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# Leading Large-Scale Change in an Engineering Program

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# Leading Large-Scale Change in an Engineering Program


## Abstract

While many efforts have been made to improve technical and professional skills in engineering graduates, there has been little comprehensive change in the pedagogy of most engineering education institutions in the U.S. Many of these efforts involve changing only one or two aspects of the curriculum, and therefore are less likely to make significant changes in the student learning outcomes. For better success, engineering curricular changes will need to address the entire education system. In order to see real, sustainable improvement in engineering education practice, both the behaviors of the participants and the systems within which these participants act must have change. Changes in education practices are unlikely to develop and persist without concurrent and structural changes at the administrative level; thus this study focuses on understanding the activities of individuals during an administrative change. Further, this study highlights the importance of how change agents work with the various groups, or sub-cultures, within universities as well as the opportunity for leadership from the faculty and department chair ranks.

This study seeks to better understand the change management activities and opportunities that occurred as the Iron Range Engineering program was developed and implemented. Iron Range Engineering (IRE) is a two-year, project-based program that allows students with two-year college degrees to complete a bachelor's degree in engineering. The program is a partnership between a community college and a state university, separated geographically by several hundred miles. The program takes place at the community college, targeting students in that part of the state and responding to the needs of local industries. Because of the complex nature of the institutional partnership, as well as the project-based, team-focused emphasis, the program serves as an innovative model for engineering education.


## Introduction

The engineering profession is becoming steadily more global in nature,[1] creating the need for engineering education to develop a graduate who is prepared for a career in this global economy. In the U.S. education system, it has been recognized by many prominent engineering agencies and educational leaders[2,3,4,5,6,7] that the current model of engineering education will not adequately prepare students to be the engineers of the future and that change is needed in the way engineering education is done in the U.S. These reports and other calls for change all point out that the key to effective curriculum development is building an engineering education model that meets both technical and professional needs of the field that graduates will enter. One action from these calls resulted in ABET adoption of the ABET 2000 criteria, a set of eleven outcomes for engineering graduates to possess.

While many efforts have been made to develop these technical and professional skills in engineering graduates, there has been little change in the pedagogy of most engineering education institutions in the U.S.,[8] despite the evolution of engineering education in many countries around the world. Many of these efforts involve changing only one or two aspects of the curriculum, and are bound to fail in making significant changes in the student learning

experience due to the limited change in the curriculum.[9] For success, engineering curricular changes will need to address the entire education system. In order to see real, sustainable improvement in engineering education practice, we must have positive change in both the behaviors of the participants and the systems within which these participants act.

The development of the IRE program is one story of change in engineering education. One of the factors that make this story of particular research interest is that it focuses on the environment in which the change is occurring and the administrative and political structures necessary for that change to be sustainable. This research, then, sheds light on the systemic barriers to change in higher education and builds on previous work, including Kolmos and de Graaff's[10] summary of institutional change in higher education and the complexities associated with movement from traditional teaching systems to project-based learning (PBL) models.

## Background

*Program Background*

It was the calls for change described above and a focus on a competency-based learning model[11] that led to the development of the IRE program, which is the case for this exploratory study. Starting in January of 2010, Itasca Community College and Minnesota State University, Mankato, collaboratively delivered the Iron Range Engineering program.[12] The program is upper division only (years 3 and 4 of the bachelor's degree) with entering students coming from community colleges and transferring from other four-year institutions.[13] Graduates are conferred a bachelor's degree in engineering. The model is based on a systems level approach to educating engineering students. As an adaptation of the Aalborg model,[14] the core focus of the model is student-empowered development of technical and professional knowledge and competencies in the context of industry-sponsored projects. The program is 100% project-based and does not utilize traditional courses. Through semester-long projects, students acquire the technical and professional competencies as part of their degree completion. Each required competency is defined by a set of measurable outcomes; for each outcome, students are placed on a continuum from novice to expert. In the beginning of the first semester, students work with faculty to establish individual starting points on each outcome. In this way, the learning model recognizes each student's different starting levels and empowers all students to build on their strengths and overcome their weaknesses as they navigate their education.[13]

A guiding principle for the IRE model is that students own the responsibility for their learning. At the beginning of each project cycle, students identify which outcomes will be addressed during the project. Working with faculty, they determine which learning modes will be applied and determine what types of evidence they will need to acquire in order to demonstrate outcome attainment by the end of the project cycle. Learning activities include planning, resource identification, self-directed knowledge acquisition, peer conversation, help-seeking, reflection, and evaluation.[15] Each project cycle concludes with the presentation of two reports: a design report for the deliverable, and a learning report that reflects on the learning process and provides evidence of outcome attainment. Students track their acquisition of employability skills through a continuous improvement "professional development plan" wherein they describe new learning, evaluate current competency levels, set future goals, and create action plans. This is done each semester and there are 9 sections in the professional development plan addressing things such as

communication, leadership, inclusivity, lifelong learning, teamwork, etc.[16] At the end of the semester, a final presentation includes an extensive oral exam session in which students demonstrate their understanding of technical engineering knowledge gained and competencies acquired. At the conclusion of each project cycle, students have a new view of their levels of knowledge and competencies.[17]

