exists in a dynamic equilibrium so that acting on a tension would shift or perturb the equilibrium. In this paper we take the point of view that tensions themselves are not necessarily a source of problems, but that negative consequences are more likely to arise when tensions are unnoticed, misunderstood, unaddressed, or when systems under tension do not have channels to foster meaningful dialog.

Common definitions of "problem" include sources of trouble, unanswered questions, and a source of vexation. Tension on the other hand arises from the Latin word meaning to stretch, used in the context of a struggle or contest. The definition includes elements of balanced but opposing forces, latent hostility, and being stretched between fixed points. This highlights another subtle but important difference between problems and tensions. A problem is a monopole, in other words it is a unique entity that is invariably framed negatively, as something to avoid. Tensions are by definition at least dipoles, and do not exist without at least two opposing and supported perspectives. Thus a tension is more dialectical in nature and while not necessarily welcome, tension does not have purely negative connotations. This sense is reflected in the use of the words problem and tension. The word problem is typically used possessively—my problem or their problem—such that some entity owns or is responsible for a problem. While tension is also a noun its usage is typically more descriptive and is used to define a state.

What occurs if a tension—an existing system state in dynamic equilibrium—is framed as a problem, i.e. a situation in need of resolution? We hypothesize that tensions posed as problems are unresolvable without changing the state of the system that gives rise to the tension. Here we are on philosophically tenuous ground since the word "system" is vague within engineering education where systems tend to exist on many different scales. We have chosen to use the definition from Meadows: "*a system is an interconnected set of elements that is coherently organized in a way that achieves something*" [16]. Tensions thus can be hypothesized to arise from interconnections within the system and thus require a change to the system itself if they are to be addressed, or in the words of problem mentality, solved. Changing systems is notoriously difficult and as pointed out in [16] may require a different perspective than one takes when solving problems. Problems, particularly in engineering, tend to be subjected to a linear decomposition mechanism. Tensions within systems do not fit this model since they represent a "natural" state of the existing system, albeit a state in dynamic equilibrium. In ecology there are numerous examples of linear solutions being applied to complex ecosystems that exacerbate rather than solve the problem the action was taken to solve. Furthermore when a tension is framed as a problem it may seem unsolvable simply due to the size of the system that needs to be changed. The human response to situations that one does not have the resources to cope with is stress [15] which can be either positive or negative in affect. Long term psychological reactions to stress include a sense of dysfunction [15] which can make the identified problem seem even more intractable.

Tensions in Engineering Education

In this section we suggest several existing problems/issues in engineering education that are drawn from three different sources. These sources are not intended to be comprehensive; that is identify all the tensions that may exist. The three sources were chosen to illustrate three different scales of the system: a human level of faculty and programs, a policy focus on the specific area of engineering education, and a policy focus at a more comprehensive, national level that intersects broadly with STEM education and engineering concerns.

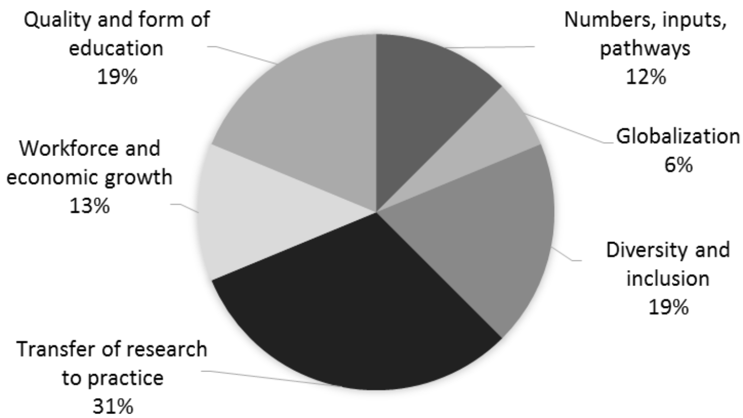
The first, human source of issues is drawn from a 2015 workshop on engineering education held immediately after the ASEE Annual Conference. Here insights on tensions within ASEE could be solicited from a small but diverse group of faculty representing a range of divisional interests. The aim of the workshop was designed to get representatives from different ASEE divisions together to discuss what a reconceptualization of engineering education might look like in the hopes that some commonalities or ideas would emerge between ASEE divisions. The participants first independently framed the "what" and "why" of their divisions—i.e. why the division existed and what actions it was committed to—and then came together to explore the intersections and differences. The framing of differing goals as tensions emerged from the dialog. Key lessons from the workshop were that engineering education stakeholders are moved more by "why" questions than "what" questions and these questions emerge from productive dissonance, disruption, tension, and discomfort. The idea of tensions was identified by participants as being central to the interests of, and issues faced by, many ASEE divisions. The issues identified by participants are shown in Table 1. The table is formatted to identify tensions by topic as well as the dialectic poles that emerged. The tension as framed at the workshop is then briefly described.

