Transforming the culture, delivery and content of an undergraduate engineering program: process, pitfalls, and potential for lasting change

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Abstract: This paper captures an initial analysis after four years into a transformational change of 80% of a program's focus, content, delivery and pedagogy. We use the lens of Kantor and Lehr's "Four Player Model" to interpret the team's dynamic process. This particular model emphasizes healthy dynamics that preserve integrity and organizational values in the change process. The major pitfall was inattention to the concerns of stakeholders during the process of change, as organizational change is fundamentally a human-centered endeavor. At this point, the potential for lasting change varies, depending on individuals' epistemological development: those with a dichotomous world view are tending toward a retraction to original pedagogies; others' change is lasting, but continue to examine outcomes for evidence of the intended outcomes. Interview excerpts and programmatic data are presented in this paper as evidence of the results and process of change.

Introduction

Amid the wave of energy being invested in engineering education, many are asking, "How can the new research knowledge in this emergent discipline transform the classrooms and curricula of today?" This question goes well beyond the issue of knowledge transfer; it fundamentally involves the learning environments that faculty create and maintain. In other words, transforming the undergraduate engineering learning experience encompasses pivotal shifts in organizational behavior. Our **research question** was, "What are the organizational conditions that facilitate lasting programmatic transformations in engineering programs?"

While the call for change in engineering education is prominent (Clough, 2005; Duderstadt, 2008; Sheppard, et al., 2009), developing useful theories of change in the academy are less so. Our broader study uses four frameworks as references for the organizational conditions that facilitated lasting change in the program under study: 1. The five stages of tribal leadership (Logan, King, & Fischer-Wright, 2008); 2. The comparative advantage of X-teams (D. Ancona, Bresman, & Kaeufer, 2002); 3. Bourdieu's concept of habitus (Bourdieu, 1990); and 4. The Four-Player Model (Kantor & Lehr, 1975). Due to space limitations, we focus on the preliminary findings through the lens of the Four-Player Model, with a reference to Ancona et al.'s work on X-teams (2002).

Context

We sought to explore this question in the context of an undergraduate engineering program. This program, situated at a primarily undergraduate, public institution, received a National Science Foundation Department-Level Reform grant to undertake the redesign of eighty percent of its

engineering course offerings. From 2005 to 2009, all of the six faculty within the program converted the culture within the department, the pedagogical delivery mode, and the content of curriculum. The faculty treated the transition holistically. That is, they designed the programmatic intervention after consideration of social, cultural, behavioural and experiential contexts of the learning process. To broadly summarize: the culture was shifted toward holistic student development and learning communities; the delivery mode was converted from a traditional lecture and lab format to a more integrated, project-based and problem-based learning format; the content was re-conceived to incorporate focus on engineering design within a context of societal impacts, sustainability, and systems thinking. The emphasis on engineering design was an intentional effort to balance the previously dominant emphasis on the science of analysis.

One of the underlying premises of the present study is that the programmatic changes that occurred are valuable and constitute a positive direction for engineering education. The efficacy of their strategies in terms of deeper learning is largely supported through a range of educational psychology research including social constructivist theories of learning and self-directed learning theory, which has been described elsewhere (L. Vanasupa, Stolk, & Herter, 2009). The program conceived and implemented changes prior to Sheppard et al.'s recent recommendations (Sheppard, Macatangay, Colby, & Sullivan, 2009) for engineering education reform. However, Sheppard et al.'s recommendations are closely aligned with the program's emphasis on authentic professional practice, systems thinking, ethical development and leveraging of learning science in the design of learning experiences. The coincidence of the program's changes and Sheppard et al.'s recommendations serves as strong evidence of the intellectual merit of the reform.

Initial indicators of the programs' success have also been published. These include accelerated student development relative to quasi-control peer groups in the areas of moral development (L. Vanasupa, Harding, Hughes, & Stolk, 2008), greater interaction with peers as learning resources, greater confidence in their ability to develop design solutions, greater confidence in project management (L. Vanasupa, Chen, & Stolk, 2008), greater situational intrinsic motivation and greater retention (Linda Vanasupa, Stolk, Harding, & Savage, 2007). They have also published data on student-reported elements of the new curriculum that played a critical role in their shifts in development toward stronger abilities to address open-ended, complex challenges (Savage, Chen, & Vanasupa, 2007).

