Managing Transformation to Crack Open Engineering Education

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Rapid changes in the worldwide engineering ecosystem are creating a compelling rationale to rethink engineering education. Tomorrow's graduate will need to collaboratively contribute expertise across multiple perspectives in an environment of rapid innovation and technological breakthroughs [1]. Meeting these challenges requires a transformational change rather than incremental improvements in how we recruit and educate engineering students. This move toward transformational change, however, also provides an opportunity to reconsider how we approach reforming structural barriers to inclusion across engineering education.

Structural barriers [2] to inclusion in engineering education, and for that matter the entire engineering ecosystem, are real, though often ignored or called "too complex" [3]. As we attempt interventions to improve engineering as a space where all are valued, both in education and in the field, curricular and pedagogical transformations provide an opportunity to rethink how we interact with the structural barriers that have evolved in our institutions, with the goal of changing the climate and culture of engineering education. Transformative educational practices can "crack open" learning spaces to make them more welcoming to a broader group of individuals through the climate we create in those learning spaces. Similarly, using student-centered learning and other evidence-based practices allow additional opportunities to value all that students bring with them, including their varied modes of inquiry as well as their social, knowledge, and experience capital [4, 5].

Credentialing is both an element of organizational structure in higher education and a key component of systemic, transformative curricular innovation [6]. Regardless of what "level" of credentialing (e.g., credit hour, degree program) we are working in at a given time, credentialing is, at its core, a question of who belongs and who does not. The act of determining how credentials are distributed is about more than just matriculation and graduation; it creates – or denies – access to a space where an individual has earning power and options. Credentialing, then, is not only a potential structural barrier to inclusion, it is core to social justice in the engineering ecosystem. Core, though, does not mean sufficient in and of itself; providing access to opportunities to earn a credential without also developing ingress points to cultural and social systems is unlikely to succeed in diversifying our field. Similarly, both credentialing and inclusion need to consider the impact on those who take alternate pathways through our ecosystem.

Given this connection between credentialing and building inclusivity, we can also use credentialing to connect transformative educational practices to structural, as well as personal and methodological, barriers to inclusion and diversity. Leveraging transformative educational practices for climate and culture change has a significant advantage within the engineering ecosystem: it is based on cumulative decisions made every day by individuals who vary in power status [7] within the system. In other words, everyone can participate now, rather than waiting to be "ready" or in a particular position of authority. Further, innovative curricular transformation is a lever of change around which concerned individuals can rally, building excitement and momentum. One of the key challenges, however, is finding ways to match inclusive and innovative curriculum with the dominant credentialing systems on which many other systems are built [6]. Essentially, fixing credentialing means better inclusion and broadened participation.

Communities of practice (COPs) have been leveraged to support change in teaching practice and pull researchers together on a variety of tasks in a range of domains. They have the potential to support large-scale change in engineering education and multiple levels. Although COPs have become familiar to many faculty, maintaining a community of practice happens best when there is a supporting culture and people who connect as community members. To meet the challenge of fixing credentialing in a supportive environment, we begin by adapting Wenger and Snyder's model of administrative support for communities of practice and ways in which membership in communities of practice add value to organizations through the following elements [8]: drive strategy, start new lines of operations, improve problem solving, transfer best practices, develop professional skills, and help recruit and retain talent. As we adapt each element to academic credentialing in this work, we are building on, and including quotations from, on-going interview-based research on credentialing innovative, transformative curriculum as described elsewhere [see 6, 9]. This will result in a process to reflect on, manage, and implement successful transformation in engineering education.

- *Drive strategy*: As we better understand the needs and contributions of all (potential) members of the engineering ecosystem and the researchers continue to push the cutting edge of knowledge, the structure of credentialing has a particularly valuable contribution in the college or university's development and implementation of goals and objectives as well as faculty development and implementation of transformative education practices.

