Why We Failed: Barriers to Participation, Management, and Sustainability of an Immersive Faculty Experience Supporting Graduate Student Professional Development

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Failure analysis is central to the work of engineers, and yet we often neglect to analyze our failures in the field of engineering education. In this paper, we examine our failure in the development and deployment of an immersive faculty experience for graduate students in engineering education. Professional development is a significant focus of graduate studies. Professional development broadly defined includes any activities supporting the acquisition of skills, knowledge, and abilities relevant to one's current or desired position. In the context of graduate studies, professional development often involves such activities like conference or workshop attendance, internships or job exploration, mentoring or coaching directed at students, and certification programs. Despite the importance of professional development in graduate school, research-based (and anecdotal) evidence supports the assertion that graduate students experience professional development unevenly. The source of these disparities is not established.

We investigated the barriers to participation in professional development, with a focus on an immersive faculty internship; however, this work revealed barriers associated with professional development in general and related to specific other types of professional development. We focused on barriers specifically because engineers examine both successes and failures in the effort to improve product design, and because our product—an immersive faculty experience for graduate students—was designed to overcome barriers identified during customer discovery research. For this analysis of failure, we relied on interviews and surveys from varied stakeholders (e.g., graduate students, their mentors, graduate program directors, representatives from grant-giving organizations, and faculty on hiring committees) to identify these barriers. We also shared our personal reflections on the challenges associated with this effort. We examined these barriers using the Ishikawa Fishbone Diagram to determine root causes of the challenges associated with scaling an immersive professional development experience.

We found that barriers to participation included time spent away from support systems, potential delays in graduation, lack of understanding of the value of professional development, and funding for participating in these opportunities. Graduate students perceived (rightly or wrongly) that their advisors do not support an immersive, off-site professional development experience. In addition, organizational challenges included facilitating a multi-site experience from a single institution that was subject to both institutional and NSF rules for budgeting. Through this analysis, we highlight how failure, and the analysis of failure, is an under-appreciated experience in the field of engineering education. Stakeholders in graduate education have a significant interest in removing barriers to professional development, including opportunities like immersive internships. By doing so, they increase graduate students' satisfaction with the graduate school experience and improve graduate students' placement and career success.

Introduction and Context

In 2017, we received a National Science Foundation (NSF) EArly-concept Grants for Exploratory Research (EAGER) grant to study the scalability and sustainability of an immersive graduate student development experience. EAGER funding supports "exploratory work in its

early stages on untested, but potentially transformative, research ideas or approaches...[that] involves radically different approaches, applies new expertise, or engages novel disciplinary or interdisciplinary perspectives." (National Science Foundation, 2021) Our program, called the Rising Engineering Education Faculty Experience (REEFE), meets many of the EAGER descriptors. Through REEFE, graduate students from engineering education PhD programs complete a semester-long placement at a primarily undergraduate institution (Hixson et al., 2015; McCord et al., 2014). These placements provide dual benefit. Graduate students experience an immersive internship in some academic role (e.g., teacher of record in an engineering department, assessment coordinator in the institutional research office, education research consultant in a teaching and learning center) and host institutions gain new perspectives and engineering education expertise in their units. For a more detailed description of participants' experiences during REEFE, please see McCord et al. (2014), Hixson et al. (2015), and Maxey (2019). The internship opportunities were created by two host institutions, with varied options being available during each application cycle. Regardless of the specific academic role, all REEFE participants were integrated into the institution as a part-time visiting faculty member. The expectation was for each REEFE participant to contribute his or her engineering education expertise in the assigned role for the improvement of the host institution. REEFE fit the untested criterion of the EAGER funding line, because to our knowledge, this program was the first to create an on-site, long-term internship for engineering education. The project was interdisciplinary by design because the host institutions did not have engineering education departments. We believed REEFE was potentially transformative based on the research regarding internship experiences and because partnerships between very-high research institutions and primarily undergraduate institutions are relatively rare.

When designing and then expanding the program, we solicited feedback from varied stakeholders: graduate students, graduate program directors, representatives of funding agencies, advisors, and representatives of hiring committees (Hixson et al., 2018). We asked these stakeholders about opportunities and needs for engineering education graduate student professional development, as well as the barriers associated with implementing graduate student professional development in engineering education. They provided robust information both in general and in relation to our program. What we heard was consistent with the literature: Graduate students desire enhanced, immersive professional development, and barriers prevent implementing this type of professional development. Regarding the latter, the triple constraint of time, money, and attention is a significant barrier (Jarek et al., 2019). Because of the ubiquity of this idea, we designed REEFE and obtained the necessary resources to accommodate these barriers (or so we thought). We ran multiple successful small-scale pilots with Virginia Polytechnic Institute and State University (Virginia Tech) as the home institution and Rose-Hulman Institute of Technology as the host institution prior to seeking EAGER funding. During these pilots, each REEFE participant had a unique role, and the experiences were largely positive.