Table 1: Tensions identified at post-ASEE interdivisional workshop

Topic	Dialectic Poles		Fundamental Tension
Knowledge & Epistemology	Universal	Contextual	Which knowledge individuals hold as universal or contextual differs between individuals.
	Theoretical	Practical	Knowledge gained from practice is not valued. But with age professionals increasingly base their work on experience.
Assessment	Formative	Summative	Should one assess the process of education or the product (student outcomes, e.g. ABET)?
	Process	Product	
	Objective	Authentic	Objective assessment places the ability to measure an outcome above the usefulness of that outcome in authentic practice.
Aims of Education	Industry Needs	Educating Individuals	There is a long standing tension between educating students for jobs or as an individual
	Utilitarian	Liberal	
Students and Student Experiences	Sharing	Security	Students as the least powerful members of academia need safe spaces to be themselves as well as spaces to engage with faculty in order to grow and develop.
	Actual Impact	Societal Impact	What we provide students as projects often does not match the lofty language we use to discuss the ideal of an engineer.
	Engineers	All Students	Tensions between need for teaching general technological literacy and teaching future engineers.
	Depth	Breadth	How does one create the proverbial T-shaped engineer under the significant constraints most programs face?
Identity	Engineer First	Intersectionality	Some populations are unwilling to take on a single identity, yet a tension exists between the professional "do whatever it takes" image of an engineer and the need to shed this identity.
Teaching	Pedagogical Research	Experience & Practice	Tension between the need for rigorous theory and methodology to prove curricular innovations and the flexibility and pragmatism to effectively implement.
	Content	Experiences	Balancing the disciplinary content needed to do engineering work with the opportunity to learn from applying that content in practice.
Diversity and Inclusiveness	Inclusion	Professionalism	The need to be more inclusive can be in tension with the desire of programs to recruit and admit the "most talented" students.
Practice of Engineering	Object-Centered	Human-Centered	How to maintain an ethical stance when engineering practice is often focused on objects and materials that are manipulated for human ends.

These tensions can be broadly classified as related to being and practice in engineering education. While Table 1 reflects issues identified at the workshop it is important to note that none of these tensions are isolated, i.e. they all depend on each other in the larger, inter-related system that is engineering education.

(a) 2003-2005: 16 issues from 6 programs



(b) 2013-2015: 46 issues from 17 programs

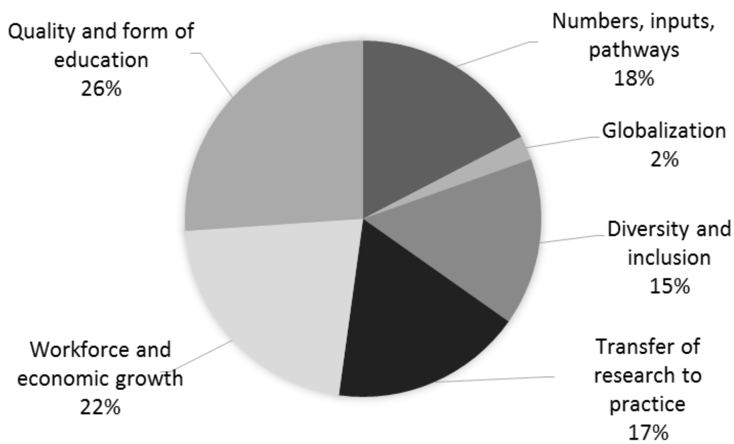


Figure 1: Comparison between major issues identified in National Science Foundation program solicitations and descriptions separated by one decade.

To understand how the issues identified by faculty participants at the workshop compare with those that are being considered and resourced by policy makers directly concerned with engineering education an analysis of issues identified in request for proposals (RFPs) was performed. Program solicitations and program descriptions from the National Science Foundation were selected over two three year periods one decade apart: 2003-2005 and 2013-2015. Programs focused primarily on undergraduate engineering education were selected. Thus graduate focused programs that overlapped engineering education—e.g. Integrative Graduate Education and Research Training (IGERT)—were excluded as were Graduate Research Fellowships. Programs focused on technician training—e.g. Advanced Technology Education—and K-12 focused programs were also excluded as were those focused on a specific non-engineering discipline (e.g. geology). Given the breadth and complexity of NSF Centers such as

ERCs and STCs, these were also excluded. From the list of all NSF programs, seventeen were in the 2013-15 time window and six in the 2003-2005 window were identified that matched the above criteria. There were 46 separate issues in the 2013-15 RFPs and 16 identified in the 2003-05 programs which were then coded into six broad categories as shown in Figure 2 below. For example "Supplying the labor market with sufficient numbers of talented and well trained US engineers" and "meet the emerging workforce and educational needs of U.S. industry" were coded as *workforce and economic growth*. Many programs identified more than one issue in their solicitations and descriptions which were coded multiple times.

