Board 225: Building a Culture of "Engineering with Engineers"

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Building a Culture of "Engineering with Engineers"

Introduction

The Mechanical Engineering Department at a private, mid-sized university was awarded the National Science Foundation (NSF) Revolutionizing Engineering and Computer Science Departments (RED) grant in July 2017 to support the development of a program that fosters students' engineering identities in a culture of doing engineering with industry engineers. The Department is cultivating this culture of "engineering with engineers" through a strong connection to industry and through changes in the four essential areas of *a shared department vision, faculty, curriculum, and supportive policies*.

As we conclude this project, we are auditing all the activities we did throughout our project. In this audit, we review our activities with an eye toward what was particularly impactful for us, the relative levels of difficulty as seen in retrospect, how educative they are to us, and the potential for others to make use of the activity. This paper summarizes these activities in each of the four areas of change. We then describe our audit process and briefly present the results of these activities.

Project Background

The theoretical background that guided us throughout the project remains unchanged; hence, this section combines content from our previous ASEE NSF Grantees papers [1] - [5] to summarize our project background.

Identity influences whom people think they are, what they think they can do and be, and where and with whom they think they belong [6] - [9]. People's identity shapes the experiences they embrace; reciprocally, those experiences shape their identities [10] - [12]. People behave consistently with their identities [13], [14], choosing behaviors with meanings that match their self-conceptions [15], [16]. When people identify with an esteemed group, they feel better about themselves and, in turn, feel better about the group [17], [18]. If people strongly identify with a group, they steadfastly defend the group, stay in it, and support it [19].

In education, identity influences whether people feel they belong in a program and what they believe they can achieve. It has been shown to influence what goals are pursued and the level and type of effort put toward those goals [14]. Research also shows that identity and fit are important factors affecting persistence in STEM fields [10]. When people perceive a fit between themselves and their fields, they persist longer in those fields [20] - [22]. Hence, identity is a determining factor in one pursuing, persisting, and persevering in engineering [13], [23].

The development of identity is a social process. People's thoughts and behaviors are shaped through relationships and reflected appraisals with others [7], [19], [24]. Identities are further derived through associations, affiliations, and identifications with groups [20], [25]. Tonso [26] observes that identity development is an enculturated process where identities are acquired

through "community-based interactions," and Beam et al. [23] concur that social contexts affect identity. In engineering education, situated learning is central to identity development [26]. Therefore, this social process of identity development can be realized through the culture of an engineering program. Cultivating a culture of doing engineering can result in graduates who not only are prepared technically and professionally with a practical, realistic understanding of what it is to be an engineer but also who identify with and are committed to the engineering profession.

Our project aims to develop a mechanical engineering program where students and faculty are immersed in a culture of doing engineering with practicing engineers from the industry that, in turn, fosters students' engineering identities.

Culture is shaped, in part, by the identities of those in the culture. It is negotiated, co-created, and reinforced through communication and social interactions [27]. It develops organically from the behaviors of a group through association and shared experiences [28]. The culture of a program plays a significant role in effective, innovative STEM education [29], [30]. It is also important to know that the priorities of the institution and department influence culture in an educational setting. Hence, this culture of "Engineering with Engineers" is built through interactions of students, faculty, and industry, participation in engineering-related activities, and reinforcement of shared experiences in our program.

Building a culture of "Engineering with Engineers"

To build a culture of "Engineering with Engineers" changes were made in four areas as recommended by Henderson et al. [31]. From an extensive review of articles on facilitating change in STEM education, Henderson et al. indicated four necessary areas of change: *shared vision, reflective faculty, relevant curriculum and pedagogy, and supportive policies*. Many actions were taken, and many changes were made in each of these four areas., Our previous NSF Grantee papers [1]-[5] chronicled the actions we took in these four areas of change. This paper outlines the audit process used to evaluate our actions and summarizes what we identified as the most impactful actions for further dissemination.

Summary of Project Activities: The Beginning of the Audit Process

To organize the actions and changes needed for this culture of "Engineering with Engineers", we compiled all of the actions taken over the past five years. In the tables that follow, we itemize the processes and products from our actions and include brief descriptions of each. We grouped our action items by the endeavor or undertaking that the action supported and grouped our endeavors by the area of change supported.

In this section, we briefly review each area of change and discuss our actions with each endeavor. This review is followed by a table for each area of change that lists the endeavors and the action items that support them.