*Organizational Change*

In order to see real, sustainable improvement in engineering education practice, we must have positive change in both the behaviors of the participants and the systems within which these participants act. This structure of change follows the dual core model posited by Daft,[18] where the two cores are the technical and the administrative. The technical core consists of the operations level activities of the organization, which for engineering education includes the decision making processes and actual education practices employed by instructors. The administrative core includes the structure, culture and climate, and policies and procedures that influence, and sometimes direct, the operations of the organization. Changes in the technical core alone are unlikely to persist, though changes in the administrative core lead to changes in the technical core;[19,20] therefore, we have focused this study on understanding the activities of individuals during an administrative change. Further, this case highlights the importance of how change agents work with the differing groups, or sub-cultures, within the university as well as the opportunity for leadership from the faculty and department chair ranks.

The organizational change necessary to build healthy, functional universities that encourage innovations in engineering education is most often thought of as either push from the top down or collectively rallied from the bottom up.[21,22] Another reason for focusing on the administrative core is that neither concept fully explains the importance of sub-cultures as well as other barriers to sustainable organizational change, such as the processes and effort necessary to shift an organizational culture and the potential pathways to build that momentum, particularly in larger organizations.

An organizational sub-group that "demonstrates the culture and traits of a learning organization" is called a learning pocket.[23] These learning pockets illustrate the third path for organizational change mentioned above: leading from the middle. Managers and faculty who form strong, healthy organizational cultures within their workgroups or units and then participate in the movement of these cultural variables from the sub-culture to the dominant culture are creating change at the whole-organization level. The diffusion of the "storehouse of pooled learning" and "the set of standardized orientations to recurrent problems"[24] of a learning pocket or a network of learning pockets to the dominant culture is a mechanism for improving the entire organization.

We frame change management with the conceptual model that when

$$D * V * F > R$$

then change can occur.[25] D is the dissatisfaction the system's participants feel, or can be encouraged to feel, with the current state. V is the strength of the future vision communicated to the participants and their feeling of alignment with this vision. F is the first steps that are already underway toward the new status, the closer the organization is to realizing the change the greater the first steps. For any organization to change, enough of the individuals must change. For the individuals to change, each individual needs to feel that the combination of D, V, and F have to

become greater than the aggregate resistance to change, R. Fortunately, these three leverage points do not need to be evenly tapped among the participants in order to have change.

We can further operationalize resistance using Kanter's[26, 27] groundbreaking "Changemasters" study, which identified ten reasons people resist change, including loss of control or face, lack of quantity or quality of communication, concerns about the type or volume of future work, and baggage from past interactions. While many of the concerns that led to resistance were based in unfounded fear, uncertainty, and lack of information, Kanter and her team found that some of the concerns were rooted in real concerns that, when ameliorated, would improve the proposed change.

**Research Methods**

This study explores the development and implementation of the IRE program ("the IRE Story") to address the following objectives:

- To understand the processes involved, barriers faced, and strategies for overcoming those barriers.
- To use these understandings to inform recommendations for others involved in similar endeavors.

The study was guided by the following research questions:

1) How did the program come about?
2) What helped or hindered the process of developing and implementing the program?
3) What lessons learned from this process can inform and improve future transformational efforts in engineering education?

Findings from this project will be used to create a case study of the IRE Story documenting not only the chronological progress of the project, but also the barriers faced, strategies tried, successes, failures and lessons learned along the way. These findings and the observational artifacts will be mapped to theories of organizational change, in order to better understand the process and how to improve future transformative efforts in engineering education. This paper presents preliminary findings addressing Research Questions 2 and 3, including resulting recommendations for others considering undertaking similar programmatic changes.

*Procedures*

In order to address the research questions, qualitative data were collected through semi-structured interviews with key participants in the project. These interviews (1 hour each) were conducted with 16 individuals who are or were involved in the process of developing and implementing the program. Three of these participants were founders of the program, and the purpose of these three interviews was to understand the history and current state of the program, including the goals, barriers faced, strategies used, and lessons learned from the perspective of the core founding group. The purpose of the additional 14 interviews was to add depth and alternate perspectives to the IRE Story by gaining insights from a wide range of participants in the process. All interviews were conducted by one researcher during Fall 2014 (14 in person, 2 by telephone). All interviews were audio recorded and transcribed.

The interview protocol consisted of the following guiding questions and prompts:

1. What was/is your role in the development of the IRE program?
2. How did you get involved?
3. When you first got involved, what did you think of the idea? Why?
4. Did your thinking about the program change during the process? How? Why? What influenced your thinking?
5. What do you feel was the biggest challenge in getting the program started? How was that overcome?
6. What challenges is IRE still facing?
7. What do you think of the current program?
    a. What do you feel are IRE's strengths?
    b. What do you feel could be done differently?
8. What do you anticipate in the future for the program?
9. What advice would you give others who are involved in similar projects? Lessons learned?

The analysis presented in this paper draws primarily on data from responses to Questions 5, 6, 7, and 9; however, the entire transcripts were coded in order to capture all data relevant to the research questions.