We sought to scale (with respect to the number of participants and institutions) and study REEFE through EAGER funding. We successfully integrated California Polytechnic State University (Cal Poly) and Purdue University into the consortium and began recruitment efforts to place graduate students with host institutions. During the EAGER funding (two years so two cycles of REEFE), two graduate students applied for REEFE and both were placed. We had funding to

support twice as many participants. Because our goal was to have a competitive selection process, we wanted applications to outnumber funded positions. However, despite our best efforts over multiple years, we were not able to increase the number of participants in REEFE. Our failure did not occur during the placement or experience phase of the process, but interestingly, we failed to scale the number of applications received. Recalling that an EAGER grant is meant to "explore work in its early stages" (National Science Foundation, 2021), our research team sought answers regarding why we had a lower number of applications than desired. So, we turned to failure analysis to identify the causes of this failure indicator.

Engineers in industry address failure (meaning an undesirable or unanticipated outcome) as a normal and regular aspect of their work. Rather than deeming failure a mark against performance or a personal defect, engineers consider failure to be "a further means towards a fuller understanding of how to achieve a fuller success" (Petroski, 2012, p. 45). In other words, examining failure is one way to accomplish process improvement, as shown by both the number and the widespread use of failure analysis tools and reports in the literature (e.g., the journals *Engineering Failure Analysis*, *Case Studies in Engineering Failure Analysis*, and *Journal of Failure Analysis and Prevention*). These tools are taught in undergraduate engineering education (Michael, Nitterright, & Edwards, 2014; Niebuhr, 2005) and through on-the-job experience (Cannon & Edmondson, 2005). Failure analysis tools in engineering include both *a priori* and *a posteriori* tools: failure modes and effects analyses, barriers analyses, five whys, Ishikawa (or fishbone) diagrams, Pareto charts, and more. A primary driver for using failure analysis tools is that they allow engineers to predict or discover failures within the context of the system in which they occur. Engineers seek to discover all sources of error, not just the most common or most influential to the system. When considering failure in engineering practice, one could argue the sentiment is not, "What do we do *IF* failure happens?", but instead, "What do we do *WHEN* failure happens?"

This sentiment toward analyzing, reporting, and learning from failure is not as accepted in academia and academic research as it is in engineering. In the education literature, failure analysis is most often mentioned as a critical concept and skill set to teach future engineers (Hilppö & Stevens, 2020; Niebuhr, 2005). More rarely do organized failure analyses inform process improvement in educational settings, usually in the context of Total Quality Management. For example, Pusca and Northwood (2016) used multiple tools of failure analysis and lean principles to improve an engineering design course. They discovered root causes emerging from instructor decisions like what to teach and how to teach, environmental constraints like traditional classroom timing and arrangements, and equipment constraints like inadequate computing resources. Ellis (2015) explored student resistance to innovative teaching methods. Early in the course, factors like confusion about the method and its effect on grades contributed to resistance, while late in the course, allocation of class time and students' perceptions of low control contributed to resistance. Like in these formal studies of failure, educational failure analysis also emerges informally through teachers' continuous assessment and improvement processes in their classrooms. While failure analysis likely occurs informally, we have seen less evidence of a formal failure analysis process occurring at the educational researcher level, and we believe we have an opportunity to gain significant knowledge from such tools when they are applied to process (in our case, program) improvement. From this thinking, we applied failure analysis to our engineering education program, with the key performance

indicator for failure being defined as "lower applications than desired." We sought to discover any factor contributing to this outcome; any information source contributing such information was deemed valuable. Because the failure indicator happened prior to a graduate student participating in REEFE, we focused our exploratory effort on the system components most relevant prior to onset of the experience. Therefore, actual participant experiences do not contribute to our analysis beyond their impact on applications to the program (e.g., word of mouth descriptions to potential applicants about their experience).

Methodology

We chose *a posteriori* root cause failure analysis, with our failure indicator being "lower applications than desired." *A posteriori* analysis is the natural fit with our project because we were doing the analysis after attempting to scale the program and observing the failure condition. A critical mindset of any root cause failure analysis is discovering reality over conforming to a suspected answer for the failure. In addition, failure analysis examines the system and its constituent parts, not the parts alone or specific stakeholders. Information from any relevant source can be utilized to inform the analysis, and additional information can be sought in any form (interviews, video, surveys, observations, website clicks, machine logs, etc.). Further, one or more specific failure analysis tools can be applied to complete the analysis.

Methods

We chose the fishbone diagram developed by Ishikawa as our specific analysis tool (Ishikawa, 1976). The fishbone diagram is an organizational strategy used to explicate different possible failure causes without assuming which cause or source is the most influential to the system outcome. The failure indicator is the head of the fish, with the bones representing different categories of specific actions that may or may not lead to the failure indicator. The fishbone diagram approach begins with hypothesized categories of failure causes. In manufacturing, basic categories include Human, Material, Machine, and Process. In our review of the education literature, we found categories ranging from those loosely equivalent to manufacturing categories to operational areas unique to education (e.g., "Students") (Table 1). We settled on the categories Resources, Goals, Marketing, Context, Design, Personnel, Logistics, Community Evaluation, and Policies in our initial brainstorming about failure (Table 2).

Table 1. Diversity of categories used in education-related fishbone analyses.