1. Shared Vision: Building a Culture that Cultivates Identities as Engineers

A shared vision is an essential foundation for a culture. As a small department with only nine full-time faculty, getting all full-time faculty involved in our RED project was important for successful culture change. Through various processes at the beginning of this project, the faculty worked together and established the vision of building a departmental culture of "Engineering with Engineers" to foster engineering identity. The faculty agreed to work towards making the Mechanical Engineering Department "a hub of engineering activity where faculty, students, and industry can share experiences and ideas."

We group the items related to establishing and sustaining a shared vision into three endeavors and each item, i.e., process or product, supporting each endeavor is briefly described in Table 1.

Table 1: Items to establish and sustain a shared vision

Area of Change	Endeavor	Item	Brief Description
Establish and sustain a	Establish the Department mission and vision	Develop a revised mission statement using a custom process	Faculty identified issues with the previous mission statement and agreed on aspects to be included in the revised mission statement [2].
		Product- New department mission statement	The new collaboratively written Department mission statement can be found in Ref. [2].
		Design and deploy identity (ESIS and IAT) measures	We track how student's identity changes, using both the explicit identity surveys (ESIS II) [32] and the Implicit Association Tests (IATs) [33].
		Product – ESIS	To be disseminated.
		Product - gender and Engr IATs	See Ref. [33]
		Share/use IAT data	See Ref. [33]
		Design and deploy senior exit (and alum) survey	A senior exit (and alum) survey is used to identify the awareness and impact of our RED project. [4]
		Product - senior exit (and alum) survey	To be disseminated.
	Confront issues	Conduct external DEI Evaluation	Earlier reports from our external evaluators, Inverness Research, revealed instances in which students did not feel included in some instances within the Department [1] – [5].
		Converse about DEI	From the situations pointed out in these reports, faculty sensed a strong need of raising the awareness of diversity, equity, and inclusion (DEI).
		Develop a process to formulate the DEI statement	A diversity and inclusion syllabus statement was discussed and established by all faculty [4].
		Product- DEI syllabus statement	See Ref. [4]
		Promote DEI training	Over the years, faculty and staff members have participated in numerous trainings in and discussions of DEI-related practices [4], [5].
		Design and deploy Inclusivity meter	A weekly short survey of seniors' experiences of working in their senior design team was used to surface concerns related to inclusion [4].
		Design and deploy belonging/inclusivity measure	An inclusion survey was administered three times across the VIDP quarter [4], [5].

shared vision	related to inclusion	Product - belonging/inclusivity measure	To be disseminated.
		Develop a lab manager position to support/create an inclusive lab environment	To address students' concerns about their unwelcoming experiences in the machine shop, a lab manager position was created to support the department's efforts in building an inclusive culture.
		Hire and sustain a lab manager committed to inclusion	A new lab manager who is committed to DEI was recruited.
		Product- New program educational objectives (PEOs)	See Ref. [34].
		Establish ME student advisory council	The Student Advisory Council creates channels to directly communicate with our students [3].
	Connect the department by holding retreats and "Teaming" exercises	Develop a process to conduct the Teaming exercise	The Department holds a "Teaming" exercise every three weeks as an avenue to converse, connect, and continue to grow as a team. [5], [35].
		Develop a process to come up with the new Societal PEO	One "Teaming" exercise was dedicated to experimenting with this process. [To be disseminated]
		Product- the new Societal PEO	See Ref. [34].
		Plan retreats	Every fall at the beginning of the academic year, the RED PI team organizes a retreat to collectively review progress made and plan for the actions in the coming year.
		Have retreats	These retreats serve an important role in connecting faculty and staff in the department and centering our focus.

2. Reflective Faculty: Strengthening Interaction with Industry & Understanding Diversity and Inclusivity

Faculty play a critical role in guiding students in developing their education and career paths and, more importantly, their identities as engineers. Strengthening faculty's connection to industry enhances their ability to facilitate the formation of students' engineering identities and ability to guide students towards becoming practicing engineers who create a "more just and humane world." Faculty's identities as educators who understand diversity and strive for inclusivity are also essential. To sustain the desired culture, faculty must reflect on their efforts to create and sustain the changes.

Two groups of change endeavors related to reflective faculty and their items (processes and products) are described in Table 2.