*Subjects*

**Table 1. Interview Subjects by Title and Program Role**

| Position | Role in Program | Number |
|---|---|---|
| State University Faculty | Curriculum Committee | 3 |
| State University Faculty | Curriculum Committee and On-(state university) Campus Program co-Director | 1 |
| Community College Faculty | On-Site Program co-Director | 1 |
| Other State University Faculty | Former Program Director | 1 |
| State University Administrator (President, former Provosts) | | 3 |
| Community College President | | 1 |
| Community College Administrators | | 2 |
| State Legislator / Chair of Higher Education Committee | | 1 |
| Former Directors of Engineering Center | | 2 |
| Former President of Community College | Higher Education Consultant | 1 |
| **Total** | | **16** |

Interview participants were recruited from the pool of individuals involved in the development of the IRE program. This pool included program directors, university and college administrators, faculty, consultants, and state legislators. Participants were targeted to represent a wide range of

perspectives, from both supporters and challengers of the project. Recruitment resulted in a total of 16 interview subjects, as described in Table 1. The interactions among these individuals are also portrayed in Figure 1.

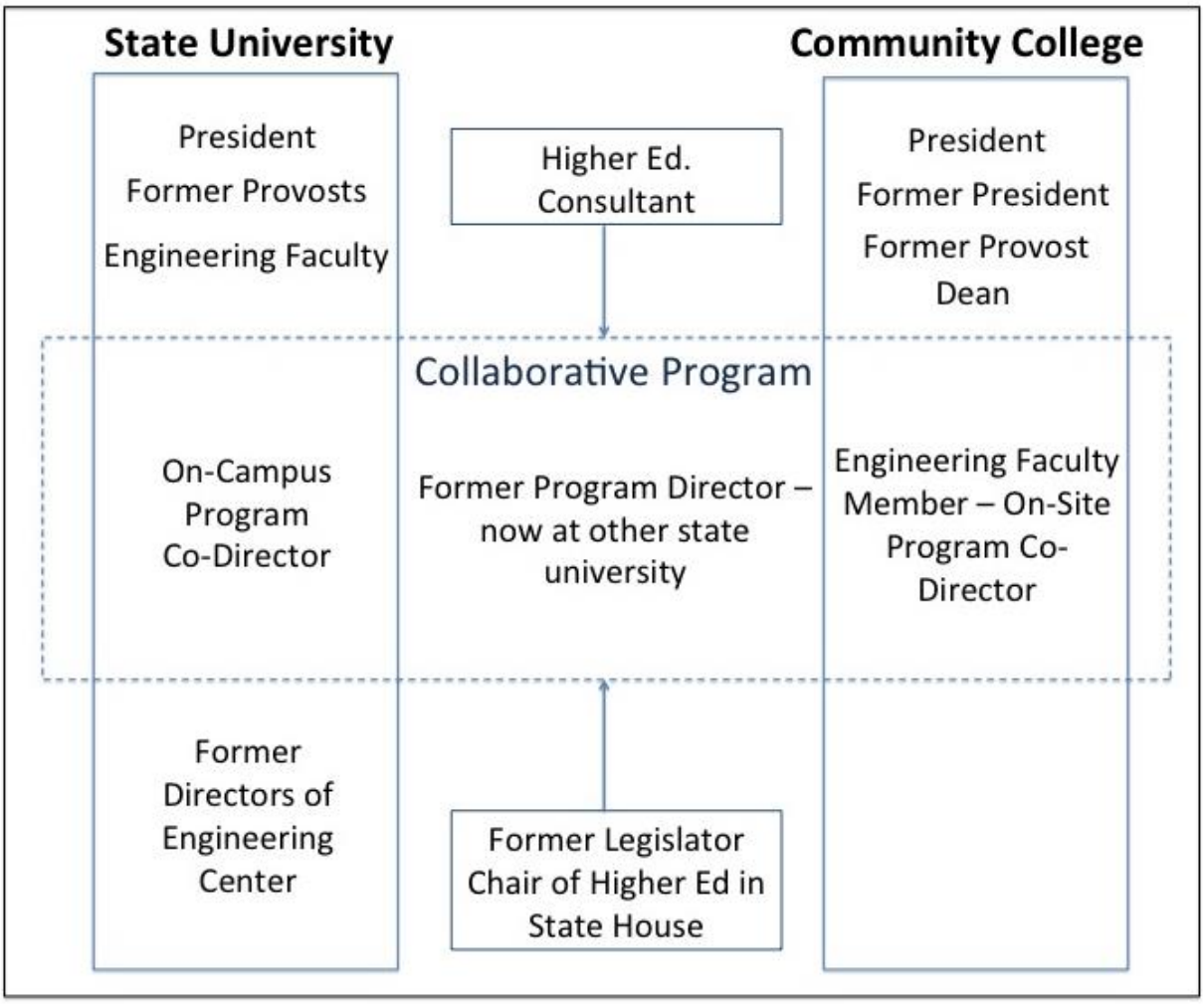


**Figure 1. Interview Subjects' Positions and Interactions**

*Data Analysis*

Qualitative analysis was conducted with all 16 of the interview transcripts, using an electronic qualitative data analysis program (Atlas.ti). An initial coding scheme was developed based on the research questions, was piloted with 5 transcripts, and was revised accordingly in order to fully capture data addressing the research questions.[28, 29, 30] Full coding and content analysis of all transcripts were then completed by a single researcher in order to identify relevant concepts within the data, as well as emerging trends and themes. Thematic coding was then done to more fully understand the identified themes. All analysis was done by the same researcher who conducted the interviews, with regular discussions of emerging findings with the rest of the research team throughout the analysis process.