Reference	Categories
Verma (2008)	Environment, People, Support, Material
Mazumder (2014)	Curriculum, Assessment, Teachers, Students, Academic Environment, Social Environment
Macchia (1993)	Administration, Student, Faculty, Facilities
Elizandro and Huddleston (2018)	Institutional Support, Faculty, Facilities, Students, Curriculum, Extra-Curricular

Table 2. Description of the hypothesized bones in our fishbone diagram.

Category	Description
Resources	Barriers addressing financial support and tangible or expendable items, including time, software, and supplies
Marketing	Barriers addressing how stakeholders learned about REEFE, the website, emails, and printed materials about the program
Design	Barriers addressing the structure of REEFE, including when in a degree program it occurs and duration of the placement
Logistics	Barriers addressing coordination of processes and successful transitions between home and host institutions
Goals	Barriers addressing time to degree and alignment with the graduate student's career objectives
Personnel	Barriers addressing relationships among REEFE stakeholders and specific characteristics of individuals
Community	Barriers addressing graduate student's concerns about personal and professional isolation or connectedness
Context	Barriers addressing disciplinary norms, institutional conventions and classification, graduation program expectations, and reputation
Evaluation	Barriers addressing the assessment of and continuous improvement of the program through data collection and analysis
Policies	Barriers addressing requirements established by graduate programs for graduate student enrollment, credit load, residency, or employment

Having established our high-level categories, we then examined three information sources:
- independent reflections of the authors,
- interviews with stakeholders as described previously (Hixson et al., 2018), and
- survey results obtained from key stakeholders in the development and implementation process.

The specific experiences of the REEFE participants during their internship experience did not contribute to this data collection. Across many types of assessment data collected during and after their participation, REEFE participants offered no information about while they or others would or would not apply. Further, we do not provide demographic data for survey participants or stakeholders we interviewed, because we are not testing hypotheses about the program (e.g., who applies and who does not; which program had more communication successes; potential applicants' family status). Consistent with the failure analysis approach, we are identifying any factors—large or small, common or rare, detailed or general—that help us understand the failure outcome of lower applications than desired.

Each information source was examined by a different author using their own fishbone diagram (summarized in the appendix) to identify any explanations relevant to our failure indicator. We explored all aspects of the system, not just those specifically related to the application process, consistent with the goal of failure analysis to explore all potential contributing error sources. All potential explanations for "lower applications than desired" were placed in their respective categories on the fishbone diagram. For example, one author added "navigating HR processes" to the Logistics category in response to concerns about health insurance. After the three independent fishbone diagrams had been developed, we reviewed them side-by-side and negotiated both the assignment of potential failure causes to the specific categories as well as the categories themselves. We refined the assignments and categories, then combined all items into a single diagram. Again, we came to consensus regarding the assignment of items to the specific categories and verified when different information sources yielded similar ideas.

