ENGINEERING CURRICULAR CHANGE ACROSS THE FOUNDATION COALITION: POTENTIAL LESSONS FROM QUALITATIVE RESEARCH

Prudence Merton[1], Carolyn Clark[2], Jim Richardson[3], Jeffrey Froyd[4]

Abstract*- The National Science Foundation (NSF) funded the engineering education coalitions program to profoundly change the culture of engineering education. The culture of engineering education encompasses not only the structure of an engineering curriculum and the methods between students and the curriculum, but also the processes through which engineering curricula grow and improve. Therefore, the Foundation Coalition, one of eight engineering education coalitions, has undertaken a qualitative research project that examines* ***processes*** *through which coalition partners have initiated and attempted to sustain curricular change. It is important to emphasize that the focus of the study is the process of curricular change, not content of new curricula. The project is organized as series of six qualitative case studies that examine curricular change at each of the partner institutions. Data for each case study is collected through interviews of approximately twenty key faculty and administrators as well as review of relevant documentation. Each case study identifies critical events and salient issues involved in that process, as well as valuable lessons each institution learned from their experience. Interviews have been conducted at six institutions and case study reports have been prepared for three of the six institutions.*

To date, several themes have emerged from analysis of the data.

- *Each of the institutions initiated curricular improvement by developing a pilot program and offering it to a relatively small number of students. Initiating improvement via pilot programs is well-accepted developmental strategy for engineering artificial systems, but it offers benefits and presents challenges in an educational environment. Expanding from a pilot curriculum to a curriculum for an entire class in a college of engineering also presents challenges in terms of faculty development and facility costs. Pilots should be planned both to study the proposed improvements as well as to support eventual adoption.*
- *Building support for curricular improvement within and beyond the College of Engineering requires significantly more design and effort than anticipated by the change leaders. Building support requires insight into the processes of change. Communication plans that facilitate change require substantial up-front investment in addition to the efforts required to implement the plans.*
- *Soliciting support beyond the College of Engineering requires interaction that is outside normal communication lines.*

Our study demonstrates that effecting major change in engineering curricula is a complex process that requires careful planning and sustained effort for success; however, what qualifies as success also changes from site to site. . It is our hope that the experience of the partners of the Foundation Coalition will be helpful to other engineering programs as they plan for curricular change.

Index Terms ¾ Curriculum change, qualitative research

INTRODUCTION

Engineering curricula continue to evolve. Comparison of the 1960-61 and 2000-01 curricula for many engineering programs shows changes. New courses have been introduced and descriptions of other courses have been significantly modified. However, within the last ten years concerns have been raised in several national reports [1-3] about the pace of change, responsiveness to concerns raised by employers of engineering graduates, and responsiveness to growing diversity of students who enter college, whether diversity is measured along dimensions of gender, ethnicity, learning styles, or learning goals. In response to these and other needs, many schools have introduced and reported curricular innovations. While these reports describe the structure of the new curricula and often present some of the new learning activities and projects, little has been published about the process through which the institution moved from the old curriculum to the new curriculum. Since the study of engineering education encompasses not only the way an engineering curriculum is prepared and shared with students, but also the processes through which engineering curricula grow and improve, the Foundation Coalition offers a "living laboratory" in which processes through which change is accomplished can be studied.

Each of the Foundation Coalition (FC) partners has initiated several curricular changes, some of which are significant in scope and depth. Many of the projects focused on altering the curriculum of an entire year of the four-year

[1] Prudence Merton, Texas A&M University, p-merton@tamu.edu
[2] Carolyn Clark, Texas A&M University, cclark@tamu.edu
[3] Jim Richardson, University of Alabama, Department of Civil Engineering, jrichardson@coe.eng.ua.edu
[4] Jeffrey Froyd, Texas A&M University, Department of Electrical Engineering, Zachry Engineering Center, MS3128, College Station, TX 77843-3128, froyd@ee.tamu.edu

engineering curriculum. In addition to curricular changes, the Foundation Coalition has undertaken a qualitative research project that examines *processes* through which coalition partners have initiated and attempted to sustain curricular change. It is important to emphasize that the focus of the study is the process of curricular change, not content of new curricula. The project is organized as series of six qualitative case studies that examine curricular change at each of the six partner institutions. Data for each case study is collected through interviews of approximately twenty-five key faculty and administrators as well as review of relevant documentation. Each interview is transcribed, coded and entered into a qualitative database. Then, researchers prepare a draft case report that identifies critical events and salient issues involved in the curricular change process, as well as valuable lessons each institution learned from their experience. Researchers return the draft case report to interviewees in order to verify accuracy and solicit additional comments to improve the narrative. To date, interviews have been completed at all six institutions. Three draft case reports have been prepared for the first-year curriculum at the University of Alabama, the engineering science core curriculum at Texas A&M University and the sophomore engineering curriculum at Rose-Hulman Institute of Technology. The study demonstrates that effecting major change in engineering curricula is a complex process that requires careful planning and sustained effort. Hopefully, the experience of the partners of the Foundation Coalition will be helpful to other engineering programs as they plan for curricular change.

