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Managing Curricula Change in Engineering at Texas A&M University*

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Growth and change have characterized American higher education for a long time [1]. Ideas for academic change have been proposed by nearly everyone, from students and faculty members to deans and university presidents, responded to by a wide array of decision-makers, and implemented within diverse administrative arrangements. Since change is omnipresent, it is important to recognize its impact on overall organizational performance. By understanding change and increasing their capacity to create their own futures, universities can continue to equip their students for the rapidly changing, highly competitive environments in which they will practice. The paper describes a change management model developed and used by the Dwight Look College of Engineering at Texas A&M University during the implementation phase of their new engineering curricula. As applications of the model the paper offers two case studies of significant curriculum change: first-year and sophomore curriculum restructuring. The change model synthesizes earlier change management models and our experience with the two major curriculum changes. Our case studies and curriculum change model may help other institutions undertaking significant curriculum change.

CHANGE MANAGEMENT IN BUSINESS AND EDUCATION

Change management in business

IN TODAY'S changing environment, ignoring the need for change places an organization at peril. To combat forces ranging from competition to technological advances, organizations soon realize they must initiate rather than respond to change. This means determining the scope, pace, and depth of the adjustments, and developing a strategic approach to change management. According to Recardo et al., organizations, in order to embrace change, will need to become **learning organizations**—entities that have demonstrated the ability to recognize changes in their environments, respond to these changes effectively, and understand their own capabilities relative to marketplace demands [2]. By understanding and embracing change, businesses can gain competitive advantages over their competitors who resist change.

Change may be viewed through two sets of glasses. First, change may be perceived as 'culture-dependent' [3]. The frustration of dealing with change is mostly cultural—partly because of the organization's remarkable capacity to resist change, and partly because the kind of change being sought is so much more radical and uncomfortable than anything required by a shift in strategy or process or corporate structure [3]. Hence, it is suggested that for change to occur, a new **organizational culture** embracing change must be adopted. Culture is then defined according to four vital signs that are common to every organization:

- power
- identity
- conflict
- learning.

Once the vital signs are identified, organizations can then determine the interventions necessary to make the 'new' move a success. Based on these signs, three interventions that will restore companies to vital agility and keep them in good health may be adopted. These interventions are:

- *incorporating employees* when dealing with business challenges;
- *leading from a different place* to maintain employee involvement;
- *instilling mental disciplines* to make people behave differently during the changing process and have them sustain this new behavior into the future [3].

Through the second set of glasses, change may be viewed as a shift in **paradigms.** Camillus and Beall propose a 'transformational paradigm', which is proactive and well-suited to bridge 'discontinuities' [4]. This transformational paradigm goes beyond predicting and adapting to actually creating the future. It forgets about competition and works in a collaboration context. In addition, it requires conventional wisdom when it comes to understanding strategy and the nature of changes affecting organizations and their environment.

There are many different thoughts about change but there is common ground on the importance of recognizing it and adapting to it. Resistance is

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inevitable regardless of the type of organization we refer to—whether it is product- or service-oriented. Resistance to change will always be a factor that, if ignored, can throw an organization into self-destruction. As stated by Morrison [5], organizations that stay in the first curve (i.e., traditional business) without learning to adapt and/or move to the second curve (i.e., innovation) have a much greater risk of losing their best customers. Organizations riding that second curve are the ones that continue to grow and thrive.

Change management in higher education

In higher education, the concept of change is equated to improvement and innovation. Institutions that stress change and innovation are regarded as viable, effective, and responsive [6]. However, social dynamics within the academic environment can make goal attainment invisible.

For the longest time, growth and change have characterized American higher education [1]. Ideas for academic change have been proposed by nearly everyone, from students and faculty members to deans and university presidents, responded to by a wide array of decision-makers, and implemented within diverse administrative arrangements. Looking ahead, it is likely that change will continue to be a persistent feature of higher education. Increasing costs, greater heterogeneity among students, and cumulative changes in knowledge will affect the shape and size of institutions. Academic programs are becoming more learner-centered, more efficient in the use of resources, more effective in articulating objectives and in assessing their attainment, and more explicit in their links to career applications. A major difficulty effecting such changes is brought up by the same drawbacks affecting change in all types of organizations, namely, **resistance.** Describing experiences in making large-scale curriculum changes and extracting lessons from the experiences may be helpful to other institutions contemplating curriculum changes of a similar scale.