We share two methodological notes. First, during our analysis, we discovered no mention of evaluation as a barrier. Our original idea was that gaps in our evaluation plan for REEFE may have limited the possibility of improving the program over time, thus continuing a trend of fewer applications when severe program design issues were present and known. Such evaluation issues were not identified in our data sources. Similarly, we began our analysis including the category Policies because we thought that graduate students might identify enrollment policies (e.g., continuous enrollment during degree) as a barrier to participating in an immersive internship program. However, no mention of policy-related limitations occurred in any information source. As per the failure analysis strategy of the fishbone diagram, we began with all categories we felt were likely to occur and winnowed the list to those that occurred given the information we collected about our failure indicator. Second, we did not rank the categories in order of contribution to the failure indicator; our data do not permit such ranking and such a ranking would be inconsistent with the system view offered by the failure analysis. Rather, we highlight below each category with suggestions for how the failure cause might be addressed should another team wish to implement this program or one like it.
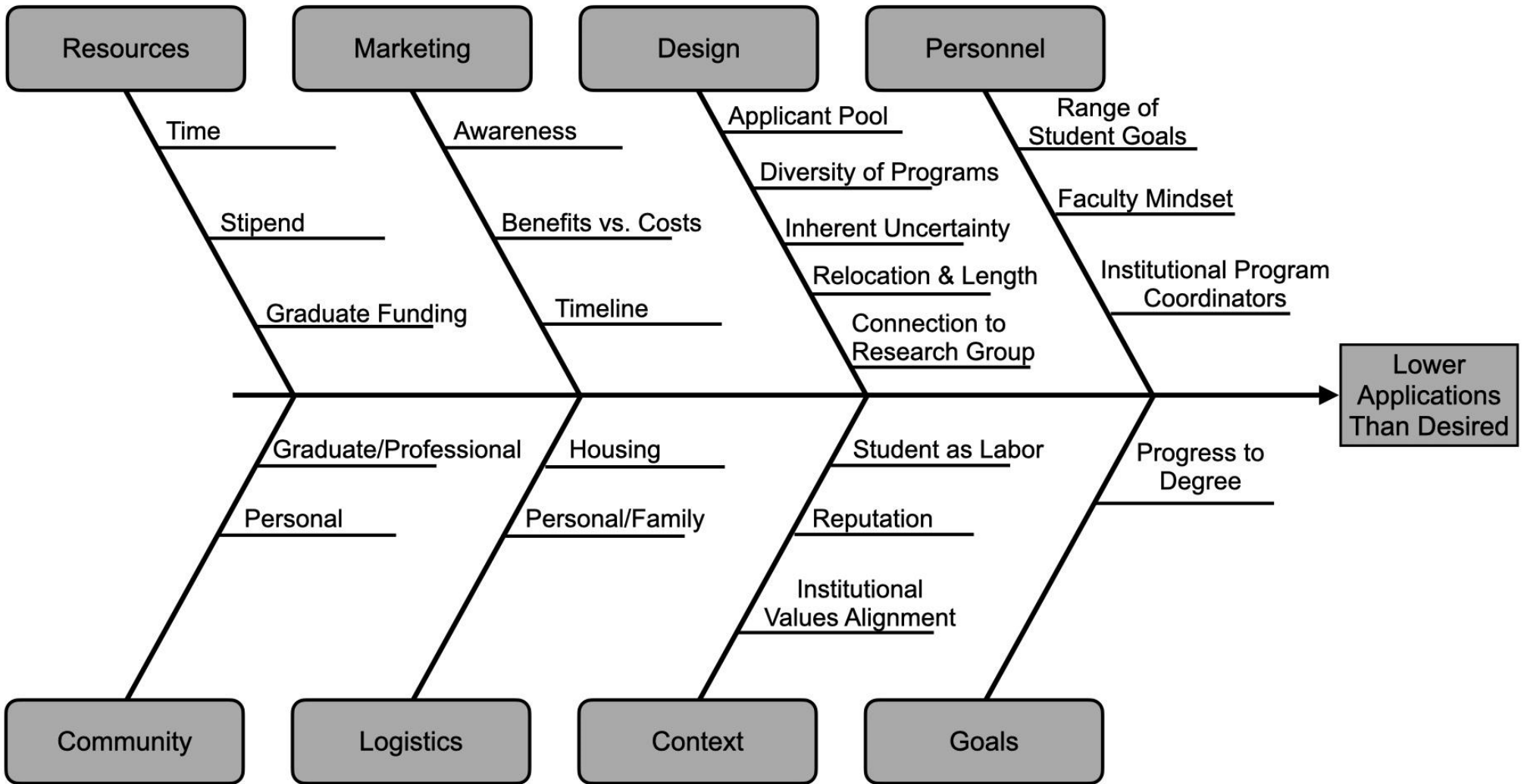
Figure 1. Summarized Fishbone Diagram for REEFE Failure Analysis

Results and Discussion

In reviewing the three information streams from this project, we identified potential sources of error that could have contributed to a low number of applications for REEFE. An exhaustive list of these error sources can be found in our full fishbone diagram, shown in the appendix, and is organized to show potential sources of error mapped to the information stream where the error was identified. All aspects of the program's system are represented. The themes generated from the appendix fishbone diagram are summarized in Figure 1. We discuss these themes further in the following sections. The order of reporting of these themes is the same as presented in Table 2. Failure analysis like the one we accomplished does not result in a ranked list of contributing factors. The goal is to identify what aspects of the system are contributing to the failure. As such, we discuss only the things we think were not successful, not all the many aspects of REEFE that were successful.

Resources

Students and advisors spoke of several concerns related to resources. First, a concern related to the time allocated to the program. Both advisors and students thought that students may not have enough time to participate in a long-term professional development experience if they planned to graduate on a certain timeline. While this concern is legitimate, our previous history with participants in the program showed no issues with maintaining their graduation timelines. Thus, this fear could have been alleviated through better communication with previous students and advisors.

Second, students discussed concerns related to monetary resources. They were concerned that the program did not offer enough of a stipend to cover the cost of relocation, the cost of living in a new city, and may interfere with other benefits like health insurance. The program was designed to provide a 20 hour per week stipend to participating students based on the average rate for a stipend at their home institution. The stipend allocated may not have been incentive enough to offset the costs associated with pursuing the program, as discussed in later sections. Because most institutions provide graduate health insurance as part of a graduate assistance package, a lapse in health insurance should not be a concern unless the model of future programs move towards a model of a larger stipend only, similar in format to the Graduate Research Fellowship Program through the National Science Foundation.

Finally, a common concern was current forms of graduate student funding. Advisors worried that they would not be able to fund a student if they were not working on research. This worry could have been due to misinformation about how a student would be funded during the duration of REEFE. Students also worried that taking a semester to participate in the program with alternative funding could jeopardize available funding when they returned to their home institution. We believe that this latter concern is reasonable and could be challenging for the future of any longer-term professional development program in graduate school. If a student's future in a graduate program is dependent on funding provided and controlled by an advisor or other faculty member, then the likelihood of an advisor or faculty member providing continuing funding upon return to the university is a significant factor in the decision. We know that many engineering graduate students identify financial concerns as a major area of cost when attending

graduate school (Peters & Daly, 2013). Any opportunity for professional development must be designed to accommodate the existing system of funding—to mitigate financial burdens or offset financial burdens with benefits from participation.