Compared to the specific tensions identified by faculty participating in the workshop, the issues identified in NSF RFPs are framed broadly and not specifically as tensions. There are overlaps between issues related to diversity, how students are educated, and (to some extent) the economic impact of engineering education. Note that NSF programs generally identified a need or a desired outcome rather than a problem or tension. For example the tension between workforce preparation and the need to liberally educate students as citizens is not often addressed in solicitations. While clear visions for what students might need to gain from degree programs and how those are aligned with national needs are articulated, the issues of time and resources faced by faculty are generally described as constraints.

The final source of problems/issues are those identified in panel reports, commonly from private foundations or the National Academies. These may be thought of as generative, in that funding programs and thus the work done by faculty often take their cue from such reports. These reports themselves rarely identify specific problems, but tend to focus more on larger issues that impact, or are impacted by, engineering education. To serve as an example *Rising Above the Gathering Storm Revisited: Rapidly Approaching Category 5* [17] was analyzed. In this report there is a prominent six page long section near the front titled "A Few Factoids", presumably to give context to the report's message. A coding and analysis of the 64 factoids is shown in Figure 2 below. Each of the identified issues was featured prominently in the report as well as the predecessor Gathering Storm report [18].

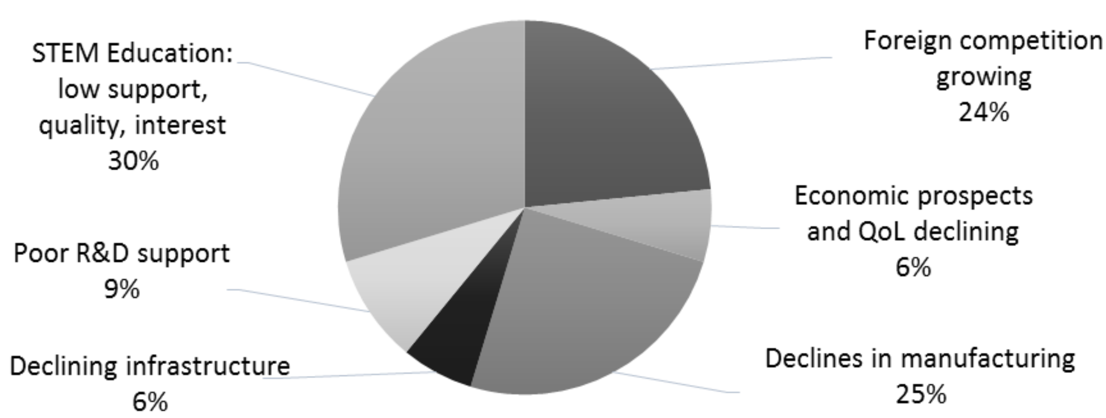


Figure 2: Analysis of contextual factoids from *Rising Above the Gathering Storm Revisited*. "QoL" in the figure above stands for Quality of Life.

As with the issues identified at other scales, each of these six issues are inter-related. For example declines in manufacturing are related to foreign competition, infrastructure, and a well-trained workforce. While each can be identified as a problem from the individual to the policy level, e.g. losing one's job at a personal level to loss of tacit knowledge in an industry, all are very large scale issues that arise from tensions within socio-economic systems and none of these issues is amenable to an easy solution. Note that none of these issues, except the 30% of factoids focused on STEM education, directly address engineering education, but the report makes clear that education impacts all these issues.

Theory A vs. Theory B

To better understand how a problem-based perspective might be different than a tension-based perspective we develop two different ways of looking at an issue in engineering education that we call Theory A (problems) and Theory B (tensions). The names are derived from McGregor's Theory X and Theory Y in organizational management [19]. In Theory X McGregor postulates that workers have little intrinsic motivation and thus need high regulated and structured work environments. In contrast Theory Y posits intrinsic motivation and encourages autonomy supported by a participatory and flexible work structure.