Table 2: Items related to reflective faculty

Area of Change	Endeavor	Item	Brief Description
Reflective Faculty	Care for students	Develop a process to make an advising checklist	Faculty discussed and agreed upon an advising process and a checklist to promote connections between students' and the program's goals [3], [5].
		Product- Advising checklist	See Ref. [3].
		Arrange alum mentor events for students	Recent graduates connected with graduating seniors to provide career mentorship.
		Have paid seniors to lead all-student Study Hall	The Department hired tutors and peer mentors who held study halls and helped other students [4], [5].
		Design and host portfolio workshops	The department piloted the use of portfolios with a small sample of students to gain insights into students' knowledge of portfolio construction and then hosted Portfolio Week for all students [3].
		Accommodate remote teaching and learning	During the pandemic, faculty utilized tools accessible to students to continue the emphasis on "doing engineering" [4]. See Ref. [36] for details.
		Promote/encourage innovative teaching	The new curriculum creates opportunities for faculty to try new approaches in their classes [3] – [5].
		Make connections with industry	Practicing engineers served as mentors to students in design projects, gave guest lectures or simply participated in social events to connect with students and faculty [2]-[4].
		Define, recruit and mentor part-time Industry Advisor(s)	An Industry Advisor with extensive experience in the industry and a passion for engineering education was hired to join the program at the beginning of the project to help bridge the program and the industry [1] – [4].
	Faculty Development	Have faculty Industry Immersion experience	The summer industry immersion program aimed to broaden the faculty's views and strengthen their ties to industry [1] – [3].
		Engage faculty DEI in training	Over the years, faculty and staff members have participated in numerous pieces of training and discussions in DEI-related practices [4], [5].
		Engage faculty in active learning training	Faculty attended several training courses hosted by various organizations on different subjects [3] – [5].
		Support collaborative spirit (co-teaching, co-chair etc.)	Collaboration among faculty and staff highlights the inclusive culture in the department. Throughout the new curriculum, there are many opportunities for faculty to co-teach and collaborate on a course [5].

3. *Relevant Curriculum and Pedagogy: Maintaining Strong Connections with Industry and Incorporating Industry Practice into the Program*

Across the revised Mechanical Engineering program, the curriculum capitalizes on close industry connections and engages students in activities that reflect what practicing engineers do. Such connections and activities require pedagogic changes to existing courses as well as implementing a series of new courses with components related to industry practice. Extracurricular activities such as seminars, socials, design challenges, and club activities also help to connect students more closely with engineering practice.

Three groups of change endeavors related to change in curriculum and pedagogy and their items are listed in Table 3.

Table 3: Items relevant to change in curriculum

Area of Change	Endeavor	Item	Brief Description
Curriculum	Revise ME curriculum	Develop a process to survey advisory board members/industry partners	The Department examined the previous curriculum and identified several ways to strengthen it and include the industry [2], [3].
		Develop a process to discern how students see Engineering with Engineers	The process of "critical doing" actively involved faculty and students in the design of the new curriculum. Details on the process of developing our new curriculum can be found in Refs. [2], [3].
	Develop and implement the ME curricular changes	Develop and implement Integrated Design Projects (IDP)	Through experiential learning, the IDP sequence facilitates integrated teams consisting of first-, second-, and third-year students to learn practice skills such as design principles, team dynamics, project management, communication, etc. [3], [37].
		Develop and implement DAQ (Data Acquisition) I & II	DAQ I & II integrates the electrical engineering and instrumentation content in a single two-term sequence [3], [38], [39].
		Design and deploy breadcrumb reflections	Short reflection exercises help students reflect on their experiences in DAQ classes [39].
		Product- breadcrumb prompts	See Ref. [39].
		Share/use reflection data	See Ref. [39]
		Implement authentic engineering problems from industry partners in classes	Faculty employ innovative teaching approaches that include using authentic engineering problems provided by practicing engineers from industry [3], [4].
		Position/frame seniors as professionals and senior design as professional practice	To simulate industry, we changed the vocabulary (e.g., colleagues and not students) and removed traditional academic schedules [3].
		Design and deploy senior growth survey	To document the influence of the changes made in senior design as well as other parts of the curriculum on students' professional thinking and skills, a pre-post assessment was developed [3], [4].
		Product - senior growth survey	To be disseminated.
	Enhance extracurricular activities	Support student clubs	Supporting student group activities was important to keep the community connected [5].
		Offer social events (with each other, with professionals, etc.)	Social events help build the community [3] – [5].

