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# Insights and Outcomes from a Revolution in a Chemical Engineering Department

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# Insights and Outcomes from a Revolution in a Chemical Engineering Department


## Abstract

Despite decades of calls for both broadening participation in engineering and for STEM faculty to adopt evidence-based teaching practices, change is notoriously slow. In response to an NSF call for projects that could accomplish such efforts, our chemical engineering department proposed FACETS (Formation of Accomplished Chemical Engineers for Transforming Society) with a vision of supporting our diverse students to be prepared to address the grand challenges of the 21st century. Our longitudinal analysis suggests that our approach has fostered persistence, especially among first-generation Latinx students. Now, at the end of our project, we report on evidence of sustained change and offer insights and implications for others interested in making change. Specifically, we synthesize the following guidelines: (1) Planned change theory, like Kotter's change model, is an accessible place to start, but don't expect the change process to be linear. (2) Embed a community of practice in existing structures and norms, such as faculty meetings. Be creative in bringing discussions of teaching into such spaces. (3) Develop multidimensional measures of student assets, growth, and development. Staying only with measures of progress on conceptual learning misses much about students' development as chemical engineers. With regard to supporting students, we also share two key strategies: (4) When teaching technical communication, offer limited but specific feedback and require revision and reflection. (5) If developing design challenges, create low-bar entry experiences that are relevant, but that have high-ceilinged, open-ended solutions.


## Introduction and research purpose

In 2014 NSF initiated the call for proposals to revolutionize engineering education [1]. Our department began our revolution by initializing changes in our first-year course, then spreading these changes throughout core courses. We aimed to support our diverse students to be prepared to address the grand challenges of the 21st century. Now, at the end of our project, we report on evidence of sustained change and offer insights and implications for others interested in making change.

## Framework

### *Change theories guide and account for organizational planned and emergent change*

The NSF call for proposals for Revolutionizing Engineering Departments (RED) required that these projects be guided by change teams that included expertise in engineering education, be led by a department chair, and that the effort be guided by theory on change [1]. While many may be familiar with change theory that accounts for change at the individual level, such as diffusion of innovations [2], such theories typically fail to account for change at the organizational level, and especially in higher education contexts [3, 4]. Organizational change theories can be categorized as preplanned or emergent [5]. Planned change theory, like Kotter's model, provides an accessible means to manage a change project, scaffolding the change team, even those without expertise in change management, to put together a promising change project [6]. This model includes eight steps for planning change: create a sense of urgency, build a guiding team, form a vision and strategies, enlist volunteers, enable action by removing barriers, generate short-term

wins, sustain acceleration, and institutionalize change. Yet, such planned change models often fail in higher education settings, in part because they were developed with the very different incentive systems of businesses in mind [7, 8]. In particular, the top-down approach of such efforts can fail to fit the high levels of autonomy faculty wield [9].

As an alternative, emergent approaches to change can capitalize on faculty autonomy [5], such as through complexity leadership [10]. This opportunity can also serve as a challenge, however, as the change theory may be unclear to the change team if they lack expertise in this area, and faculty may use their autonomy to head in divergent directions. Although characterized as focusing on individual rather than organizational change [5], a community of practice (CoP) approach [11, 12] can also be organized to address organizational concerns by forming them with attention to specific principles: plan for emergence; create opportunities for the CoP to interact internally and with outsiders; allow a menu of participation options; leverage familiar activities but incorporate opportunity; and embed CoP activities in regular activities [12].

Looking across the RED projects, we note that teams took up varied change theories. We report on how our project began with Kotter's model [6], which provided an easy way into the project, and ultimately developed a CoP [12].

### *Learning about asset-based learning*

With a change effort like those the NSF RED program envisioned, there are many learning needs and opportunities. Engineering faculty, and especially those employed at research universities, typically begin their positions with little prior teaching experience, little to no formal knowledge of how people learn, and with a preponderance of experience as learners in traditional, instructionist classrooms [13]. It is unsurprising then, that many faculty teach in instructionist ways, favoring lectures, and even when incorporating active learning techniques, prioritizing content-centered approaches, such as using clickers in class to support students to acquire content. While such approaches are overwhelmingly better than traditional lectures [14], they are limited in their capacity to develop diverse and marginalized students' sense of belonging in and commitment to challenging courses of study.