Marketing

Marketing was highlighted as a source of potential error in REEFE. First, through several information streams we received feedback that eligible participants and advisors did not know about REEFE, highlighting an issue that the marketing conducted through website development, emails, and seminars had not reached a wide audience among the two target programs. Our marketing strategy relied on 1) graduate program directors disseminating information to advisors and graduate students, utilizing the existing communication systems in the target graduate programs, and 2) advisors communicating the opportunities to their graduate students. We discovered many layers to disseminating information, which created many opportunities for breakdown in the marketing strategy (Eva, 2015).

Of advisors and students who had heard about the program, several individuals communicated that our marketing efforts had not adequately described the benefits of the program in comparison to the relative costs. This imbalance kept some advisors from passing along the opportunity to their graduate students and some graduate students from applying. One advisor noted that providing information on the experiences of past participants would have been helpful in communicating potential benefits. Although the REEFE website provided testimonials and seminars from past participants that were given at both home institutions, this feedback shows that these marketing efforts did not address the relative costs and benefits. Because some advisors did not see benefit to their students in participating in the program, a gap in the communication chain was developed that caused potential applicants to not know about the program. This gap can be attributed to both a failure on the part of the REEFE team to communicate value and relying on gatekeepers to pass along information. In the future, marketing efforts for substantial PD programs might target students and advisors separately, and even use physical mailings and fliers to avoid automatic email-delete behaviors.

Several graduate students noted that the timeline of marketing was their major concern, noting that the timeline for releasing applications and conducting interviews did not leave sufficient time for them to make decisions about whether to apply for the opportunity. We agree that this limitation was a source of error for this iteration of the program. Due to the short timeline of the grant process, we could not communicate the opportunities more than a few months ahead of time. For future iterations of similar programs, we believe that this problem would be minimized, because future potential applicants would learn of the opportunity several rounds before they plan to apply.

Design

From our information streams, we learned of several concerns related to the design of the program. First, the design of REEFE under the EAGER process led to a limited pool of potential applications. Because the initial consortium comprised only two major engineering education programs, we limited the possible number of applicants to only these two institutions. We

believe that this error source should be minimized because programs in engineering education continue to grow in size and increase in number. Also, for other types of engineering departments (e.g., mechanical, electrical, or civil) that are investigating this option for professional development, this error source is likely not applicable, because those programs enroll many more graduate students.

We required applicants to have completed their qualifying exam before applying to the program. We wanted to ensure that participants would have an adequate level of foundational knowledge to contribute to a host institution; thus, we required that participants had reached this milestone in their academic program before applying. The need to create value for both the graduate student and the host institution make this potential error source challenging to mitigate. In addition, many graduate students and advisors expressed hesitancy in sending students who were near graduation on an experience like REEFE because they feared participation would remove the student at a critical time in their dissertation process. While this fear is understandable, one participant used the experience to collect and analyze data for the dissertation while another developed the framework for the dissertation during the placement. We believe that this fear could be mitigated with planning and creativity. By focusing on the opportunities in the latter part of the degree, a REEFE-like experience can be valuable.

One objective of REEFE was to provide a unique experience tailored to the graduate students' goals and skills. However, the host institutions that provided work options were similar in nature. This similarity limited the candidate pool further to those interested in the types of opportunities we had available in the consortium. At least one survey participant noted that they wanted to participate in REEFE but were seeking a different type of job description than what we had available. As a project team, we did not have the capability to provide the diverse range of opportunities needed to suit the interests of the candidate pool we had available to us. We do believe that the opportunities provided allowed for experiences not typically available in graduate studies. These opportunities aligned with several key gap areas identified as needs for graduate student professional development, including teaching, service, and administrative opportunities as well as an opportunity to socialize in a faculty role (Austin, 2002).

Because REEFE was intended to be a program unique to each student's goals and experiences, uncertainty existed about the job responsibilities the graduate student would undertake until meeting with the unit they would be working with. While the opportunity was very flexible and could be suited to the graduate student's needs and abilities, this lack of clarity was unnerving for some which caused them to pass up the opportunity.

Participating in REEFE required that graduate students commit a semester away from their home institution, research group, advisor, and personal support system. Graduate students feared that this disconnection would lead to stunted progress in completing coursework or dissertation requirements. We know that research groups play a critical role in supporting graduate students in engineering through their academic process (Crede & Borrego, 2012), thus the program design should help graduate students maintain their connection to support systems if the program requires physical separation. Future work in this area should focus on developing the system of programmatic elements that encourage and assess the connection and communication between graduate students and support systems during long term professional development opportunities.

Many engineering graduate students identify balance among life and school as a cost for attending graduate school (Peters & Daly, 2013). If a program further jeopardizes that balance, benefits to participants must outweigh the increased costs. Resources allocated to relocation expenses or defraying housing costs as well as assistance with planning housing options may alleviate some of the burdens of participation and tip the balance more towards benefits in potential participants' minds.