4. *Supportive Policies: Changing Expectations in Departmental Reviews and University Policies*

Culture takes time to grow organically, and changes cannot be forced. A shared vision builds a solid foundation for change. Reflective faculty and a new curriculum create pathways to change. Actions that bring faculty, students, and industry together cultivate this culture change of doing engineering. However, these changes in shared vision, faculty, and curriculum can only be sustained with supportive policies. Therefore, for the change to have a long-term impact, it is essential that we collaborate with other departments, the College, and the University in developing supportive policies.

Items to establish supportive policies are listed in Table 4.

Table 4: Items to establish supportive policies

Area of Change	Endeavor	Item	Brief Description
Policies	Establish supportive policies	Change to Annual Performance Review (APR)	The Department modified its APR process to recognize and commend faculty's engagement with industry, the changing culture, and curricular and pedagogical revisions. The College APR form also recognizes the value of various types of service faculty do such as mentoring students and contributing to professional societies [3] – [5].
		Change to Tenure and Promotion Process	The Department worked closely with the University ADVANCE [40] team to revise the University tenure and promotion guidelines, which now recognize contributions from a broader list of faculty activities relevant to sustaining changes initiated by our RED project [2] – [5].
		Support College-wide and University-wide efforts on diversity, equity, and inclusion (DEI)	The Department actively participates in the College's and the University's movements in raising awareness of DEI issues and building an inclusive environment [4], [5].

Evaluating the Project Activities: Continuing the Audit Process

The aim of the audit was to identify which of the RED project's efforts to prioritize for dissemination. We sought to determine which *Processes* or *Products* were most critical to the changes in our department and to surmise which might be most valuable for others interested in changing their academic unit.

As described above, the audit began with identifying all the endeavors and items listed in Tables 1 to 4. All five RED PIs reviewed and agreed on the items.

Next, we asked ourselves the following three questions about each:

- *How critical (impactful) was it for the culture change to happen in the Department?*
- *How easy was it to materialize or use this item?*
- *How likely is it for other departments to adopt it? (Consider limitations on finance, dept size, etc.)*

Each of the five RED PIs individually evaluated each of the items shown in Tables 1 to 4 using the instructions below:

Rate each item as high (H), medium (M) or low (L). This rating should be based on the cumulative efforts in the past five years of the project. Please add a comment to help us understand how/why you rate an item a certain way. If you cannot rate a particular item for any reason, please use "?". If you feel strongly about modifying any item so you can give it a rating, please highlight the modification you make.

For example, each PI evaluated how critical (impactful) developing a mission statement was for the culture change to happen in the department. An "H" rating meant that the PI considered the item highly impactful. Each PI also evaluated how easy it was to do and how likely it is that other departments would adopt it. This was done by each PI for each item.

After collecting responses from all PIs, results were assembled in a table and shared back to all PIs. In subsequent PI meetings, results for each item were discussed. Results for the example item are shown in Table 5.

Table 5. Audit results for an example item

Item	How critical (impactful) was it for the culture change to happen in the Department?	How easy was it to materialize or use this item?	How likely is it for other departments to adopt it? (Consider limitations on finance, dept. size etc.)
Develop a revised mission statement using a custom process	H H H H H	M M H M M	M M M H M

Discerning what to disseminate: Concluding the Audit Process

Using the ratings described above, we identified items that were most impactful for the culture change we observed in the department. Items with low impact were not considered further; items rated as having a medium or high impact by most PIs led us to consider the other two questions. Items that were rated as somewhat or highly easy to use (rated M or H) and somewhat or highly likely to be adopted were prioritized. This assessment led us to identify ten categories to prioritize for sharing. They are presented in no particular order, and some items are grouped into one category, as they are likely to be discussed together.

1. Develop a revised mission statement using a custom process. All PIs agreed this was critical (and impactful) to the culture change in the Department. The process unified faculty around a shared understanding of the department and the program's goals. The process we developed is also a model that others can use to initiate a culture change process.

2. Conduct external DEI Evaluation & Converse about DEI. Based on the report from the external evaluators, the entire Department became aware of the exclusion felt by some

underrepresented students in the program. The Department had in-depth conversations and discussions to determine actions to take to combat these DEI issues.

3. Develop a lab manager position to support/create an inclusive lab environment & hire and sustain a lab manager committed to inclusion. The external evaluator's report revealed that some students felt excluded in the machine shop. The Department developed a new lab manager position to replace the original machinist position. The new lab manager not only takes care of the machine shop and assists with labs but also is an integral part of the Department in building an inclusive culture.