  "Whether or not the word 'credentialing' was invoked, we argue that the types of barriers cited most frequently by those involved in the development and implementation process fall under the larger issue of credentialing, namely the challenge of fitting something new and non-traditional into existing boxes. In addition, our participants represented multiple levels or pieces of the larger system within which credentialing issues operate, highlighting the systemic nature of the barriers and the necessity of understanding how the various pieces are intertwined before real solutions can be found." [6]

  "There were lots of moving parts. The [State University System] is composed of about seven universities and 25 community colleges -- 32 institutions with 50 sites all over the state, over 300,000 students. It is huge and cumbersome and it has three cultures because it was put together by the state universities, the tech schools and the community colleges, all of which have different philosophies and unions. … There's no common culture in all those schools. So we're dealing with a tech school -- a community college in the [region] District. We're dealing with a pretty traditional university in [region]. And we've got this big corporate structure of the [State] College and University System overlaid on this, who wants to create change and everybody else doesn't." [9]

- *Start new lines of operations*: The intersection of the structure of credentialing and transformative educational practice is an incubator for new curricular ideas and research and assessment questions that promote inclusion and diversity.

  "We came up with the idea to…rather than using existing programs that [university] already had, we would create a new engineering program, a general engineering degree.

And I think that was less threatening to the [university] faculty because…I don't think they worried as much that it would jeopardize their accreditation. And there were enough faculty at [university] who were kind of interested in this idea and were kind of willing to participate that if it was this separate program, they were willing to be involved. And then we agreed we would hire faculty to be focused in that program. … At some point we just started building this thing that people could at least live with.… It felt like all of that was necessary to finally get to the place where people could move forward." [6]

"Change initiatives in higher ed[ucation] are challenging. … The moral of the story really is sometimes in higher ed[ucation], after one has exhausted the possibilities of using your existing structure -- so you don't jump immediately to an alternative structure, but if you've really tried to get the existing structure to do it and they can't, then a new structure is what you do. And then actually that works even better because you've founded something that is committed to the foundational idea." [6]

- *Improve problem solving*: Access to all of the silos and disciplines involved in credentialing allows individual members to leverage the expertise of one another to find better solutions faster when problems arise.

  University administrators conveyed a university-level perspective, often focusing on getting degrees granted: "They needed to get a degree and it needed to be on the books. And what could we do in terms of curriculum that would let it get on the books? Then once I got on board, a bunch of my work was negotiating the curriculum and saying how much of the content do we actually have to specify?" [6]

- *Transfer best practices*: The structure of credentialing spans discipline and organizational boundaries, and thus provides additional mechanisms for colleges and universities to find and implement best practices in both inclusion and transformative educational practices.

  "I think having its own separate entity helped in that way that we didn't-- weren't as concerned about any impacts that might potentially be there. But also, it was easier to go through the curriculum process where they had to still get some support from the other engineering programs, but it wasn't all reliant on us, you know, approving or not approving. It was just part of the general curriculum process at that point." [6]

- *Develop professional skills*: Bringing together the varied parts of the institution involved in credentialing and transformative educational practice increases the availability of peer mentors involved in promoting inclusion and provides increased opportunities for members to read peer reviewed journals, attend conferences, network with colleagues, and learn new techniques directly from the researchers and developers.

  "[The On-Site Director] is, I would say, the key to the program up there. He's the guy that really, having an engineering background himself, was able to put this all together. And in coming from that area I think he saw things that nobody else could see in terms of relationships with the engineering mines up there, and…he's a local, and is held in really high regard. I would say he was the architect of the plan from the [region]. He had to

sell it to everybody up there, and then he had to come down here and take abuse from our deans…and department chairs. And so he went through quite a few hurdles to sell it. And also promote it nationally." [9]

- *Help recruit and retain talent*: Highlighting the intersection of transformative education practices and organizational structural understanding through credentialing helps deans and department chairs identify both talented individuals and the opportunities that will improve inclusion while allowing the individual to develop as a leader.

  "You need a champion, yes, absolutely. There's got to be a champion in there someplace, because along the way, you're going to run into various barriers. Whether it's a high barrier or a low barrier, it doesn't matter, and if you don't really have the champion there, it's so easy to get discouraged and just say, you know, it's not worth it. So, yeah, having somebody like [the On-Site Director] there is very important." [9]

Each of these ways to improve higher education has its own merit and business case. When used intentionally, however, these mechanisms can also be used to promote inclusion and broaden participation. This means that even if you are working with colleagues who do not prioritize diversity, leveraging these practices provides the opportunity to use processes such as credentialing (and potentially accreditation) to achieve both the stated goal of systematizing a transformative educational practice *and* the not necessarily stated goal of reducing a structural barrier to broad participation. For example, when transferring best practices on how an innovative course is credentialed at one's institution, intentional leveraging of the mechanism provides the opportunity to frame the language of the best practice to be inclusive while developing other innovative courses.