Many participants noted that REEFE was a significant commitment that would be difficult or that they were unwilling to make. If they were willing to make the decision to leave for a full semester, many students and advisors noted that their choice would require significant planning on their part. They would need to plan one to two years ahead to ensure they could take this time to participate in the program. Due to the nature of REEFE and the EAGER funding that was secured for testing the consortium model, we did not have adequate time available to allow for this long-term planning for potential participants. Having a longer time horizon for planning would likely reduce this concern and may lead to an increase in applications over time.

Logistics

Dealing with the logistics of REEFE was a significant undertaking. First, participation would require graduate students to temporarily relocate for a semester. To relocate, participants would need to find new housing, deal with their current housing situation (through a sublease, release of lease, leaving housing empty, paying two leases, or other means), and move some belongings from one location to another. Some graduate students noted that relocation was too complicated, so they rejected the REEFE opportunity. In relocation, some participants noted they would either relocate families with them or leave these people behind. For those with families, concerns regarding childcare, schooling, and employment were significant. These costs were sufficiently high for many that they did not apply. We noted that the concern was not that the on-site requirement of the program was inappropriate (e.g., the program's design), but that the planning required was unpalatable.

A few students noted that they would be unable to continue taking courses at their home institution while participating in this opportunity. This hurdle can be exacerbated if required courses are only offered during one semester per year. In other words, the system of REEFE and the system of the graduate curriculum were in conflict. We do not see a way to reduce this conflict.

Goals

Our review of the project revealed that both graduate students and graduate faculty expressed concerns that participation in REEFE would pose a threat to a student's achievement of their goals. In the REEFE context, student goals often referred to the student's progress toward completion of their degree and whether participation in the experience would slow down or delay degree completion with the possibility that REEFE would be a "distraction" from dissertation work (Gaff, 2002). While completion of a dissertation is important work and a critical milestone for PhD students, a dissertation is not the only and most important outcome to be generated through graduate work. In a study of physical scientists four to eight years after graduation,

many respondents said skills like critical thinking, communication skills, and working in an interdisciplinary context were used often in their current position, while a small minority reported using their dissertation work in their career (Gaff, 2002). The results of this study remind us of critical skills needed for future careers that may go beyond the dissertation and provide a rationale for professional development opportunities like REEFE.

We discovered a barrier with respect to career goals, namely whether potential applicants intended to pursue an academic position at a teaching-focused college, rather than a research-focused university. One of the primary purposes of REEFE was to provide an immersive opportunity for graduate students to experience faculty life at an institution they did not have access to at their home institution. Because graduate students came from research-intensive institutions, the available opportunities for the program came from teaching-focused institutions. Therefore, this institution type created an imposed limitation in the applicant pool based on the design and mission of the program; in other words, the REEFE system has constraints that cannot be alleviated. Future iterations can look at expanding the mission and partnerships within REEFE to offer a wider variety of potential opportunities.

Personnel

The need for resources to manage the program was notable on the part of the host institution, because management of that side of the program was unfunded throughout REEFE, even when the project received NSF funding through an EAGER. We found most interesting the fact that the success of the project depended largely on the interpersonal relationships among the project managers at the home and host institutions. Without those interpersonal relationships, founded on their network connections rather than positional power, the project would not have operated (Kezar, 2012; Lawrence, 2015). While interpersonal relationships made REEFE possible, institutionalizing the program would likely require engaging individuals with positional power within both the home and host institutions.

Community

We saw a recurring theme regarding the loss of the graduate student's community during their time in REEFE. Specifically, the respondents identified community as both the community of other graduate students and faculty (their professional community) located in their home department and the community in which they and their families live (their personal community). Although we identified time as one of the several resources that is impacted by REEFE, time in the context of community took on a different meaning. Respondents identified the loss of time that would normally be spent with family during REEFE. They also referenced loss of time with graduate advisors, which appeared as a potential loss of expertise that is important for progress to degree. We know from many empirical studies the critical role that community plays in the success of graduate students (Beqiri, Chase, & Bishka, 2009; Hoskins & Goldberg, 2005; Peters & Daly, 2013). Therefore, concerns related to losing connection and community are not surprising. While REEFE was designed to integrate participants into the host community quickly, the loss of known community can cause stress and anxiety related to a change that already has other costs identified.

Context

In responses related to context, we noted a concern regarding the alignment between the culture of a student's graduate program and the stated objectives of REEFE that may have affected the number of applications we received. REEFE emphasized the development opportunity offered to graduate students and the impact the opportunity could have on the students' identity as professionals (Ellestad et al., Under Review). Further probing, however, caused us to examine the degree to which the value system embedded in a student's graduate program would determine whether REEFE should be viewed as a valuable opportunity. Several respondents pointed out that a graduate student must leave their department during REEFE. While such an absence was intended to benefit the student, this absence poses a threat to the essential labor that graduate students provide to their graduate advisors. Without that labor, several respondents noted, the graduate advisor may risk their own research agenda upon which their tenure and promotion depends. One respondent explained that advisors whose students accepted the REEFE opportunity would then be required to seek out, hire, and train other students to ensure that research work continued uninterrupted. Given the labor issue, several respondents suggested that advisors could possibly view the REEFE opportunity negatively because of its impact on the availability of graduate students trained to conduct research, and therefore made them unlikely to support a student participating in the program. This finding aligns with concerns presented by Austin (2002), who posited that graduate education was equally as focused on the smooth operation of the university through graduate student labor as on preparing graduate students for future careers—the system requires this dualism to function. One potential solution to this issue would be to encourage early planning among advisors, researchers, and graduate students so that cross-training can occur, should a graduate student desire to participate in an opportunity that may take them away from a group or project. This solution provides more flexibility to graduate students in pursuing opportunities, ensures projects have adequate staffing, and allows graduate students to widen their research skills by being cross-trained in multiple areas.