At this point in time, the program has grown from about 118 undergraduates in 2004 to 188 in 2008 ; this occurred against a national backdrop of declining enrollment in similar programs for the same period of time. Increases in total number of students have been achieved primarily through greater retention of existing students and an influx of students from other engineering and non-engineering majors. The first students to experience the full extent of the programmatic changes are currently juniors. While there are some indicators of advanced cognitive, social and affective development relative to their institutional peers in other engineering programs, neither faculty nor students are convinced that their non-traditional skill set and knowledge will serve them throughout their professional lives.

Methodology and Theoretical Framework:

Ethnography typically works toward creating a framework rather than beginning with one, which is consistent with an inductive research approach. In contrast to an evaluation process, an ethnography looks at what is, as opposed to the comparative measure of what was proposed and what was delivered. It allows a richer exploration of our stated research question compared to methods that propose frameworks *a priori* by addressing the agents of change and their roles in making and sustaining changes against the backdrop of the institutional environment. This phenomenological study examines the lived experience of participating faculty, supplemented by perspectives from outside experts familiar with program and student interviews. Eight individuals (faculty and staff) involved in the programmatic changes were privately interviewed by R. Herter whose background is in ethnography. The interviews provide a first glance at faculty perspectives and begin a casebook, documenting participants' roles in the process of change.

At the time of this writing, the analysis is not complete. Participants are reviewing the transcripts of their interviews for accuracy before the coding process begins. Unlike experimental studies, objectivity and distance from the data are not goals. However, it is Herter's intent to use the grounded theory approach of Glaser and Strauss (Glaser & Strauss, 1967) for coding and categorizing the interviews. The emergent themes from the interviews will be examined in light of a complementary set of student interviews, faculty narratives, and outside evaluator assessments of the program's health. Using Scollon and Scollon's nexus analysis (Scollon & Suzie Wong Scollon, 2007) will focus this ethnography on the actions of participants rather than on language. This will allow for a look at the curricular and pedagogical changes made within the department as well as faculty participation in and response to changes.

In the Four-Player Model, healthy team dynamics occur when there is a balance of two pairs of "players"; each player acts to oppose those of their counterpart player (Deborah Ancona & Isaacs, 2007), and can be pictured as representing the four points of a compass: North=Move; South=Oppose; East=Follow; West=By-stand. The units of analysis are the actions, both team and individual, that result in positive change. Those actions create patterns (Kantor and Lehr, 1975) that take the form of core acts: move, follow, oppose, and by-stand. Each of the acts is linked to the player's positive intentions, but can be perceived negatively and/or can become unhealthy. For example, *move* is intended to provide direction. Healthy versions of *move* provide vision, unhealthy can be controlling. *Oppose*, paired with *move,* seeks to ensure integrity of the outcome. Without the healthy *oppose* actor, teams can adopt direction at the cost of losing something valuable. Unhealthy *opposers* act as nay-sayers. *Follow* ensures completion of the work. Unhealthy versions of *follow* are indecisive. *By-stand* provides the critical input of perspective, such as "I see us pursuing this idea without examining how it aligns with our goals." An unhealthy version of *by-stand* can take the form of apathy.

Findings and Conclusions:

In culture, the department in question sought to shift away from the traditional transactional model of education (the "marketplace" model) to a community-based model (the "learning community" model). The program used proxy measures as evidence of their success, such as comparisons between the test cohorts' self-reported level of interaction with peers as a learning resource compared to that of quasi-control cohorts. As mentioned above, these data are published elsewhere. Student cohorts experiencing the complete transformation have not yet graduated; therefore all data at this point can only inform the evidentiary picture of the program's efficacy, rather than prove success. As additional evidence, the program in question is one of four engineering programs at its institution that has consistently exhibited a net gain of engineering students during the freshmen and sophomore years during the past three years (5 of 51 in the entering cohort). The others are biomedical engineering (8 of 179), industrial engineering (19 of 46) and civil engineering (15 of 162). The program's gain in students represents a sharp contrast to the program's history prior to the grant in which, like the majority of engineering programs at its institution, it was a net exporter of 30-50% of its students during the first two years. A comparison of various persistence rates for the 2007 Freshman cohort is shown in Figure 1 below.