## Results

Preliminary analysis addressed in this paper focused on addressing Research Questions 2 and 3 of the study:

- What helped or hindered the process of developing and implementing the program?
- What lessons learned from this process can inform and improve future transformational efforts in engineering education?

This analysis yielded insights which may be informative for others considering embarking on a similar process, in regard to common barriers and strategies used to surmount those barriers, as well as lessons learned by key players in the process.

### What helped or hindered the process?: Barriers and Strategies

#### *Barriers*

Preliminary analysis of the interview transcripts resulted in the identification of 32 categories and subcategories of perceived barriers to the development and implementation of the IRE program, which were used to code a total of 299 units of text across the 16 interviews. The most frequently cited types of barriers fell into the categories of credentialing, ownership, and culture clash/resistance to change.

*Credentialing*

Of the 32 types of perceived barriers, 10 were determined to be rooted in the issue of credentialing. A total of 145 units of text, or 48% of all text coded as perceived barriers, were coded with these 10 credentialing-related codes. Therefore, it appears that credentialing is a significant hurdle to implementing a program such as IRE. It is also apparent that when stakeholders talk about this type of hurdle, they may not use the term "credentialing," but rather focus on the piece of the credentialing process most relevant to their own position or role.

For example, the IRE co-directors may have the most comprehensive view of the program and its challenges, reflected in one co-director's comment that specifically references credentialing:

> "It's a credentialing battle, which is a university battle…. It's an industry thing, but universities are in the line of credentialing. And so if they can't credential, if it's not the universities that say who is an engineer, then who does?"

University administrators understandably 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?"

> "We were sort of using our existing curriculum and trying to adjust it to meet the needs of the Iron Range program, but we did not yet have curriculum approval for a distinct Iron Range program. We were using existing mechanical and civil engineering courses, allowing the students in the Iron Range program to enroll in them and then trying to make them, you know, do project-based learning and use the kinds of pedagogy and teach the

kind of content that we wanted for the Iron Range program. But it was not an approved degree program at that point on the Mankato campus."

"It was a problem because there was no department of integrated engineering in Mankato, and we had the classical civil, electrical, mechanical and computer engineering, and where did it go?"

A higher education consultant understood the curriculum-level challenges of the new program, as well as the challenge of meshing with the existing institutional culture:

"Well, project-based learning approach as opposed to a standard, you know, a thermo class and a dynamics class and all that kind of stuff. So it wasn't a good cultural fit in that sense with Mankato, but they could grant the degree. So it had to be structured in such a way that they could retain control of what was going on and still be accreditable."

Finally, Minnesota State Mankato faculty tended to speak from a department-level position, often intertwined with concerns regarding curriculum, accreditation or departmental territory:

"I think a large hurdle was just, how do we measure it. … It's the accreditation piece. How do we show that the students have met the outcomes that we want them to reach, and it's difficult in a traditional curriculum to show that they're getting what they need. It's all the more difficult when you have a little bit less, I guess, rigidity and the traditional box curriculum as to how things are measured and how the outcomes are met."

"There was a need for where would these courses plug into our department."

"I think that just the general curriculum process…is set up for the traditional boxed curriculum, where you're saying, you take these classes, you have these outcomes associated with those classes, and you end up with a degree when you've completed those classes successfully. … They [the IRE program] have to specifically say to approve this class in the curriculum process, this is the concept, this is the topic, this is the sample syllabus associated with it. When it really doesn't fit. It's not a boxed type thing."

"The mechanical engineering department, they finally took a vote and they didn't want it listed in their courses. My department took a vote and they said the same thing. They didn't want it listed and they did not want the graduates to be called electrical engineers or mechanical engineers because we didn't feel that they were."

Regardless of the exact terminology used, we argue that the types of barriers cited most frequently by those involved in the development and implementation process can be placed under the larger umbrella of credentialing, or the challenges of fitting something new and non-traditional into existing boxes. As such, this topic merits further investigation in order to better understand how it is understood by various stakeholders, why it is so often perceived as a difficult barrier, and what can be done to work through such issues. This preliminary analysis also highlights the need for further data collection with individuals more closely involved in the credentialing process, such as university registrars.