In the next section, a series of generic change management models used in business and education will be presented. Then, history of significant changes in the sophomore and first-year engineering curricula will be related in later sections to illustrate the types of challenges that occurred and the responses to these changes. Abstracting from these implementation experiences a new change model for curriculum change at Texas A&M will finally be presented.

EXISTING CHANGE MANAGEMENT MODELS

The idea of using models to depict concepts and ideas is not new. Models have been used for many years to present success stories, lessons learned, or even the latest thinking. They are tools, which are often used to clarify and simplify complex theories. Models can provide a useful structure for vague concepts because they focus on the main elements, ignoring less important details.

For the reasons stated above, models, which focus on the detailed practices in change management, have been considered important. To compete

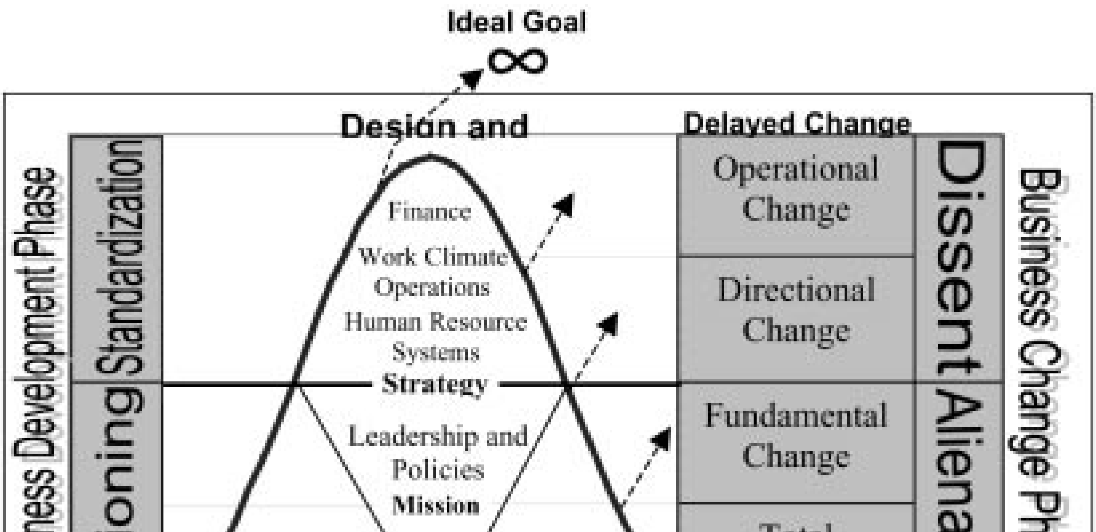

Fig. 1. The Business Change Cycle.

effectively in a changing environment, a thoughtful, ongoing organization-wide analysis must be made, both of internal capabilities as well as of external change forces. In educational settings, university faculty and higher education reform groups have also worked to change general education on university campuses throughout the last several decades [7]. It is a known fact that for organizations to survive change, a methodological approach must be followed. Following are several models that have helped organizations manage change, both in general industry and in higher education.

An interesting methodology is presented by Want [8]. His model is presented as a **Business Change Cycle** for organizations to effectively anticipate and respond to change with unique strategies that are appropriate to the marketplace and beneficial to the business. This model presents change as an opportunity for developing the business and adding value to its products and/or services, as well as for growing the business. The Business Change Cycle represents a natural flow that every organization encounters. It plots business functioning along axes of performance (i.e., growth and development), operational and cultural functioning, and the impact of change on the organization (Fig. 1). In addition, it provides a constant developmental framework for evaluating the business organization, regardless of where the organization is currently situated in its Business Change Cycle. This allows companies to tailor change initiatives or turnaround strategies to fit current change conditions.

Another change management model [9] focuses on five key success factors thought to be the drivers for successful change:

- commitment
- social and cultural issues
- tools
- methodology and interactions
- communication.

According to Clarke and Garside [9], the use of this model can provide any organization with a structured and measurable method for improving the way in which it manages change. The model provides:

- exposure to best practices in change management;
- a measurable way for organizations to audit and benchmark themselves;
- a means for identifying priority areas or where to target improvements;
- a tool which could contribute towards improving corporate learning by encouraging sharing of information across sites .

Not much has been published in the higher education sector with regards to change management models. Cummings et al. [7] present an interesting approach that provides a descriptive analysis of processes used and the problems encountered when implementing general education reform at a land-grant university. The model is based on three aspects of curriculum change:

1. The process used to develop a proposed general education curriculum.
2. The processes used to gather information from and disseminate information about general education to the university as a whole.
3. The overall process in terms of the involvement of the academic colleges.