PILOT PROGRAMS: BENEFITS AND CHALLENGES

Each of the three institutions initiated curricular improvement by developing a pilot program and offering it to a relatively small number of students. While initiating improvement via pilot programs is well-accepted developmental strategy for engineering artificial systems, it offers benefits and presents challenges in an educational environment. First, an innovative pilot program is much easier to implement than similar innovations across an entire class in a college of engineering. Costs are significantly lower and the task of recruiting faculty members to implement the innovations is much more manageable. Second, the effects of the pilot program are confined. Should the innovations in the pilot program prove to be harmful to students, then only a small fraction of the student body is effected. Despite these advantages of a curriculum pilot, there are also significant challenges.

First, each institution implemented its initial pilot at a scale or in a fashion that would be incompatible or unaffordable for implementation across the entire college. For example, the University of Alabama initiated its pilot first-year curriculum with a single section of 32 students. This new curriculum integrated calculus, engineering, physics and chemistry. Many solid reasons justified the size of the first implementation. Working with only 32 students required the college of engineering to purchase fewer computers and secure a smaller classroom to accommodate the students. Only four faculty, one from each discipline, had to be recruited to teach in the program. If the integrated curriculum pilot "failed" in some fashion, only a small number of students would be impacted. Finally, the pilot was designed for students who were ready to enter first-semester calculus, while about sixty percent of the engineering majors at the University of Alabama start their mathematics before calculus. When Rose-Hulman implemented its sophomore engineering curriculum, the vast majority of the participating students were electrical and computer engineering majors. This was because the Electrical and Computer Engineering (ECE) Department adopted the sophomore engineering curriculum before it had been piloted. So, in one sense, the sophomore engineering curriculum was not piloted at Rose-Hulman. In another sense, the ECE Department piloted the sophomore engineering curriculum for the entire college. Texas A&M University initiated its engineering science core with honor students under an assumption that can be briefly stated as "We're initially working with students who will be able to learn in spite of us." This first pilot for engineering science core curriculum Texas A&M was inititated at the beginning of the 1989-90 academic year, before the Foundation Coalition was initially funded. [4] When Texas A&M initiated a pilot for the second iteration of the engineering science core curriculum in the 1995-96 academic year, student participants were representative of the entire sophomore class. This decision was based on lessons drawn from the experience of the first pilot and questions raised about the validity of assessment results for a sample composed entirely of honors students. For very sound reasons, these schools implemented their initial pilot curricula in a context that prohibited a straightforward expansion.

Second, there were also significant obstacles to sharing the results from the pilot curriculum to the rest of the college. Communication between the implementation team and the entire faculty was constrained. Sometimes this was due to the size of the pilot faculty team relative to the number of engineering faculty. Sometimes it was the difficulty of communicating across departmental boundaries. For example, at the University of Alabama, the engineering faculty member on the implementation team was from the mechanical engineering department. While his presence facilitated communication with the ME department, communication with the other engineering departments was more difficult.

Third, it was unclear what type of assessment data would be accepted as indicative of improved performance. While improved performance on national normed instruments might indicate improved learning, chemical engineering departments, for example, might be more interested in performance in subsequent chemistry and chemical engineering courses. In addition, if assessment data on student performance in the pilot(s) indicated improvement, many questions could be raised. Was the superior performance due to the curricular innovations or could it be accounted for by the enthusiastic, high quality faculty team or by the smaller section sizes or the nature of the honor students?

Fourth, if the college contemplated expansion of the pilot curriculum to the entire college, the pilot did not address all the issues that the expansion might raise. For example, what was the workload for the faculty who taught in the innovative manner employed in the pilot curriculum? How would the college accommodate students who did not fit the constraints used in the pilot curriculum? How would the college accommodate non-honors students or students who started in pre-calculus? Conversely, if the pilot curricula had been required to address all these questions and more before it could be initiated, an innovative approach might never have been tried.