In terms of the organizational conditions that facilitated lasting change, it is first important to mention that the faculty members of the program are themselves questioning some of the particulars of the changes. True to their culture, they are reflecting on the available data and asking if they have achieved their goals. All members express a discomfort with the loss of the information provided by the traditional lecture and test approaches, even in the midst of several indicators of greater student engagement and persistence.

Students, particularly in the first two years of the changes, frequently expressed their anxiety about the changes, pointing to concerns over whether they were getting "the right" education and their feeling of being "guinea pigs" in the study. They also expressed anxiety about the availability of futures classes as more dramatic changes were implemented. The program addressed this by developing a forward-looking brochure of the changes and their underlying learning science theory. They also held tow-hall type meetings with the students to address concerns. We note that these same students, upon graduation in 2009, offered praise for the programmatic changes they experienced, stating that they

were at first very skeptical, but can now see the value in the learning experience, particularly after interviewing for employment.

Underlying the overall changes was a shared commitment to teaching and learning. In fact, the department as a whole consisted of a team of award-winning faculty, which was in a sense, one of the things that made transformation so difficult. All individuals had records of success in an individual-faculty model, where they alone had control of the classroom. The most challenging dimension of the curricular changes was authentic team teaching in a project-based setting for the entire junior engineering course sequence. Pairs of faculty agreed to share the responsibility for a course which met for 12 hours per week. This model of team teaching had both faculty present in the classroom, with a goal of utilizing active modes of teaching at least half of the class time. This goal was largely achieved.
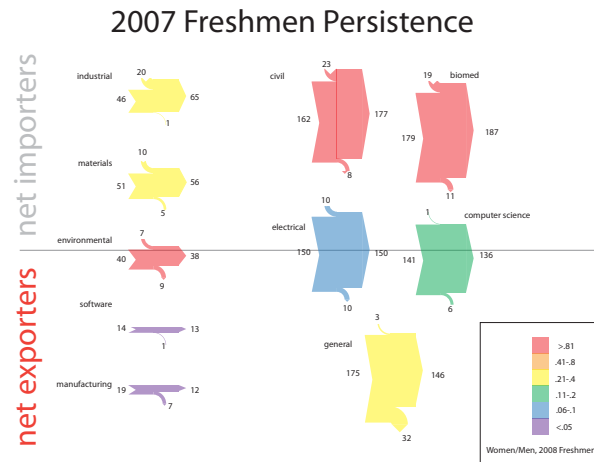

Figure 1: Comparison of persistence rates across programs.

By many measures, the fact that the faculty was able to cohesively implement and sustain such significant programmatic change is a profound achievement in an academic setting. The sense of accomplishment came through in their ownership of the changes,

> "So at the senior level, we kinda dabbled around with – with changing the curriculum, to getting them to think more about being professional engineers, thinking about being responsible to society, and ethics, and the global impact of technology, and the culture of a company, and how that's important." Faculty #5

and an excitement in the transformation opportunity,

> "I mean to have that – that funding to – and that luxury and freedom to actually change the whole curriculum. So when I gave some talks on this, a lot of the responses I would get from colleagues at different places – like, oh, wow, that's great." Faculty #3

One of the things that strongly contributed to the department's advance was that throughout the course of their transformation, actions of individuals were aligned with the Four-Player Model, with each of the individual actors rotating, unawares, through the four core acts: *move, follow, oppose,* and *by-stand.* On the whole, the team exhibited a healthy dynamic, particularly beginning in 2007, when they introduced three new faculty into the group. This constituted a net growth mode for the program, however, only one of the three individuals now remains at the institution. One was a visiting scholar and the other has since left under positive terms. The following comments reflected their view of themselves as a healthy, functional team:

> "When it came time to implement, it was very team-based. You really needed all–everyone on board for this to really work." Faculty #3

> "Faculty–it actually takes a big effort to go work in teams." Faculty #5

> "It's a process that's evolving... I'm not sure we can keep the whole team thing going." Faculty #8

The individuals, however, tended toward their strengths which were often in one of the four acts. For example, the department chair at the time of the grant, was self-described as a *mover,* who is far less skilled in the *oppose* role. Others' view of her as a *mover* was confirmed through several comments:

> "(She) certainly took on the lead on the writing the proposal, and had a lot of experience with writing these kinds of proposals." Faculty #5

> "(She) had a direction and she decided to lead us in that direction. We talked about it as a faculty for a long time. We investigated different things, and we all came on board with our eyes open. I said, this looks like a great – a good thing to do, and she was our leader." Faculty #8

> "So all of our faculty, I think, were pretty on board with wanting to do this, which is probably unusual." Faculty #5

At times, according to the self-described *mover,* her actions took on an unhealthy nature. In the interview, the same *mover* expressed that one of her errors was in being too strong an advocate for her own ideas, and not genuinely inquisitive enough about competing ideas. She reflected that her less-healthy *move* action at times created an atmosphere where all others actions were also less healthy: would-be *opposers* complied rather than asserted their views; *by-standers* became apathetic. She suspects that her past inability to consistently and equally consider the views of others' currently threatens sustained change. She also describes the quality of not seeking the perspective of others as endemic to U.S. engineering culture, captured in the idiom, "Not invented here," and an unfortunate intellectual by-product of the engineering curriculum. Her self-evaluation is not supported by text from the other interviewees. When asked about this, she felt it that it was quite possible that out of concern for her, other interviewees would have hidden negative responses around her leadership. The evidence that the some faculty would like to revert to the traditional lecture indicate that not all are convinced that the changes are better,

> "I think our classes look a lot different now.... I think we're still changing, you know – how much of what to put in. Some people want to go back to the more traditional curriculum – that we had – a lot of content-driven stuff. Other people might want to do more of the, you know – how it fits into society part." Faculty #3

On the other hand, the group began in 2006 to take actions that have induced sustained change. In particular, they began to turn their focus from their internal success to a focus on bigger purposes within their institutional setting. A hallmark of this shift was the interaction and integration of individuals outside their program, college and eventually beyond their institution. This has directly resulted in new research collaborations across all traditional boundaries. It has also influenced the vision and mission of the college of engineering in which the program resides, with the college adopting a vision statement directly aimed at serving humanity. This contrasts with the previous college vision which referred to preparing students for jobs in industry.

The shift in focus of the program's faculty from internal to external interactions is consistent with new models of sustained organizational change described by Ancona et al. in their categorization of X-teams (D. Ancona, et al., 2002). In their model, the teams that have been observed to have the greatest performance advantage are those that exhibit three important tiers of engagement: the core tier, the operational tier and the outer network. Sustained growth is facilitated by the core team membership, envisioned as the core sphere of a series of three concentric spheres, collaborates with those outside in the surrounding operational and outer network tiers. The actions that exhibited shifts toward collaboration were the following: significant use of grant funds to provide release time to faculty external to the program for the purpose of collaborating; development and submittal of proposals for external funding with individuals external to the program; research, teaching, and publication collaborations with external agents, initiation and funding of learning events open to the general campus. While the Four-Player Model dynamics ensured healthy and functional changes, the X-team dynamics provided the seeds for lasting change through involving others outside of the change initiative.

Recommendations and Future Research Plans:

As more programs seek to implement lasting change in engineering education, the Four-Player Model of team dynamics serves as a mental model that can facilitate healthy interactions within the core group. Academic units seeking profound change must begin with a shared vision, but implementing and sustaining change draws on healthy team dynamics as described in the Four-Player Model. Awareness of the model and its use can assist other programs seeking to transform. Furthermore, the X-team approach, which requires awareness of and collaboration with those outside the core team, enables a sustained source of energy and ideas for the change process. Our future research directions include a second round of interviews involving the original faculty and an expanded set of stakeholders that include students.

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