Its general focus is on 'student outcomes' that are based on surveys from various constituent groups and discussions with deans and faculty members. These data then helps generate a set of alternative 'curriculum models' that are then open for discussion (involving students, faculty, and staff) to help build a final distribution model that serves as a basis for ongoing discourse within the general education reform process.

DESIRED CURRICULUM CHANGES

From an exploration of change and change management concepts for arbitrary organizations, we shift our focus to a specific college of engineering where it is being recognized that the complexity of engineered systems is growing at increasing rates [10].

> '. . . complexity makes modern technology fundamentally different from anything that has gone before. Large, complex systems such as commercial airliners, modern microprocessors, digital communication networks and nuclear power plants require large, complex organizations for their design, construction, and operation.'

Therefore, engineering graduates must be able to both design and manufacture complex artificial systems and function adroitly within their associated complex human organizations.

Based on its perceptions of changing engineering practice, Texas A&M University has been restructuring its curricula to prepare all of its engineering graduates to excel in complex, rapidly shifting socio-technological environments. College-wide curriculum restructuring requires moving curricular change from a novelty to a norm: where faculty, students, and future employers participate and interact in the learning experience; where learning experiences facilitate consistently high quality graduates; and where adaptations and updates are made responsively to increase quality.

To date, Texas A&M has focused on using active and collaborative learning, student teams, curricular integration across courses, and technology in the classroom to allow more realistic problems and projects to be the tools for the students to learn the fundamental concepts of engineering. Efforts have, so far, concentrated on the first two years of the engineering curricula. The courses involved have included first-year engineering, engineering science, calculus, differential equations, physics, chemistry, composition, and technical writing. While making these changes, assessment, evaluation and improvement of the students' learning and retention have played integral parts. One of the major accomplishments in curricular reform efforts at Texas A&M has been the development and initial documentation of the processes that occur on campus.

The move to institutionalize these reforms is a significant task considering both the size of the undergraduate program (approximately 8000 students) and the effort required to get faculty across several colleges to adopt new courses. Since the curricular changes also call for significant behavioral changes in the classroom for many faculty members, commitment to this vision by departmental faculty and administrators is a noteworthy accomplishment. Our experiences in managing curriculum changes have led us to develop a model for navigating change in curricular processes.

Before we present the model, we will describe two cases of significant curriculum change at Texas A&M. Using the case studies as concrete examples, we describe our model for curriculum change management that synthesizes earlier change management models and our experience with two major curriculum changes. Our case studies and curriculum change model may help other institutions undertaking significant curriculum change.

THE SECOND-YEAR ENGINEERING CURRICULUM

Curiously, curricular changes in the second-year of the engineering curricula at Texas A&M began in 1988, before changes in first-year curricula. Some faculty noted that the students enrolled in the engineering science courses, taken by all engineering majors, did not understand why they were taking these courses nor did they see relationships between the course topics in many cases. Further, feedback from industry representatives about our graduates emphasized the importance of solid conceptual understanding and the ability to work with engineers from all disciplines. Therefore, a small, interdisciplinary faculty team took material from the first courses in statics, dynamics, thermodynamics, fluid dynamics, materials, strengths of materials, and circuits and explored ways to make these courses more connected and useful to students regardless of their major. Ultimately, the faculty team integrated the material from the different engineering disciplines into a common framework.

Second-year fc pilot programs

In 1988 the faculty team began planning a curriculum that integrated engineering sciences around a set of common themes. Themes included identification of a system, its inputs, its outputs and identification of quantities such as mass, charge, linear momentum, or energy whose amounts are constant in the universe. Students then developed models for particular physical examples based on the conserved quantities and specific constituent relationships. Faculty organized the new approach to engineering science into four 4-hour semester courses [11].

Students who took these courses were able to see and value connections and similarities among the basic engineering science courses. They performed as well as traditional students on exams with questions like those found on the Fundamentals of Engineering (FE) examination for engineers-in-training. This exam is developed and administered by the National Council of Examiners for Engineering and Surveying (NCEES). The only performance criticism of the students in these integrated courses was that they sometimes did not do rote problems as quickly as the other students did, partly because they approached the problems from more fundamental levels and missed some shortcuts [12]. On the other hand they retained the information, especially the information used more in other majors, much more effectively. Further, they were much more competent at solving complex or open-ended problems, especially new problems that did not closely resemble problems they had seen before.