The Theory A perspective identifies issues as problems that are *a-priori* assumed to have a solution of some form. A solution is defined to be a change of sufficient magnitude that the problem is resolved or becomes significantly less pressing on local or national agendas. Theory A posits that a solution can be causally achieved by some action or coordinated set of actions by specified actors. The actors have responsibility for the solution(s). The path to a solution can be mapped out in advance, at least in general terms, so that actions can be planned. Issues that are not able to be resolved are assumed, perhaps implicitly, to remain intractable due to lack of sufficient resources, failure to engage needed actors, or the inability (as of yet) to articulate a valid solution path. The role of the change agent is that of an engineer or manager.

In contrast Theory B views issues as tensions between portions of the system and/or multiple actors that represent a dynamic equilibrium within the system. This equilibrium is the state of the system as it currently exists and the state in turn is defined by the existence of tensions. The tensions do not exist by design, rather they arise almost coincidentally from rational or defensible positions taken by actors or organizational units within the system. In other words the dialectics need not be in direct opposition to each other but can rather arise from actors adhering to a rational and historical script that is based upon their place in the organization or past experiences. In Theory B issues are addressed by clarifying relationships, enabling actors to see their position in new ways, and reframing the narrative underlying the overall system. Problems are not solved since any rearrangement lessens some tensions while strengthening or creating others. Thus the role of a change agent is not resolution but adaptation.

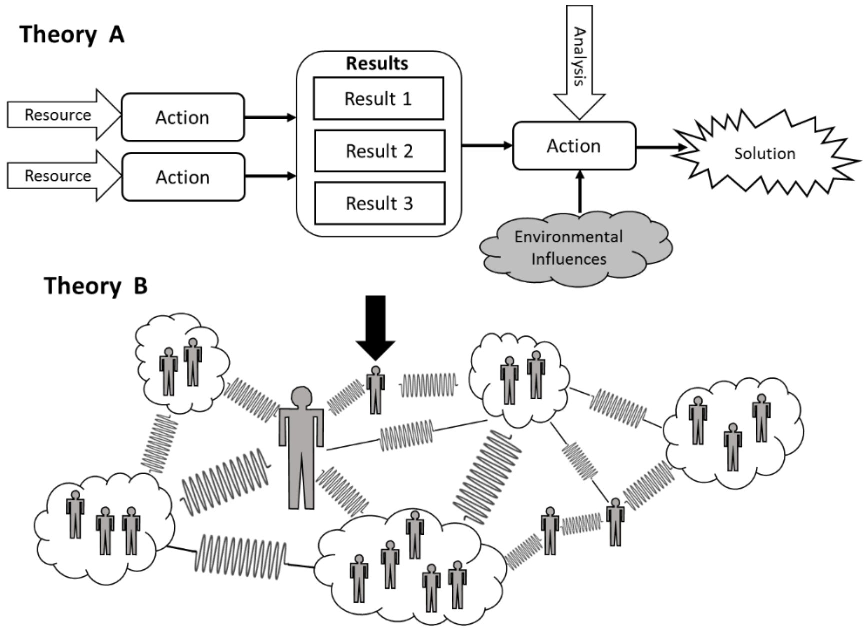


Figure 3: Graphical representations of Theory A and Theory B

Following McGregor [19] Theory A and Theory B are not opposite ends of a scale, rather both coexist and both can be useful in exploring change. Both theories are represented graphically, if imprecisely and representatively, in Figure 3. Theory A is drawn in a way that resembles logic models [20] and theories of change that are often used in both Federal and private funding agencies. Theory B on the other hand represents connections between individuals and groups as springs. A force on one individual (black arrow) can cause shifting relationships in the entire network. Unless there is a reconfiguration of connections the network (system) retains a common configuration.

To illustrate the tensions vs. problems or Theory A vs. Theory B approaches three tensions identified at the workshop are explored in more detail next. The purpose of this discussion is not to suggest that Theory A be replaced with Theory B, but rather to understand how shifting a perspective may give greater insights into the complex issues raised in reports and program solicitations. Participants at the 2015 workshop on the ways to reconceptualize engineering education reported on the value of productive tensions (disruptions, discomfort) in engineering education. The examples below are illustrative of the differences between problems and tensions but they should not be read as proposing a solution or as an accurate reflection of the actual issue.

Aims of Education

Many of the issues identified at the workshop and from NSF RFPs are related to beliefs about teaching which reflect beliefs of what the overarching goals of education should be. From Table 1 representative issues are whether engineering programs should be theoretical or practical in nature, the relative merits of summative vs. formative assessment, and the balance between serving industry needs or liberally educating individuals. In the framework of Theory A a stance on these issues is taken, then a problem is identified which is framed discovering how to improve student learning, and finally the discovery is broadly applied. In Figure 2 these are associated with the categories "quality and form of education" and "transfer of research to practice". From the Theory B perspective tensions arise between utilitarian and humanistic aims represented by different disciplines and traditions within the academy. These tensions are manifested through discussion of which courses should be included in a curriculum. Similarly the long simmering debate on four year vs. five year engineering degrees in the United States reflects the tension between professional preparation and a liberal education.