4. Plan & have retreats. At the beginning of every fall before the start of the academic year, the RED PI team planned an all-faculty and staff retreat according to the goals to achieve that year. These retreats allowed faculty and staff to work and make plans together as a team. Shared understandings and significant action items resulting from the retreats. For example, during our first retreat, the Department worked on revising the mission statement.

5. Develop a process to conduct the Teaming exercise. Stemming from the retreat at the beginning of year five of the project, the Department wanted to have more opportunities throughout the academic year to connect and share deeper thoughts. Hence, the "Teaming" exercise was developed and implemented. In each "Teaming", a prompt was given to initiate the conversation, and then discussions were carried further beyond the given prompt. "Teaming" gave space for faculty and staff in the Department to build trust through sharing their personal thoughts and experiences.

6. Accommodate remote teaching and learning & promote/encourage innovative teaching (e.g., inverted classroom/ active learning, etc.). With the support from the Department, the faculty are willing to try innovative pedagogy in their teaching. During the COVID-19 Pandemic, the faculty utilized new tools to enable students to continue "doing engineering". Many faculty inverted their classes to leave room during lectures for more active learning or authentic problem-solving.

7. Make connections with industry & define, recruit and mentor Industry Advisor(s). The Department puts efforts into actively connecting with industry through various means. One very specific action we took was to hire an Industry Advisor who came to campus once a week to provide students with a visible connection to the industry. The Industry Advisor provided students with career advice and technical help on various projects.

8. Develop a process to discern how students see Engineering with Engineers; Develop and implement Integrated Design Projects (IDP); Develop and implement DAQ I&II. In revising our curriculum, we found it particularly significant to include our students. Our students let us know what learning experience was essential to them and what they thought was missing in our previous curriculum. Hence, we developed the IDP and DAQ sequences and implemented them in our new curriculum. Additionally, IDP and DAQ sequences created opportunities for co-teaching, which was an important contributor to the collective spirit existing within the Department now.

9. Position/frame seniors as professionals and senior design as professional practice. The senior design course sequence in our program has had great success in connecting seniors and the industry for more than 30 years. To simulate industry and to position seniors as professionals, we changed the vocabulary and removed traditional academic schedules since the second year of the RED project. Based on interactions with our students and alums, it appears that this was important in helping our students build their engineering identities. We do not have a specific assessment to quantify the impact of this action, although we did survey students on their professional skills at the beginning and end of the design sequence.

10. Celebrate RED-related actions in the Annual Performance Review (APR). It was essential to recognize and celebrate the faculty's and staff's efforts put into this project to create this culture change. It provided additional motivation for faculty and staff to invest in the success of the project and continue the work.

Conclusion

To build an environment that fosters engineering identity, we changed the culture of our department in the four essential areas of shared vision, reflective faculty, relevant curriculum and pedagogy, and supportive policies. Across the duration of our RED project, we engaged in a variety of actions in each of these areas. This paper shares a way of assessing or auditing the actions we took to make this culture change. We listed the many actions we took within each area of change and organized them by the endeavor they supported. Each PI then assessed for each action what was particularly impactful for the department, the relative levels of ease and difficulty as seen in retrospect, and the potential for others to make use of the product or process we developed. We realized that many actions we took are not limited to our unique setting (i.e., small, teaching-focused, mechanical engineering program) and can be adopted in different settings. Discussion of the PIs' collated ratings led us to see what is important and what we should initially disseminate. It has also helped us to identify the method of dissemination beyond the traditional publication route. As of now, we are planning to share our experiences with the ten categories above through workshops, co-design activities, demonstration videos, etc., all as part of a comprehensive toolkit.

We have invested significant effort to build an inclusive culture and environment to foster engineering identity. Our focus on identity can have a long-term impact. It could encourage reflection and a larger discussion about how students see themselves, their education, and their profession. Identity has been shown to be an important factor for women to persist in a field [26]. A culture of "Engineering with Engineers" with incentives and training that promote industry engagement and build strong industry-education connections is essential for technically and professionally prepared graduates with a practical, realistic understanding of what it is to be an engineer. As we conclude this project, we are focused on sustaining the changes and continuing to share our experiences. We welcome your input. If there is any item about which you are interested to learn more, please don't hesitate to contact us. We also appreciate comments and suggestions on how you would like us to share our experiences with the engineering education community.

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