To address this issue, scholars advocate for asset-based pedagogies that focus on identifying the strengths students bring from their everyday and cultural experiences, and that can be activated as a foundation for learning [15, 16]. In these approaches, rather than stripping problems of the complexity and reducing them to abstract, technical topics, students engage with sociotechnical problems, including as design problems [17-20]. Rather than making such problems harder, the problem context provides endemic clues for learners and offers varied entry points.

### *Power dynamics provide insight into whether and how change occurs*

In considering the shift from instructionist to asset-based pedagogies, we acknowledge the importance of attending to power dynamics. Consider, for example, two faculty, one standing at the front of a lecture hall, assessing students' comprehension through polling and exams, and the other moving round a large learning studio filled with round tables and listening to students' conversation. In both cases, the faculty member maintains a great deal of structural power via course policies and grading, but power is still distributed differently across the two classrooms

[21]. By taking a closer look at how power is enacted intersectionally through cultural, interpersonal, and disciplinary norms, we can identify ways the latter classroom is more equitable [22], and notice how in this equity, students have greater responsibility for their learning. We also employ this intersectional framework [22] to understand ways power dynamics play out across faculty engaged in change projects. Structural power can prevent meaningful changes, such as when policies demand inflexibility in grading, or when change-ready faculty primarily occupy more vulnerable roles like lecturer, assistant professor, and adjunct. Structural power can also propel change, as when those in leadership positions commit to and support the change effort. From this intersectional approach, the practices and norms, and the culture that reflects and sustains these, reveal much about the progress of change.

## Methodology

### *Research design*

We adopted a design-based implementation research (DBIR) approach [23], in tandem with a change model [6]. DBIR is an extension of the hallmark research method of the learning sciences, design-based research (DBR). Whereas DBR aims to develop contextualized learning theories by instantiating them into learning designs and iteratively testing them in real world conditions [24, 25], DBIR tackles organizational issues from a learning lens. Specifically, DBIR involves identifying a persistent problem of practice and collaboratively designing and studying interventions [23]. Most DBIR has taken place in school districts, for instance, supporting teachers across multiple schools to learn and implement new pedagogy [26], though some studies have also investigated curricular reform in higher education settings, including medical school [27] and in cross-campus efforts to improve the quality of online teaching [28].

Our study employed DBIR to investigate ways to support shifts in departmental culture from primarily instructionist, sometimes deficit-based stances to a culture that jointly values the assets diverse and marginalized students bring and can activate these as a foundation for learning, using instructional strategies aligned with how people learn. As a change strategy, we employed DBR, engaging in multiple collaborative studies of pedagogical innovations.

### *Setting and participants*

The change project occurred in a chemical engineering department at a research university with a high enrollment of students from *marginalized* groups—a term we use deliberately in place of the more common *underrepresented minority*, which conveys that the low numbers of people from certain groups is perhaps a probabilistic mystery rather than attributable to systemic exclusion and oppression [29]. Over the period of data collection, the department included approximately 20 core faculty. Class sizes ranged greatly, as enrollment climbed in the first few years, then dropped during the pandemic, resulting in class sizes from 30 to 125, depending on the course and level.

### *Data collection and analysis*

Both DBR and DBIR studies commonly include both qualitative and quantitative data, omnivorously and sometimes opportunistically documenting progress. We documented departmental culture, norms, and interactions, as well as pedagogical practices from fall 2015 to

spring 2022. We collected data about faculty meetings, workshops, and retreats, how courses were taught, and how faculty interacted with one another. This entailed creating a data corpus by video and audio recording meetings and class sessions, interviewing faculty, staff, and students, collecting field notes, documenting participation and interactions through emails, handouts, and slides, surveying and assessing students, and collecting other course assignments. We curated the data corpus, adding metadata (date/time, researchers and participants, context, duration of recording, and noting if the data provided insight into key foci: assessment practices; teaching technical writing; deficit versus asset-based stances; collaborative, design, project-based learning; faculty buy-in; and community of practice). This resulted in a data corpus of over 80 hours of recordings and thousands of documents.