The next step, then, is to consider the six elements of the model as a bundle. Borrowing from the Six Dimensions of Wellness Model [10], we visualize the adapted Wenger and Snyder model as a wheel, where each element is represented by a wedge and the relative strength of the element is represented by the number of colored segments in the wedge. Figure 1 shows a situation where all six elements are at full strength. When an element is lacking in strength, at best it makes organizational functioning bumpy and shaky and at worst it causes organizational functioning to wreck and derail your goals. We call this situation, as seen in Figure 2, a "flat tire".

A reflective process can provide insight and direction, allowing an organization to best define next steps towards transformation and structures that support inclusivity. For a given situation, department, or organization where you want to improve inclusion, take stock of where you are in each of the six areas of the bundle by assessing your group's success, performance and/or potential in the six areas. This could be done individually, or better yet collectively, with results shared either openly or anonymously. Figure 3 shows an organization where there is room for improvement in all of the elements; however, "drive strategy" and "transfer best practices" are in particular need of improvement. Using this reflective process creates an opportunity for organizational leader to perform a "reality check" on their assumptions of the strengths and

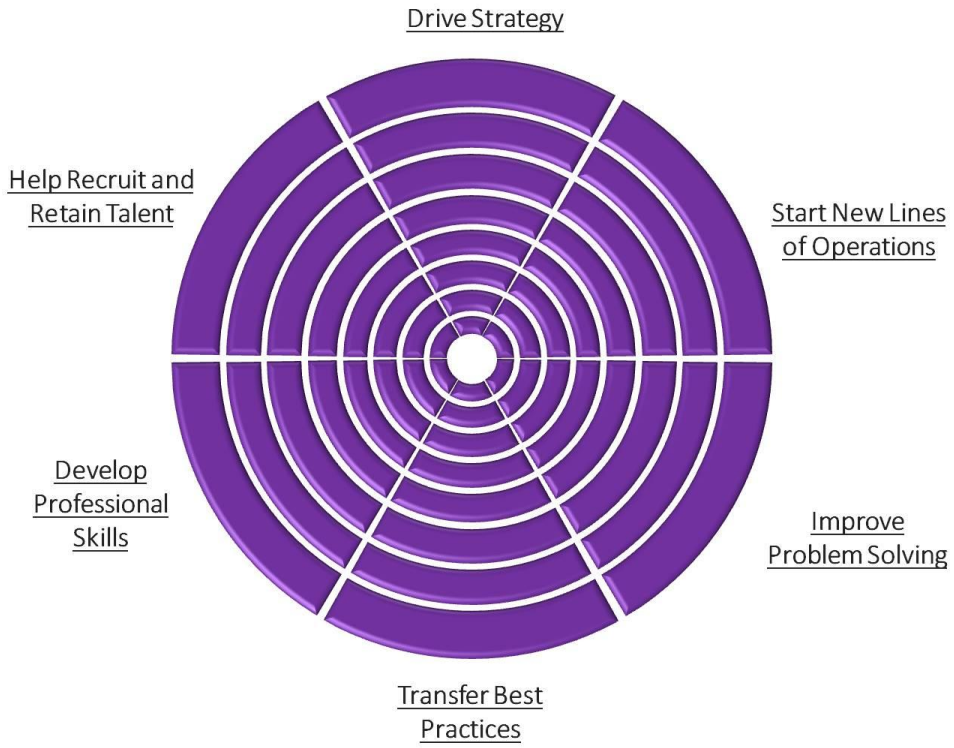

Figure 1. All Six Elements of the Model for Supporting COPs at Full Strength

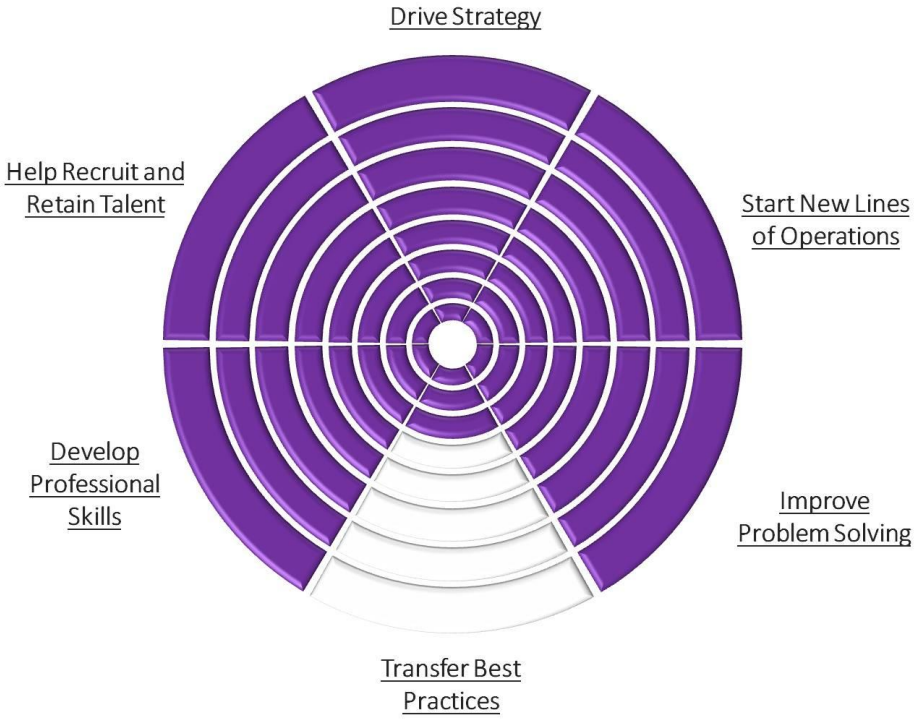

Figure 2. The "Flat Tire"

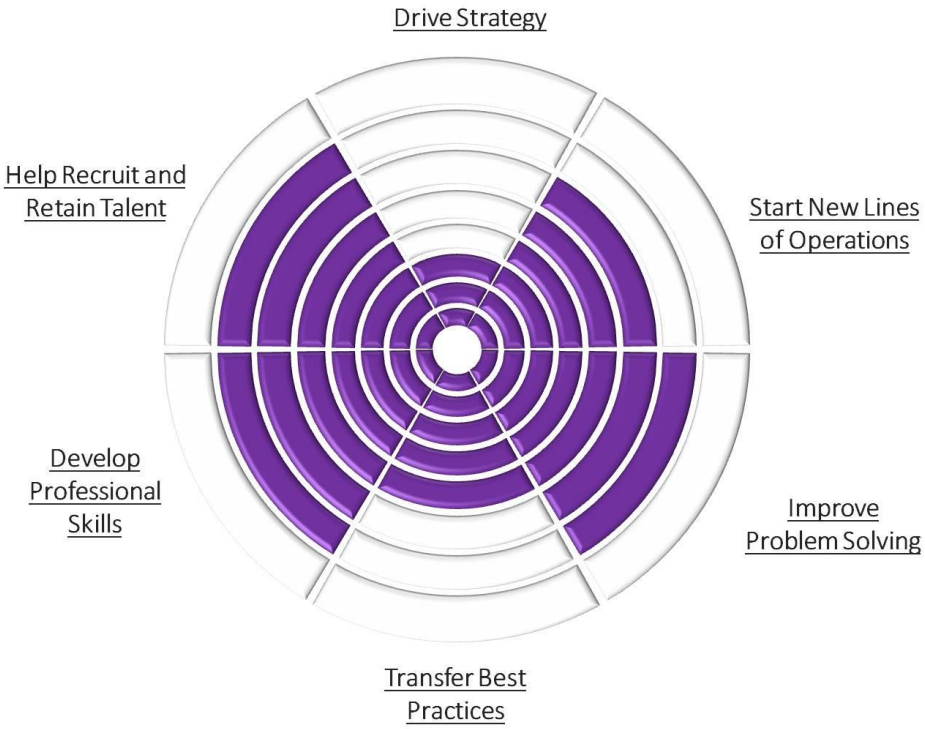

Figure 3. An Example Organization's Wheel

weaknesses relative to the wheel model. For example, a department head or dean may have different beliefs from at least a portion of the faculty regarding how well the department or college is performing in parts of the wheel. This reflective process, then, provides an additional opportunity for minority voices to be heard, also contributing to inclusion.

The key questions to the reflective process of taking stock seem simple, but draw out significant nuances of opportunity for transformation in the organization:

- *What element(s) of the wheel has the most color?* In our example, "Help Recruit and Retain Talent", "Develop Professional Skills", and "Improve Problem Solving" have the most color. These are the areas where our hypothetical organization is demonstrating the most strength and thus can be used to help buffer the areas which are weaker. It is important, however, not to diminish these elements while working on improving the other areas of the wheel.