We also noted that, given its early stage of development, REEFE does not yet have status among graduate programs in engineering education and consequently would not confer to participants a distinction that graduate advisers would appreciate. Unlike a dissertation award from the National Science Foundation or other recognition conferred upon the student, REEFE would appear not to contribute to the reputation of either the graduate advisor or the student. While we acknowledge that REEFE could not assume such an elevated status (the program was, after all, funded because it was "potentially transformative") during its initial two years, we see distinction possible for any engineering education department who might take on REEFE and incorporate it as an expectation, perhaps even a requirement, for its graduate students. We could re-envision the "failure" of our paper's title by considering REEFE a success if others in graduate engineering education would adopt our model and learn from our achievements as well as our mistakes.

Implications and Conclusions

Our goal in this work was to identify sources of error that contributed to a lower number of applications to our program than we expected. By design, this approach to failure analysis does not result in a rank order of importance of sources of error to the failure indicator. All the sources

of error we identified contributed in some way to our failure outcome: lower applications than desired. However, our experience and expertise in this area lead us to postulate several implications from this study that we believe are beneficial to the future of REEFE and graduate education in engineering education more generally.

The future of REEFE or the success of a similar program depends on being able to clearly communicate both the benefits and costs of participating in the program. The REEFE team knew the anecdotal benefits of program participation and were working diligently to provide empirical results to the community on REEFE outcomes. We believe that future publications coming from the REEFE team will describe the benefits of the program to show its efficacy. Future program development teams should use these results to communicate the benefits to potential future participants. Through this work, we have been able to define some of the challenge areas that presented high levels of cost to potential participants. These identified costs (e.g., relocation costs and logistics, connection to community, dissertation progress) need to be a focus of program design improvements for future iterations of REEFE; in other words, systemic improvements are needed, not just better recruiting to the applicant pool. Clear communication of empirical evidence of benefits as well as design improvements to mitigate costs can lead to increased interest and participation in the program. Future work must focus on ways to support the continued connection among the REEFE participants, their advisors, research group communities, and home communities. At the same time, program organizers should help REEFE participants develop a supportive community while at the host institution. We believe this specific focus will further reduce concern about participation and may increase applications.

One source of error identified in this study related to the need for graduate students to serve as hired labor for faculty to maintain funded work. The need for hired labor may be superseding the goals and ambitions of the graduate student. We believe that the finding of a conflict between hired labor and program participation highlights the need to rethink this issue. As noted in Borrego and Henderson (2014), we know that faculty reward structures can both help and hinder change in higher education. We pose the question: What faculty reward structures can simultaneously allow graduate students to prepare for their future career? We believe that a flexible reward structure for advisors would allow them to support their graduate students' pursuits while not incurring deficits to their own career. This implication addresses the system of graduate education in engineering education directly.

We also believe now is a critical time for engineering education programs to think about how their graduate programs are aligned with future career objectives for their graduates. The issue of graduate student preparation and alignment with career objectives is a long-standing conversation across graduate disciplines. Several new engineering education programs are developing over the next several years. We would encourage these programs to consider ways to distinguish themselves from existing programs by thinking about how to offer graduate programs that better align with the career objectives of diverse opportunities. Models exist for terminal degrees that prepare graduate students for jobs other than as research faculty. We believe that new engineering education programs can help the community continue to grow and expand by considering alternative programs and degree paths to prepare graduates for jobs in administration, student affairs, teaching, and industry.

After reviewing multiple data streams to look at failure in REEFE as a system, we found an accumulation of barriers layered one on top of the other, like one would expect for a multi-institution, multi-year, multi-personnel project. This complex system of barriers created challenges for the REEFE team to work through with the goal of increasing applications to the program. The process of conducting the root cause analysis for REEFE was enlightening and has created an excellent starting point for future professional development programs like REEFE. We propose that the engineering education community could benefit from what we have learned about challenges and barriers associated with implementing professional development opportunities for graduate students. Furthermore, we encourage the engineering education community to consider the beneficial activity of failure analysis as a critical method for learning and information dissemination.