*Ownership*

In addition to talking about credentialing barriers, several participants (represented in 20 coded units of text) also mentioned the related issue of ownership. Some had observed challenges with departmental feelings about ownership of the new program:

> "I think the biggest challenge was they wanted to try and have one of our current engineering departments take ownership of it, and none of them was willing to, partially, again, because they felt it was being foisted on them. And part of it is they had doubts about the proposed method of delivery and so on, being more individualized kind of learning. I mean, they were worried that their accreditation might be at risk if they also were sponsoring that. … So, I think that was probably the toughest part of it, and I'm still not sure [the program has] much buy-in from those who were in the engineering programs at the time." *State University Faculty*

> "We really kind of ran up against a brick wall, because what had happened, as you might imagine, is all of our engineering departments were concerned. They were concerned from several different perspectives. One was ownership. In other words, who is going to teach in the program, who would the program report to? How would it be funded? Where would the faculty come from? What would the quality of the program [be like]? How would the curriculum be developed? Who would be responsible for it? All the normal kinds of academic questions that you have to have good answers for." *State University President*

Other comments referred to ownership struggles between the University and the Community College:

> "I think it was, well, we just can't turn this loose and let the two-year colleges run it or let somebody, whoever we hire, the engineers up there, run it without having some responsibility and tie back here to the institution. So we were concerned about public relations and marketing. And so we had to be relatively firm once we decided to go ahead…because there were often stories that would come out or announcements or pronouncements and they'd forget to name the university. So it would be, you know, Northeast Higher Education is offering a new engineering program, an integrated engineering, project-based engineering program, or Iron Range Engineering program, [however] they referred to it. And they'd forget to mention [the University]." *State University President*

> "I remember one time in a Curriculum Committee meeting we were going to explain, before we dropped the curriculum off on them, what the philosophy was. … [The On-Site Director] went to that meeting and I had him speak because they had known [him]. I was new, so I wanted him to [speak]. Well, then they saw him as being at Itasca Community College telling them how to educate engineers at a university. We're a community college, they're a university. Oh my gosh. One guy stood up and…yelled at us and he goes, 'This is just a ploy by community college to take over engineering education!' No." *Former Program Director*

Although the issue of ownership was negotiated jointly at the program onset with contractual agreements, ownership is an ongoing issue for the program. This is a barrier that must be addressed through continual work and relationship building.

*Culture Clash/Resistance to Change*

In addition to more specific issues of fitting courses into boxes and determining who owned which boxes, participants also cited broader barriers such as institutional culture and general resistance to change (represented in 18 coded units of text). As an advisory board member pointed out, the development of the program took place in an environment already complicated by multiple competing visions or institutional cultures:

> "There were lots of moving parts. The Minnesota State College and University System is composed of about seven universities and 25 community colleges -- 32 institutions with 50 sites all over the state of Minnesota, 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 Northeast District. We're dealing with a pretty traditional university in Mankato. And we've got this big corporate structure of the Minnesota College and University System overlaid on this, who wants to create change and everybody else doesn't." *Higher Education Consultant*

Some participants commented on the perceived tendency of engineering – or higher education as a whole – to be hesitant about making any sort of change:

> "Things are changing slowly, glacially. If engineering education change was riding on a glacier, what would it say? 'Wheeee, it's going too fast.'" *Former Program Director*

> "I think higher education, the irony of it is you're trying to develop critical thinkers, and you're trying to develop people who can go out and change the world. Higher education, that structure is set up such that it's resistant, really, to change. I mean not that change doesn't happen, but it's not really-- if you look at any type of endeavor that is out there, they're not really equipped for rapid change." *Community College Administrator*

The former Director of the Minnesota Center for Engineering and Manufacturing Excellence took an even broader view, and was philosophical in her reflection that resistance to change is simply a very common occurrence, and perhaps to be expected:

> "Whenever you shift a paradigm, whenever you do something that's different than what's been done, people are always very reluctant, and I think it's going to be one of those things that is just going to take a number of years and studies to show that, 'You know what, this has worked just fine.' I really do."

The issue of change, whether resistance to it or frustration with the lack of it, is a barrier that can elicit emotions, defenses and difficult reactions which can result in burnout on both sides if not addressed from multiple perspectives.

***Strategies***

Participants were also asked about their perceptions of what strategies, decisions, or key events helped the program move past the various barriers. The qualitative analysis found that 18 types of strategies were discussed, in a total of 107 coded units of text. Of these strategies, the most frequently cited had to do with (in descending order of frequency), 1) having "champions" at all levels, 2) creating new boxes into which the new program could be placed, and 3) having "translators" at key bridging points between stakeholder groups.

*Champions at All Levels*

Over one-third (34, or 37%) of the comments about what helped the program surmount its barriers had to do with the importance of having "champions" to advocate for the program. Many of these comments referred to the Co-Director based at Itasca Community College and the Former Program Director. However, several participants also highlighted the importance of having similar champions at other levels, such as the department, institution, or state level.