MAINSTREAMING - EXPANSION TO THE ENTIRE COLLEGE

Once the pilot was designed, implemented, assessed, and improved, each college began to ask how some or all of the features of the pilot could be offered to all engineering majors. However, building support for curricular improvement within and beyond the College of Engineering required significantly more design and effort than anticipated by the change leaders. Although procedures were in place at each partner campus to approve/disapprove new courses or delete courses, evaluation and action on curricular changes of the magnitude implemented by the Foundation Coalition partners were not always in place. For example, several partner campuses had initiated curricular changes that involved not only the college of engineering but also colleges outside engineering. (except at Rose-Hulman where there is only one academic dean for the entire school). The complexity of the decision process is illustrated by the remark of one faculty member, "We have found lots of people who can say no, but no one who can say yes."

Designing a new curriculum is an exercise in futility unless implementation is supported at all levels of the institution. Building the required level of support throughout the organization is a complex and challenging issue. The three institutions we've looked at so far have had mixed success. All, however, have learned useful lessons from their experiences.

Communication

Widespread, ongoing communication is often stressed as a critical element for facilitating change. While generally true, this simple prescription fails to provide the details actors in other organizations need to apply the prescription to their situation. To help illustrate the types of communication that help facilitate change, consider the following observations.

One characteristic of the interview transcripts of participants from the same school is the variety of accounts of the change process presented by different interviewees. Each account emphasized different aspects of a large, complex process. Different people have chosen to focus on different elements of the story of change at their institution, choosing those elements that are of greatest relevance and interest to them, as well as using the information that was available to them. Taken together these accounts can be interpreted as contributing to the story of change at each institution. The concept of the change story is consistent with the view of organizational change as sense making. [4] Indeed, storytelling in organizations is "...the preferred sense-making currency of human relationships among internal and external stakeholders." [5] A change story as sense-making story differs from two other possible stories. In one, an energetic pilot team designs, implements and assesses an innovative curriculum and uses positive data to change the curricula across the college of engineering. In the second story, administrators use positive results from an innovative pilot curriculum to drive a curricular change across the college of engineering. Karl Weick describes the story of organizational change as sense making in the following words.

> *"[During significant changes] answers to questions [like Why change? In which directions should change be attempted? Was the change successful? How do we know students are learning more or better?] flow throughout the organization…. Those answers can be characterized on at least three dimensions. [4] They have some degree of generality (answers have degrees of abstractness and may or may not apply to many different kinds of units). They have some degree of accuracy (answers fit the specific circumstances of a specific unit more or less fully). And they have some degree of simplicity (answers are more or less easy to grasp). If these criteria are arrayed around a clock face with generality positioned at 12:00, accuracy at 4:00, and simplicity at 8:00, the dilemma in addressing the question, 'What's the story?' becomes apparent. A story that satisfies any two criteria is least able to satisfy the third." [6]*

From this perspective, the three possible stories: sense making, innovation-driven change, and top-down driven change all have different degrees of generality, accuracy and simplicity.

Further, the concept of organizational change as sense making can be interpreted as the process of competing stories. [7] Each individual receives different stories, synthesizes his/her own story from the competing stories and his/her own individual stories, and tells a new story. As change proceeds, some stories are retold and reinforced while others fade. Viewed from the perspective of competing stories two observations become apparent. First, stories never enter a void. Other stories are already present and new stories will have to compete with existing stories. Therefore, new stories should anticipate resistance; resistance is inevitable since competition with existing stories is inevitable. One response to resistance that is often advocated is communication. In this perspective, the second observation is that communication is simply the introduction of new stories into the mix. To be effective, communication must present stories whose combination of accuracy, simplicity and generality allows it to be retold and reinforced and causes one or more alternate stories to recede.