Table 1 shows the four courses and what they

Table 1. Piloted second-year curriculum vs. traditional curriculum (1991–1994)

New Courses	For EEs	For MEs	For CEs
Conservation of basic properties (4)	Statics (3)	Statics (3)	Statics (3)
Conservation of macro-properties (4)	Free elective (3)	Materials (3)	Materials (3)
Conservation in systems and fields (4)	Thermodyn. (3) Circuits (4)	Thermodyn. (3) Circuits (4)	Thermodyn. (3) Circuits (4)
Conservation of micro-properties (4)	Free elective (3)	Strength of Materials (3)	Strength of Materials (3)
Total 16 hours	Total 16 hours	Total 16 hours	Total 16 hours

Table 2. Piloted second-year curriculum (1995–96)

	Fall semester	Spring semester
Integrated courses	Mechanical Science (3 hrs.)	Material Science (3 hrs.)
	Thermal Science (3 hrs.)	Systems & Flow (3 hrs.)
	Physics (3 hrs.)	Electrical Science (3 hrs.)
	Calculus (3 hrs.)	Differential Equations (3 hrs.)
	Technical Writing (1 hr.)	Technical Writing (1 hr.)
Elective courses	Humanities (3 hrs.)	Social Science (3 hrs.)

replaced in the traditional curricula of some of the majors.

The main criticism of the integrated courses was that students had to take all sixteen hours to obtain credit for the traditional courses listed in Table 1. Faculty members also felt that the courses were very challenging to teach because a faculty member would be teaching problems from all of the engineering fields. Nonetheless, the Aerospace, Agricultural, and Civil Engineering programs required the new courses for their degree programs. However, in an effort to lower resistance from faculty in the larger engineering departments, we began to explore other course structures (Table 2) in 1994. Alternative course structures would provide more flexibility and accommodate all engineering programs.

In order to improve the delivery of the courses, we moved to incorporate collaborative learning and technology-enabled learning. The model piloted in 1995–96 maintained the integration and framework, but structured the material in five 3–hour courses. Classrooms were renovated to facilitate teams of four, and to provide a laptop computer for every two students during class. In addition, integration with math and with English was explored [13, 14].

Adopted second-year curriculum

In the fall of 1997 every engineering department voted to adopt the second-year curriculum for all students. However, there was flexibility in the number of courses adopted. Table 3 illustrates which courses each department required for students in their majors. All courses are currently taught in a room where the students have access to laptop computers and can easily work in teams. Faculty members are trained to use the systems and conservation framework in the courses. The Calculus III course fits with the Calculus I and II courses that were being restructured for the first-year program below. We did not adopt technical writing as piloted since the English Department could not teach one-hour courses on a cost-effective basis.

Table 3. Adopted second-year curriculum (1997)

Course	Programs adopting
Mechanical Sciences (3)	All programs
Thermal Sciences (3)	All programs except ChE
Material Sciences (3)	All programs except EE , CompE
Systems and Flow (3)	All programs except ChE, EE, CompE, IE
Electrical Sciences* (3)	All programs except BioE, EE, CompE
Early Vector Calculus 3 (3)	All programs

* A new course, which uses the same pedagogy as these courses, has been developed for electrical systems for the BioE, EE, and CompE majors.
Engineering programs include Aerospace, Agricultural, Biological Systems, Biomedical, Chemical, Civil, Computer, Electrical, Industrial, Mechanical, Nuclear, Ocean, Petroleum, and Radiological Health.

Curriculum change management for the second-year curriculum

Because resistance to changing the second-year curricula was greater than the resistance to changing the first-year curriculum at Texas A&M, we made the changes in the second-year first. Some of the reasons for greater resistance to changing the second-year curricula at Texas A&M are:

1. While the first-year curricula involved more colleges and departments than the second-year curricula, engineering majors typically represent around 25% of the campus enrollment in either freshman or sophomore non-engineering classes. Therefore, the many departments teaching introductory courses for engineering consider it to be an important service component. Within administrative and economic bounds programs servicing engineering students are open to ideas and discussions about the needs unique to engineering.
2. In engineering curricula, engineering faculty build junior and senior courses upon the foundation in the engineering sciences. Therefore, the intellectual arguments for changing these courses must be strong.
3. More engineering faculty, as individuals, are impacted by changes to the second-year curricula of engineering.
4. Administrators in engineering have more student credit-hours at risk in the second-year than in the first-year of the curricula. (Student credit-hours help to justify faculty positions.)