At the program level, a champion is needed who can address multiple levels of investors, whether academic, industrial, or legislative:

> "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." *State University Faculty*

> "[The On-Site Director] is, I kind of think of him as the St. Paul of project based engineering. I mean, he's the evangelist, right? He's the guy that got it started. I don't know if you get that reference, but his ability to evangelize on that made me one of the faithful, let's just say. I mean, I was up there with my hands in the air, 'Praise ABET,' or whatever. And he's right. I mean, he's so passionate about it, but he's so articulate, and at the end of the day he's right." *State University Provost*

> "[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 Iron Range. 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." *State University President*

> "You can't say the name [On-Site Director] enough. Because the champion is a critical component. Without a champion, willing to just, I mean, three o'clock in the morning jump in his car and drive down to St. Paul to testify in front of a committee, or to meet me instead of playing with his kids when they were younger. To meet me at a restaurant in Virginia back in 2006 or '07 to talk to a legislator on the other end of the Range about what could be. Yeah, you need a champion like that." *Higher Education Consultant*

Along with having a program level champion, this type of committed support is also needed at the faculty and administration levels:

> "In my mind, without [the Former Director] and [the On-Site Director], it would never have happened. Now there are plenty of people who objected to [these Directors] and thought they were the devil and, you know. But they had the fire, and the knowledge and experience of the kind of curricular innovation, and the vision. And so I think you do need champions, and then you need champions at the faculty level, and then champions at the administrative level. *State University Interim Provost*

When finances are at stake for a state institution, champions at the state legislative level are key:

> "I introduced [the State Legislator] to [the On-Site Director], and all that. … [The On-Site Director] kind of drew out what the vision was in very simple [terms]. … And [the State Legislator] liked it. Except he goes, 'But it will be in Virginia,' and that wasn't our intent. It was to do it here [in Grand Rapids]. … And there were lots of heated discussions, lots of conflict, but in the end, I think the whole key was, 'What is really best for the whole region?' And this isn't going to work if we just keep saying, 'We're not doing it there, we're going to do it here in Grand Rapids.' So there's a point where you just say, 'What's for the better good?' And that's where we came to, and [the State Legislator] was the champion. I mean, he definitely was the champion on the whole thing." *Community College Administrator*

In this case, champions were clearly needed at multiple levels to get the program off the ground.

*Create New Boxes*

Another 28 comments (26% of all text coded as strategies) highlighted the importance of creating new boxes into which the new program could be placed as a strategy for overcoming barriers. These "new boxes" strategies directly addressed the challenges discussed above related to credentialing, as well as some ownership and institutional culture issues.

> "We came up with the idea to…rather than using existing programs that Mankato already had, we would create a new engineering program, a general engineering degree. And I think that was less threatening to the Mankato faculty because…I don't think they worried as much that it would jeopardize their accreditation. And there were enough faculty at Mankato 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." *State University Interim Provost*

> "Going to general engineering, I think, saved it. That was not in the original agreement. It was supposed to be a mechanical engineering base. That was what was signed…and I made an argument, and people bought it, that, and I think it's right, that we would be more effective for the region if we were general engineering. And so it really got the heat off our back at Mankato." *Former Program Director*

"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." *State University Faculty*

"We had department chairs that thought that the program had potential. But one of their biggest concerns was jeopardizing their own ABET accreditation. … . And they were quite concerned about that. That if this program was a failure it would reflect poorly upon their individual [program], whether it's mechanical or electrical or civil or whatever kind of engineering it would happen to be. And so we saw that right away and we knew we wouldn't get past that barrier. And so we said, 'All right. So would you oppose our offering the program as a separate program, separate from any department?' And they'd say, they ask, 'How would that work?' And we explained, 'We'll create a brand-new department, and it'll be, you know, it'll be independent from all of you. But on the other hand, you'll all have an opportunity to participate and provide guidance and direction.' So we didn't leave them out. Although they wouldn't be managing the department, we'd have a new department chair. So just like they were department chairs. And the dean of the college would be supportive of it. The provost and the president are all supportive of it, and so they went along with that. They agreed to that. That was the icebreaker right there when they realized that their accreditation wouldn't be jeopardized, that they wouldn't be losing faculty lines, which was the other major concern, is, you know, everybody's starving for more faculty." *State University President*

"At some point when you're trying to do innovation and change and you bend over backwards to try to work with the structures you have, with the faculty you have and give them all the opportunity to innovate and you put the resources out there and say, 'Here's the money, here's the opportunity. You'll get new faculty lines; you're going to get new resources.' And if at some point they just sort of say, 'You know, no thank you,' that's when you realize the only way to do it is to create a new structure. And so at some point in Mankato we just realized we're going to have to create a new department here, that these departments aren't going to be capable of doing this, it'll always be this unloved stepchild." *State University Provost*

"We helped…dodge some of the issues, by having a general engineering program so we could have more control and less influence from outside, as opposed to being put into a mechanical engineering program that would have the influence from Mankato. That would have made it really difficult. … It's a different degree, and ABET goes by programs. … So this is a different program, and then you look at the faculty for the program, and since it was its own program, it's easier to have the local faculty in control." *Higher Education Consultant*

"But 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." *State University Provost*

Attempting to work within existing credentialing and organizational structures did reveal some ways that engineering education change would not work in this setting. This then established/emphasized the need for creating new boxes, and galvanized support across multiple levels.

*Translators in Key Bridging Positions*

Finally, 25 comments (23% of all text coded as strategies) noted the importance of having translators in key bridging position to facilitate communication across stakeholder groups. Supporting change in an academic setting requires input and action at multiple levels, as seen here with the range of interviewees. Communicating across these levels and addressing the values and perspectives held at the different levels is rarely straightforward because of these different perspectives. The term "translator" is used here because these roles translated across academic, industrial, legislative, and accreditation levels, whether for advocacy or implementation.