Assessment Stories as Competing Stories

As an example of competing stories consider the assessment story. As traditionally told, the assessment story is data that is carefully and accurately collected and suggests a positive change in student retention and/or learning, will overwhelm competing stories. In fact, each coalition partner discovered that assessment data are necessary, though not sufficient, to win widespread support for the new curriculum. Assessment data are necessary because once a pilot curriculum is implemented, everyone is asking whether the pilot made an improvement. In response to these questions, answer stories will be generated based on a rumor, on an anecdote provided by a participant in the program, or an anecdote provided by a non-participant. From the sense making perspective, stories will always be generated in response to questions as people attempt to construct meaning from the information available to them. The only question is which stories will persist. The necessity of assessment data is to provide stories based on recognized methodologies and carefully collected data that can compete with the stories constructed from rumors or anecdotes. However, the assessment story may be insufficient because the assessment story, like many scientific explanations, is not simple. There are limitations on the types of research questions that can be formulated and addressed with human subjects, such as students. Further, the generality of the assessment story may be limited because only a limited amount of data can be collected with limited resources. Some faculty members may be interested in data, such as the amount of time required to teach in the pilot curriculum, and this data may not be available. So while the assessment story may be accurate, its lack of simplicity and generality limit its ability to compete with alternative stories. Some of the challenges faced by the assessment story are illustrated by the following account of curricular change at one Foundation Coalition partner, the University of Massachusetts-Dartmouth.

> *"For example, rigorous assessment was shown to be critical to decision-making processes that came after a pilot; however, we noticed that faculty and administrators placed dissimilar weights on assessment data and required different levels of detail. Faculty members placed great value on direct comparisons of learning performance such as would be seen in common exam questions. Often they were suspicious of conclusions drawn by others and wanted data in the least refined form so they could reach their own conclusions. Administrators, on the other hand, wanted conclusions and tended to place emphasis on success rates, retention, and cost of delivery." [8]*

FC partners were not equally successful in generating compelling assessment stories, but those who made assessment a priority early on had an easier time generating a dialogue with faculty that brought the curricular change closer to adoption.

One-Way and Two-Way Communication

Communication can be either one-way or two-way. In one-way communication, new information is added to the story mix without responses being solicited from the audience. Examples of one-way communication are announcements, memos, or newsletters. All one-way communication is intended to keep people informed about what is happening. In two-way communication, the story is altered through the process of dialogue. In general, stories developed through two-way communication are more effective, i.e., will tend to persist longer, since participants are more likely to accept and retell stories that they have helped create. However, these “two-way” stories require more effort since input from the participants must be incorporated into the final narrative. Input that is solicited and then ignored quickly condemns the supposed two-way story or in the words of a common maxim, "Don't ask the question if you don't want the answer." In addition, incorporating input may require construction of revised story that is substantially different from the initial story. In the case of curricula, asking for feedback and suggestions about a pilot curriculum may require a revised curriculum that is substantially different from the pilot curriculum in order to respond to the feedback. Then, concerns may be raised that the pilot is being "watered down". An effective communication plan must balance the combination of one-way and two-way stories.

In the process of moving from a pilot curriculum to across-the-college implementation, almost every partner relied upon two-way stories and these two-way stories were critical to successfully mainstreaming the pilot curriculum. At the University of Alabama, the Dean of Engineering appointed a task force to evaluate the pilot first-year curriculum and prepare a recommendation for the College. Faculty members selected for the task force were respected by their colleagues and widely viewed as objective arbiters with respect to information about the first-year curriculum. Several interviewees mentioned the task force as a key step in the curricular change process. However, the task force initiated conversations principally within the College of Engineering. Input from faculty members in the College of Arts and Letters, e.g., chemists, mathematicians, and physicists, was not solicited. So while operation of the task force created a story that persisted across the College of Engineering, faculty members in the College of Arts and

Letters received a different story. At Texas A&M, two-way stories were initiated in attempts to identify sources of resistance and respond to concerns expressed by these sources. [9] Responding to resistance required flexibility and the willingness to make adjustments while striving to adhere to the underlying principles of the innovation. However, flexibility by associate deans and department heads was often viewed as compromise for the sake of mainstream adoption by many of the faculty members who developed the pilot curriculum. At Rose-Hulman Institute of Technology, faculty members who were designing the curriculum initiated meetings with each department on campus to solicit their feedback on the initial draft of the curriculum. Then, they modified the design in response to consistently expressed concerns that were extracted from the feedback. This consistent two-way communication contributed to the outright adoption of the program by one department without a pilot. Based on the experience of the Foundation Coalition, mainstream adoption will require one or more two-way stories and alteration of the pilot curriculum may be anticipated.

Multiple Constituencies

Support must come from multiple constituencies. Engineering faculty as well as department heads and deans must see the value of curricular change and be committed to the principles of the new curriculum. Students have to see the new program as valuable. Department heads and deans of other colleges providing courses for engineering students, e.g., physics, math, chemistry, English, need to have incentives for participation in the curriculum. The university community, especially provosts and presidents, must see benefits of a new engineering curriculum for the entire university. And industry should believe that their future employees will be better prepared to meet the challenges that employers will confront.