Diversity

It is widely recognized that some groups—including women, African Americans, and Hispanics—are under-represented in engineering programs compared to the US population as a whole, or their groups' representation in other university degree programs. Framed as Theory A a combination of the correct interventions—increasing faculty diversity, providing research opportunities in formative year, or identifying engineering norms that contribute to under-representation—can "shift the needle" on this intractable problem. From the Theory B perspective the issue of representation may result from universities legitimate concerns with the "quality" of incoming students as measured by existing metrics [21] and faculty belief systems of what engineering is. This may be framed broadly as a tension between perceptions of the relative importance of student professionalism or competency vs. inclusion. The existing equilibrium is supported by program concerns with status that are reinforced by quantitative ranking systems, as well as long-standing disparities in K-12 school systems that derive from models of how public schools are funded and national beliefs around how school performance is measured.

Engineering Identity

One of the goals of engineering education is to create a professional identity within students since engineers are members of a profession. Students who assume this identity generally do better in their degree programs [22]. Sub-themes to the question of identity are often played out around what an engineer is and reflect views of engineer as scientist, engineer as designer, or engineer as manager [13]. A Theory A approach seeks to build an engineering identity around one of these models and a role of faculty is to identify which are the most transformative experiences that create this shift in identity. A Theory B perspective emerged from the workshop where tensions around engineering identity were discussed in terms of intersectionality [23]. In this view students have overlapping identities with expectations and norms that may be in direct conflict with the "engineer first" identity that degree programs are seeking to create. These tensions are personal and difficult to resolve in a fast-paced engineering degree program.

Conclusions

Engineering education, as are all educational processes, exists in a state of tension. These tensions arise from differences in viewpoints and experiences between educators, policy makers, and citizens since education is an arena is which our hopes for the future are played out through the preparation of the next generation to take over when we exit stage down. These tensions have led to an ongoing dialog within engineering education played out mainly through reports of blue-ribbon panels, funding programs, and how engineering programs are constituted and maintained. Since the identity of an engineering educator includes that of problem solver, faculty may perceive these tensions as a problem to be solved rather than as necessary and generative. This paper has highlighted a small subset of tensions drawn from various scales of engineering education dialogs, discussed differences between a problem- and tension-centered view, and proposed a problem-focused Theory A and tension focused Theory B that operate concurrently and independently.

It is not proposed that Theory A and Theory B are unique or new contributions. For example the approach broadly framed by Theory B is common in the social sciences as well as organization literature [24] while Theory A reflects much organizational thinking. Rather we argue that the Theory A approach is much more common in engineering and this approach serves as a double hermeneutic, which supports existing states of a system to be viewed as a problem. From this perspective the system is defined by organizational units that interact in discernable ways. Changes to the system are possible through direct intervention to this organizational structure. We offer the observation that many policy organizations that have an influence on engineering education seem to operate from a Theory A perspective. Theory B, on the other hand, is centered on the dynamic relationships of agents clustered in complex ways. These agents have beliefs and values derived from their own experiences and seek to support their point of view. While external influences can cause a temporary disequilibrium, only by changing viewpoints or removing agents or agency can the system change. In Theory A tensions are perceived as problems to be solved while in Theory B tensions are necessary since they are a natural part of human affairs and generative in that tensions highlight dialectics from which new truths or perspectives emerge.

From this perspective a key element of faculty development in Theory A is to provide actionable knowledge about the most effective approaches for identified learning goals and the resources needed to enact these approaches. Evaluation of outcomes gives insight into the effectiveness of the approach and is used to dynamically adjust the process of moving towards the specified goals. If this sounds familiar it is the framework that underlies the ABET accreditation process. In Theory B knowledge is framed relationally and the tensions that arise are the source of creativity. Thus the pathway to meaningful changes includes knowing one's own points of view and being able to build connections and dialogs with those who differ. From this perspective the disciplinary structures of higher education such as departments and colleges may serve to inhibit interaction. Faculty development involves helping all members of the community articulate a defensible personal philosophy that both lets one navigate and learn from the inevitable tensions that will arise in practice and contribute to larger dialogs from which new systems and forms of education emerge. It is an open question what forums exist in engineering education for such participatory dialogs to occur, whether such forums are needed for systemic adaptation to occur, and the best method to support meaningful, scholarly dialog.

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