For this paper, we conducted retrospective analysis [30-32], reviewing both data and our publications to examine how and what change we have brought about, for both students and faculty, and with particular attention to the change strategies that consistently supported the work. For those interested in particular outcomes, we direct them to the papers concisely summarized. Rather than reporting the results of a single or particular aspect, our present aim is to synthesize collective insights.

## Results, discussion, and implications

We summarize the results of our retrospective review, first focusing on evidence of faculty engagement and department cultural change, and second, on student impacts. In tandem with these results, we offer concrete strategies, based empirically in our experience, and linked to these impacts.

### *Planned change theory is an accessible place to start, but don't be too linear*

We began our change project guided by Kotter's change model [6], forming a guiding team, vision, and specific strategies. This model was new to most of the team, yet we could quickly identify with and understand it. However, unlike Kotter's linear depiction of change, we enacted steps out of sequence and iterated responsively. This was in part driven by our use of DBIR, and in part because of our primary aim of changing department culture. With careful attention to fostering buy-in, we changed our guiding team and strategies [33]. For instance, when a faculty member expressed frustrations related to teaching technical writing, the guiding team agreed that incorporating this issue could jointly fit the vision and engage more faculty in the change effort.

Our key strategies are transferrable to other departments and include threading sociotechnical design challenges through core courses and using a process of feedback-revision-and-reflection to teach technical communication. These approaches helped faculty understand how interested and excited their students actually are, and in turn, helped them value and build upon the everyday assets our diverse students bring.

Overall, we characterize our initial change effort as accessible and low-bar entry. We made it easy for faculty to try out new ideas or to participate in simple ways, such as serving as an expert consultant to students working on a design challenge or as a panelist evaluating students' pitches. This meant we could consistently meet faculty where they were, change-ready or change-hesitant, and find ways for they to grow.

### *Embed a community of practice in existing structures and norms*

Most departments offer seminars and invite speakers. By including engineering education researchers in the rotation of technical speakers, we created opportunities for faculty learning as well as enhancing student buy-in. We brought in faculty from other universities and departments, not only to learn from them, but to learn *together*, as we found that the most engaging and useful workshops were those that opened up discussions of concerns and shifted into generative discussions of ways faculty could resolve their concerns and try out new approaches [34]. This approach supported faculty beyond the guiding team to engage in inquiry about their teaching and its effect on learning [35]. In addition, early in the project, through external evaluation, we discovered a covert value: all of our faculty expressed that they valued teaching, but many assumed their peers did not likewise value it. By revealing teaching as a shared value, it became a more acceptable focus of faculty time in other typical activities, like departmental meetings.

Analysis of the department meetings and documents during the pandemic show a further shift as faculty consulted one another on emergent needs, like modernizing assessment amidst the pandemic. While many departments relied on surveillance software to maintain their typical assessment practices, our faculty agreed that such software was invasive and unfair to our students, and this led to deeper discussions of assessment practices. And there was time for such discussion, as most faculty meetings included conversations about teaching and learning, an indicator not only of departmental change, but also that a CoP practice had evolved. This CoP sustained the still-new approaches, allowing faculty a creative space to pivot and innovate. Even during the early pandemic, faculty found ways to engage students in design challenges, for instance, offering simulations and access to data from prior courses [36]. Faculty used care to guide their decision-making process during this time [37, 38]. By embedding a CoP in existing norms like seminars and faculty meetings, we know it is more sustainable and that it will persist after the grant period and funds end.