Political Strategies

It is also important to choose influential people to be involved in the change process. At all three institutions that meant selecting faculty for leadership in the new program who were not only good teachers but also well regarded by their peers. One institution purposefully included a few notable researchers to give greater legitimacy to the new curriculum. In working with colleges outside engineering, they learned that they needed to carefully identify the influential faculty in the relevant departments. In one case, the early involvement of willing faculty member who did not command the respect of colleagues in a non-engineering department meant that the department did not fully support the pilot curriculum and has not supported mainstream implementation to date. In this case it was a mistake from which they have not yet recovered.

All three institutions learned the importance of political strategizing, often from their mistakes. At UA, for example, there was some support from the dean and the provost, but for the most part it was a bottom-up effort, being pushed by the faculty who developed the curriculum. This was not an effective strategy. RHIT and TAMU learned to gain the support of people in leadership at all levels. All agree that the earlier this is accomplished, the better. Building support also implies soliciting input from these people and being willing to incorporate it in some way into the curricular design.

CONCLUSIONS

Although study of curricular change processes at the six institutions in the Foundation Coalition through the review of over 120 interview transcripts have indicated that major curricular change is a complex process, it does appear possible to abstract a set of observations that other institutions might find helpful. First, using a pilot curriculum as a step to college-wide implementation offers benefits comparable to constructing a prototype when designing an artifact. However, human elements and the complexity of curricular design generate a set of challenges that may be unique to social systems.

- Considerable thought and energy is required to maintain communication between the team tasked with implementing the pilot curriculum and the rest of the college. Senge et. al. [10] indicate that pilot program leaders will face the challenge of being perceived as being too isolated and arrogant in the process of sustaining and expanding the change effort.
- Assessment data, collected with limited resources, is unable to address all the questions that could be asked.
- Pilot curricula, designed for a limited student audience, do not necessarily indicate how a college-wide curriculum can respond to a more diverse student body.

Therefore, the challenge of designing a pilot curricula that will be able to address the wide variety of questions that could be demanded of it is daunting.

The process of moving from a pilot curriculum to a curriculum that responds to the diverse needs of the student body for an entire college is very involved. Important elements include communication where the importance of competing stories is woven into the communication plan, support from multiple constituencies, and the necessity of political strategies.

REFERENCES

[1] "The Green Report: Engineering Education for a Changing World," Report of a Joint Project of the ASEE Engineering Deans Council and Corporate Roundtable, American Society for Engineering Educators, 1994

[2] "Restructuring Engineering Education: A Focus on Change," Report of an NSF Workshop, NSF 95-65, National Science Foundation, 1995

[3] "Engineering Education: Designing an Adaptive System," Report of the NRC Board on Engineering Education, Washington, D.C.: National Academy Press, 1995

[4] Fournier-Bonilla, Sheila D., Karan Watson, César Malavé, and Jeffrey Froyd, "Managing Curricula Change in Engineering at Texas A&M University," *International Journal of Engineering Education*, (17)1, 2001

[5] Weick, Karl E., *Sensemaking in Organizations (Foundations for Organizational Science)*, Sage Publications, 1995

[6] Boje, D.M. The storytelling organization: A study of story performance in an office-supply firm. *Administrative Science Quarterly, 36(3):106-126)*

[7] Kleiner, Art and George Roth, *Oil Change: Perspectives on Corporate Transformation*, New York: Oxford University Press, 2000, pp. 201-202 in Oil Change Learning History

[8] Laskin, Emma and Howard E. Gardner, *Leading Minds: An Anatomy of Leadership*, Basic Books, 1996

[9] N. A. Pendergrass, Raymond N. Laoulache and Paul J. Fortier, "Mainstreaming an Innovative 31-Credit Curriculum for First-Year Engineering Majors," *Proceedings, 1999 Frontiers in Engineering Conference*, 10-13 November 1999, Puerto Rico

[10] Fournier-Bonilla, S., Watson, K., Malavé, C., Froyd, J. "Managing Curricula Change in Engineering at Texas A&M University," *International Journal of Engineering Education*, to appear

[11] Senge, Peter M., Art Kleiner, Charlotte Roberts, George Roth, Rick Ross, Bryan Smith, *The Dance of Change: The Challenges to Sustaining Momentum in Learning Organizations*, Doubleday, 1999