The majority of these observations focused on the translating and bridging role played by the On-Site Program Co-Director located at Minnesota State Mankato. One could argue that this Co-Director was also a champion of the type discussed above. However, in addition to the champion role, and perhaps more importantly for the program, she also functioned as a critical bridge between the program developers, the Community College, the State University Administrators, and the State University Faculty.

"[On-Campus Program Co-Director] is all the difference now.... She's there on the ground to advocate at that mid-level to make sure things happen, and if she wasn't there it would be very hard for IRE to continue to evolve and develop because I think there would still be that resistance of, no." *Community College Administrator*

"We had people identified to shepherd it through the process or sort of did the advanced legwork. And they were insiders to the university, as opposed to [former Program Director] who was perceived as an outsider. So there were other things that were ultimately helpful. But I do think probably part of it was just that the curriculum committees had an opportunity to express just how frustrated and upset they were with the whole process." *State College Interim Provost*

"The value is hiring the faculty there, but also having faculty back on the campus so the linkage, you know, in this case, and I think one of the reasons things went so well is because [On-Campus Program Co-Director] was here. And people liked her. They knew her, they trusted her. She kept them informed on what was going on. And so long as we can continue with that, I think we're going to be fine. But if we ever get out of the loop from the main campus I think there could be some concerns." *State University President*

> "So we got [On-Campus Program Co-Director] engaged. She did a lot…she was very engaged and took ownership and leadership of the program, and that has had just the most profound effect of allowing Iron Range Engineering to not deal with the day-to-day issues that can be present at a university. She does that, she contributes to the growth of the program in so many ways, and has allowed Iron Range Engineering to have a continuous improvement program, where we're looking forward to how to make tomorrow better, and improve the entire system daily, and have none of those things that we dealt with for that first year and a half. She's that buffer." *On-Site Co-Director*

In addition to this Co-Director's translating/bridging work, some participants also noted the importance of other translators positioned elsewhere in the network, as illustrated in the following quotes from the Former Program Director:

> "It was a bloody battle so when you look at what are the pieces that made this? You had the zealot. You had the risk-taker. You had this internal person that worked through and could work behind the scenes and that's [the Program Co-Director], from the faculty perspective. Then you had the person quietly working behind the scenes with the administration and getting different pieces, chess pieces, moving. That was [the State University Interim Provost]." *Former Program Director*

> "So [State University Interim Provost]…then started to jump in and she got the meeting between the president, the union, a couple of faculty members, myself, and [On-Site Director]. She was at the table. I'm probably missing some others, but we just started to sit down at breakfast meetings and hammer this stuff out and pretty soon it was like, okay. The union guys said, 'I understand what this is now. I think we can find a way to support this.' So then pieces started to fall and eventually, then, we would go down and go through all the curriculum committees and there'd be blood here and blood there but we were making progress." *Former Program Director*

Translation was a crucial aspect for working across the academic implementation levels. Since large-scale change requires moving beyond individual classrooms, it was necessary to have translators at multiple levels.

**Lessons Learned**

When asked about lessons learned during the process of developing the program, or what advice they would to give to others, most participants reiterated their views on which strategies or events had been most helpful in the process, such as having champions or translators in key positions:

> "Well, one thing that we could've done differently is figured out how to much earlier have [name] be the champion for Iron Range Engineering on the Mankato campus. That would've changed the trajectory of Iron Range Engineering for the better, at an earlier point in time." *On-Site Program Co-Director*

Others emphasized the importance of creating new boxes in which to place the new program:

> "We knew we wouldn't get past that barrier [of accreditation]. And so we said, 'All right. So would you oppose our offering the program as a separate program, separate from any department?' And they'd ask, 'How would that work?' And we explained, 'We'll create a brand-new department, and it'll be independent from all of you. But on the other hand, you'll all have an opportunity to participate and provide guidance and direction.' …That was the icebreaker right there when they realized that their accreditation wouldn't be jeopardized, that they wouldn't be losing faculty lines." *State University President*

The Community College President suggested that others follow their strategy of establishing guidelines and agreements with partners in advance:

> "The academy created bumps in the road for us, and how was it overcome? A Memorandum of Agreement. We wrote it early on. … We'd meet, faculty from Minnesota State University, and our folks, and we'd sit around the table and we'd talk about every bump that there could possibly be brought to the table and he created this Memorandum of Agreement to address those issues. There was a lot…of departmental kind of pushback. Where does this belong? Is it truly pure engineering, or is it that darn two-year college stuff that really we don't know what it's about? But again, we're past all that. And so, that tool…writing a Memorandum of Agreement and guiding principles that you can always go back to in the relationship, was very important to us."

One interesting thing to note is that several participants reflected that, if given the chance to do it over again, they would not change very much, reasoning that even the most unpleasant barriers led to necessary conversations, without which important understandings would not have been achieved. One participant even likened the process of program development itself to a large-scale project-based learning exercise, suggesting that valuable learning took place throughout the process.