- *What element(s) of the wheel have the least color?* These are the areas that make the wheel "flat". In our example, "start new lines of operations" and "transfer best practices" are certainly areas of concern and need improvement, though "drive strategy" has the potential to be a catastrophic flat tire for the organization.

- *If you have done this process before, how has the balance of your wheel changed?* Like most reflective tools, taking stock of the balance of your Wheel should be done every so often both to track changes over time and to keep the goals of inclusion and broadening participation fresh and vibrant in the organization.

Finally, once the reflective process has provided the picture of the current situation, we leverage the process from Bates et al. [11] to turn our research insights on large-scale change [9] to recommendations that move the Wheel to action. Organizations that need to improve their wheel balance in the areas of improving problem solving and transferring best practices are likely to benefit from considering where they have people in bridging positions [9]. These people act as gatekeepers between programs, organizational levels, and administrative silos.

Figure 4. Wheel Segments that Relate to "Translators in Key Bridging Positions"

Organizations that need to improve their wheel balance in the areas of help recruit and retain talent and develop professional skills are likely to benefit from developing and supporting champions at all levels of the organization [9]. These individuals are advocates for the program regardless of where in the organization they sit. Additionally, champions are positioned to mentor others and help secure resources.

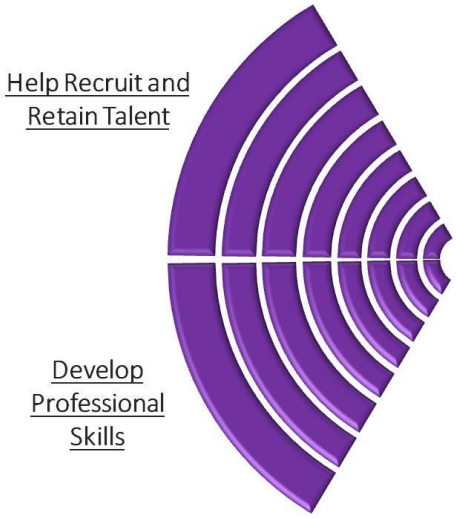

Figure 5. Wheel Segments that Relate to "Champions at All Levels"

Organizations that need to improve their wheel balance in the areas of drive strategy and start new lines of operations are likely to benefit from creating new boxes [9] in their processes. Creating a new course, program, department, or whatever level is appropriate for the size of the desired change, allows you to connect strategy and operations to broader goals, like inclusion, while building on your stakeholders' feelings of ownership of the program or process. This is particularly important if your stakeholders represent a variety of current "boxes" or if at least some of your stakeholders are connected to "boxes" that currently demonstrate barriers to inclusion, such as a degree program with a negative organizational climate.

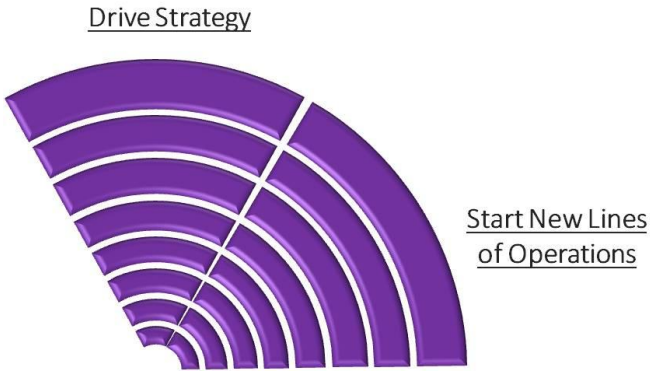

Figure 6. Wheel Segments that Relate to "Creating New Boxes"

The depth of structural processes, such as credentialing an engineering degree, that are necessary for transformative educational change provide an opportunity to additionally attack structural barriers to inclusion and broad participation. The research-based, reflective process outlined in this paper provides mechanisms to intentionally leverage these situations effectively. We see here that credentialing can be a driving force for inclusivity in the engineering ecosystem, though it needs to be done with intent and forethought. The reflective tool provided here is a starting place for systematically using credentialing to improve inclusive access to engineering education and careers as well as improve inclusive access to the mechanisms through which we make important decisions in the academy.

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