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Appendix

Resources		
Personal Reflections	**Customer Discovery**	**Barriers Survey**
	The need to "pony up" funding and offerings	Time in graduate schedule to participate in opportunity
	Grad programs are understaffed	Finances or funding to move
	General lack of resources	Existing funding or fellowship
	Access to health insurance	Challenges of collaboration
	Long-term funding is difficult to find	Personal circumstance for funding
	Participants cannot take a financial hit (both students and advisors)	The stipend may not cover the difference in cost of living between home and host institution
	Advisors cannot fund if a student is not doing research	Possible financial burden
	Advisors and students only have a certain amount of bandwidth	

Marketing		
Personal Reflections	**Customer Discovery**	**Barriers Survey**
Relied on graduate directors and advisors to communicate the opportunity to graduate students	Need for critical mass to become credible	Need to hear about opportunity earlier for planning
Marketing did not adequately communicate the value of the program in comparison to the costs	Not all opportunities are communicated to advisors; some go directly to students	Lack of awareness of program; need to promote program more effectively
	Department marketing to graduate students	Knowledge of host institution
		Need to hear about experiences of previous participants
		Lack of knowledge of benefit to students

Design

Personal Reflections	Customer Discovery	Barriers Survey
Limited pool of candidates: two schools to recruit from; passed qualifiers	Program needs to meet specific desires of a range of students	Lack of clarity of work responsibilities and workload at host institution
Graduate students and advisors do not see benefit of the program that outweighs costs	Length of program too long	Uncertainty about scheduling
This opportunity is not the right fit for every student	Uncertain about the appropriate timeline (length and timing)	Do not know what to expect from opportunity
Work expected of the position did not align with the expectations of the potential participant	Requires significant planning for advisor and student	Uncertain about structure of program and support for student
Limited diversity in job opportunities	Better as a reciprocal arrangement (one for one swap) for teaching only	Seeking opportunity with a faculty member who is not a current partner institution
Limited diversity in potentially interested graduate students		Not far enough along in graduate program
Limited interaction between members of consortium - institutional partners did not have opportunity to think and contribute across the program		Turn around from application to participation too quick

Logistics

Personal Reflections	Customer Discovery	Barriers Survey
Participation required relocation to a different location	Access to services for family	Difficulty taking classes
Leaving partners and families Leaving current housing	Health insurance	Figuring out logistics at host institution
Finding new housing	Baby sitting	Moving to a temporary location and finding temporary living arrangements
Marketing did not adequately communicate the value of the program in comparison to the costs	Relocation	Duplication of housing costs or subleasing and roommate arrangements
Overall risk aversion towards a new, unknown program	Need for critical mass	No appropriate positions
Timing for opening applications and making a decision not ideal		Time away from advisor
Lack of administrative support to complete logistical work to support program		

Goals

Personal Reflections	Customer Discovery	Barriers Survey
Concern about lack of progress towards degree	Must remain connected to existing work Slower progress towards degree	Distraction from dissertation work Goals of student and program must align May not be interested in teaching-focused positions; lack of alignment with career goals Time taken away from degree progress and graduation goal; longer time to graduation Need more information on the value to students (plan of study, career goals)

Personnel

Personal Reflections	Customer Discovery	Barriers Survey
Intervention relied on interpersonal relationships instead of multi-institutional partnership; lacked positional power Program required added administrative work for home institutions without added resources Lack of alignment in graduate training and current job placement (most graduates go into non-tenure track positions but most training relates to tenure track work)	Direct advisor resistance due to uncertainty about student preparation Student apathy toward change and the opportunity Diversity of students (e.g., progress in graduate school, career goals) Lack of expertise in required areas	

Community

Personal Reflections	Customer Discovery	Barriers Survey
Loss of community (both professional and personal)	Loss of student from graduate community (loss of expertise and perspective) Advisors have varied expectations for grad student PD	Time away from or commitment to family Relocation of children Time away from home Time away from graduate cohort Time away from research and dissertation work Time away from home institution Disconnection from research group

	Context	
Personal Reflections	Customer Discovery	Barriers Survey

Personal Reflections	Customer Discovery	Barriers Survey
Conflict between what the experience offers and what departments value	Direct advisor resistance (losing productive students)	Potential lack of support from advisor
Degree progress	Lack of standardization in what PD or graduate training looks like	Interruption of current work (dissertation and funded projects)
Research institution goals vs teaching institution goals	Newness of field; lack of understanding what ENGE really is	Opportunity does not fit within current program
Advisors hesitant to suggest opportunity due to potential loss of resources or workers (need to continue grant progress)	R1 vs teaching norms (being treated as a "second class" citizen)	Lack of interest in non-R1 institutional context
Student and advisor risk adversity due to new opportunity	Varied disciplinary norms	Opportunity should not require full time presence
Host institution credibility concerns: are PhD students qualified to teach?	Goal misalignment between advisor and student	Difficulty taking classes
Bringing different and diverse people to campus may cause clash due to cultural differences	Graduate programs are focused on academics, technical fields, and research	Potentially a way to exploit "cheap labor" from grad students
Change requires tremendous activation energy which we had limited access to		Changes in funding
		Need planning time to ensure advisors and committee members have aligned expectations for students during experience
		PIs will need to backfill students that take opportunity; PIs need graduate students to work on their own grants; PIs do not want to give up trained graduate students
		Lack of prestige for advisors
		Advisors and graduate program directors do not see the program as valuable