**Discussion**

In analyzing the perceptions and experiences of multiple stakeholders in the development and implementation of the [Name] program, we found that the most challenging barriers had to do with issues of credentialing, ownership, and general resistance to change. The ways in which participants talked about these challenges varied depending upon their positions and their roles in the process. However, these three categories were found to encompass the majority of cited barriers. This suggests that, despite the many details of the program and its development process that are context specific (such as regional industry needs, funding climate, or relationships among specific institutions), the issues that proved to be the largest stumbling blocks are not context specific after all, and might be found in any higher education setting where significant programmatic changes are being considered.

The strategies cited for overcoming perceived challenges or barriers, or what participants felt helped move the change process along, are also relevant beyond the context of the IRE program. Our findings highlight the importance of having champions at all levels, creating new boxes for the new program, and having translators positioned at key bridging points. If, as argued above,

the challenges faced by the IRE program are likely to be common in other settings as well, the strategies found to be successful for the IRE program are also likely to be applicable in other settings. For example, a critical point in moving the IRE program forward occurred when the credentialing barrier was addressed by moving the program out of the existing departmental boxes and giving the degree a new name. A similar approach may work in other settings as well.

These findings have implications for others considering undertaking similar programmatic changes. In particular, there are some things that can be considered or put in place in the very early stages of program development.

*Create a new "box" at the beginning of the process.* Because of the significant challenges related to credentialing and ownership, it is unlikely that new programs will easily fit into or attach onto existing programs. In the development of the IRE program, the first approach attempted to fit the program into an existing department and degree at Minnesota State Mankato. Eventually it became clear that this would not work, and a critical point in moving the program forward occurred when the program was moved out of the existing departmental boxes and the degree was given a new name. However, before reaching this point, large amounts of time and energy were spent and some relationships were strained. If those working to develop new programs can create a new "box" early in the process, some of the struggles experienced by the IRE program might be avoided. Higher level administrators could play a role in this by proactively creating external programs or departments in order to support change.

*Ensure that there are champions at all levels.* All of those interviewed recognized that the On-Site Director played a significant role in driving the program from concept to reality (regardless of their opinion of the program). To all involved, he was clearly a champion of IRE, and it is critical for any new program to have such a champion at the ground level. However, it is also important to recognize the necessity of champions at other levels in the system. As seen in the IRE example, there must also be champions who advocate for the program at the university and departmental levels, and perhaps other levels as well. For a new program to come into being, decisions must be made at each of these levels (including the state legislative level in the case of state institutions). Without at least one champion well-positioned at each of these levels, it is unlikely that the program will receive the support necessary to become a reality. We suggest that those developing new programs consider in advance who their champions might be, and to foster relationships with those individuals early on.

*Pay attention to the bridgers.* In any system there are individuals positioned at key bridging points between levels or entities, such as college deans who serve as bridges between departmental faculty and upper administration. In the [Name] case, these individuals proved to be critical gatekeepers in the program's progress, in either positive or negative ways. Our findings show that it is not enough simply to have people in these bridging positions. These people also need to play a translating role in order for change to move forward. In the development of [Name], there were clearly a number of bridgers who effectively translated across groups, helping each group understand the motives and needs of the other groups. However, there were also bridgers who did not do this translating work, resulting in negative impacts on the change process, ultimately raising barriers rather than lowering them. For others undertaking similar projects we suggest taking note of the individuals who are currently in

positions that bridge levels or entities involved in the program, and try to anticipate whether these individuals will be able to serve as translators. Strategies can then perhaps be adapted early on given that knowledge.

Each of these recommendations is rooted in strategies that the interview participants generally agreed were critical to moving IRE forward. Those most closely involved in the program also noted that implementing the three strategies discussed above at an early point in the process may have avoided the challenges faced regarding credentialing, ownership, and resistance to change.

Returning to the conceptual model of change presented earlier (D*V*F>R), we are reminded that these recommendations do not have to have the same impact on all stakeholders in order to be effective. The champions and the bridgers can point out opportunities for improvement in the current system (D) and paint the picture of the possible new system if the change occurs (V). Creating a new "box" at the beginning of the process can occur with minimal input from other portions of the college or university, but can still be a first step toward change (F) and can build up momentum. Combining the recommendations not only creates a synergy of positive change levers, it also provides a variety of potential mechanisms to overcome resistance to change at both the individual and organizational level (R).

## Conclusions and Next Steps

The analysis presented here tells just a small part of the complex story of large-scale change in an engineering education program. There remains more to explore in this rich data set, and the current work has highlighted other areas that require additional investigation and analysis. However, this analysis has also provided insights into the inner workings of this type of organizational change, from a wide range of stakeholder perspectives. These insights are applicable broadly, beyond the specific context of the IRE program, and may be useful for others undertaking similar programmatic changes.

Moving forward, the research team will:

- Continue improving the program with ongoing change and building relationships between Program and Campus communities.
- Continue to study the past and current change process, particularly as it relates to credentialing issues and university-level implementations.
- Facilitate translations of this program to new contexts by encouraging colleagues to consider the likely barriers and related strategies, and also notice contextual differences which may play a role in implementing change.

In addition to providing practical recommendations for practitioners, this research also sets the stage for further investigations into and deeper understandings of change in engineering education and credentialing on a broad scale.

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