### *Develop multidimensional measures of student assets, growth, and development*

In order to support our efforts, we recognized that we needed new ways to measure impact on students. First, we knew we knew we wanted to identify the strengths and assets salient for engineering that our diverse students develop from their everyday and cultural experiences. We conjectured that because many of them had to “make it work” and “make do” that they had developed everyday ingenuity that could serve as a strong foundation as engineers. For instance, when asked, “How have you used a table knife?” our students respond:

- a screwdriver
- a putty knife
- changing the volume on my stereo after the knob broke off
- getting into my car after the handle broke

We developed a survey using published questions about knowledge of design problem framing, engineering self-efficacy, their identities as engineers, and their persistence intentions [39]. Had we begun this work a few years later, we would have incorporated other items [15, 40]. We also developed a measure of design problem framing ability, a performance-based assessment that can be scored with a rubric to evaluate students’ growth in problem framing skills [41].

These measures helped us identify the often-hidden strengths our students bring [42]. For instance, we found that students from groups marginalized and minoritized in engineering held more expert-like views of design than their privileged peers. They recognized that design is iterative and involves learning, not just getting directly to a right answer. Yet, these same students tended to doubt their abilities more than their privileged peers.

### *Impacts on students*

Ultimately, as a result of the changes, our students developed more expert-like skills related to designing [43-46], more sophisticated ethical reasoning [47, 48], improved collaboration skills [44, 49], and all without having a negative impact on conceptual learning. Our longitudinal analysis suggests that our approach has fostered persistence, especially among first-generation Latinx students, in part because of a focus on students' assets [50, 51].

### *Offer limited but specific feedback on writing and require revision and reflection*

An emergent approach in our project was focusing on teaching technical writing. Like many faculty, most of us took a bleed-all-over-it approach to feedback, offering detailed line edits. The effort of this, of course, meant that it was challenging to get feedback to students in a timely fashion. And frustratingly, the feedback seemed to have little to no impact! In working with experts and consulting the research literature, we discovered the missing element in our approach: revision and reflection. We also learned the importance of not making it easy for students to just "accept all" changes, instead focusing on modeling just a few changes and asking students to make the edits themselves. We found that faculty had ideas of various ways to implement these ideas, from using peer-reviews to component submission, yet all of these variants supported student growth, both in terms of conceptual learning and as technical writers, provided the students had to make revisions [52, 53].

### *Low-bar entry, high-ceilings*

Based on analysis of more and less successful design challenges over the course of the project, we synthesized a framework for design challenges, focusing on balancing authenticity with accessibility, and creating low-bar entry, high-ceiling learning opportunities [54]. As a result of threading such design challenges through core courses, students' funds of knowledge were activated. For instance, in the first-year course, students developed more expert-like problem framing approaches, focusing on underlying need and considering stakeholders and contexts of use [55].

## Summary

A key insight from our work is that efforts to shift to more asset-based teaching must also take an asset-based stance to faculty development. This means meeting faculty where they are, engaging their curiosities and concerns, and offering safe ways to try on and try out new teaching strategies. We consider the insights and advice above to be practical for departmental chairs as well as for faculty seeking to makes changes in their courses. This includes practical strategies about productive discussions during faculty meetings, fostering (or finding) communities of practice that can support implementation dips and reflective improvements along the way,

finding joy in students' excitement, and showing care for students as a means to help them reach high expectations.

In sum, making time consistently during faculty meetings, and normalizing discussions that focus on student learning, and multiple forms of evidence of student learning is a feasible practice to foster. When planning a major change, we advocate for starting with an accessible organizational change model, like Kotter's model, but suggest avoiding a linear approach. Finding ways to fold faculty into the effort, whether they are ready or not, is critical. This depends on finding simple and respectful ways to engage them.

### *Limitations*

Our insights, though gained over years and following rigorous methodological standards, is sited in just one institution. While we have benefited from participating in the broader community of RED projects, our specific context differs from others. While we argue many of our approaches are feasible for others to try, we invite collaborations and comparisons as a necessary step in furthering this kind of work.


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