The resistance to changes in the engineering science core courses is illustrated in Fig. 2. The relative value of the momentum to change and the resistance to change are qualitative measures that have been translated to the representation shown. These measures included attitudes of the faculty, students, and administrators in the college, adoption of the courses by departments, voluntary

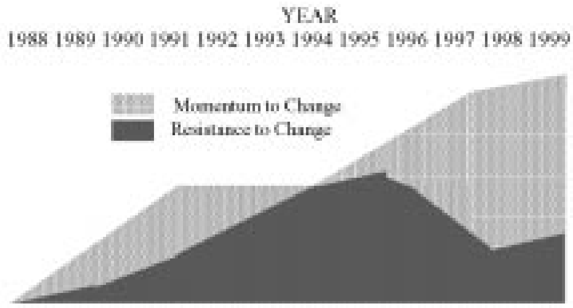

Fig. 2. Relative resistance to momentum to change: second-year curriculum.

enrollment by students, faculty assignment to teach courses, and administrative support for the changes. Table 4 gives some of the events that were used to assess the change situation.

Figure 2 and Table 4 document the fact that the resistance to any changes in the second-year curriculum nearly overcame the momentum to change the curriculum in 1994. What is not clear in Fig. 2 and Table 4 is that both the increase in momentum for change and the decrease in resistance to change can be attributed to inattention to the reasons for resistance for changing. In 1993, some of the primary reasons for resisting change were assumed to be the lack of published or readily available results from the pilot efforts and/or the availability of course materials. However, after more analysis, the following reasons were found to be dominating the resistance:

- The option that a student must take all or none of the 16 hours in the four courses was unduly inflexible for most majors.
- The belief that the new courses were much harder to take or to teach was widespread, especially among academic advisors.
- The perception that the courses did not offer enough advantages to merit the effort it would take to change.
- The concern about who would be burdened with supplying instructors for the courses.
- The lack of clarity about who was even the target for enrollment in the new curriculum.
- The devaluation of the 'champions' efforts to promote the courses, especially because they had textbooks to sell now.

With these major resistances firmly entrenched, the advocates for change began a new strategy for managing the change in 1994. The main points of the new strategy included:

1. Forming a new team to explore and propose even greater pedagogical advantages to

Table 4. Relative momentum and resistance for change of the second-year curriculum

Year	Momentum for change	Rel. Max.	Resistance to change	Rel. Max.
1988	Received NSF funds	1.5	Concerns about when external funds end, and about need for the change.	0.5
1989	Run first Pilot with Honors students	3.0	Perception that it's an honors program for some majors.	1.0
1990	Good results from previous pilot; Run next pilot with regular students	4.0	Prior results devalued because honors. Poor interface with academic advisors.	1.5
1991	Draft of new texts developed	5.0	Texts are not as polished as existing books.	2.0
1992	Optional sequence for all majors, and required for Aerospace. New faculty trained to teach sequence.	5.0	The faculty believe it's very hard set of courses to teach and some majors do not want the entire sequence.	3.0
1993	Agricultural engineering adopts as required courses. Funds from NSF are complete (TAMU does not use NSF FC funds for second-year developments)	5.0	Perception that the program has been unresponsive and inflexible.	4.0
1994	Civil engineering adopts as required courses. New team formed to evaluate the second-year and propose pedagogical changes.	5.25	New team explores the format of the courses and other pedagogies (active and collaborative learning, and technology).	5.0
1995	New classroom available for new courses. Faculty and administrators given timeline for deciding and voting on new courses.	6.0	Results are shared with faculty who have traditionally taught the required courses. New formats with flexible entries and exits are planned.	5.25
1996	New administrative structure for courses with new pedagogy. Two new classrooms renovated for courses. Faculty and administrators vote to adopt new courses.	7.0	Evaluation team to evaluate and present options for the college. Administrative loads and other issues are considered.	5.25
1997	Aerospace, Agricultural, Civil, Computer, Electrical, Industrial, Ocean, Petroleum—require new courses. Many new faculty in new courses.	8.0	New coordinators are selected to maintain the quality of content and pedagogy in courses. They train new faculty.	4.5
1998	Biomedical, Chemical, Mechanical, Nuclear, Radiological Health require new courses. More new faculty in courses.	8.5	Administrative logistics are ironed out as reach full implementation.	2.5
1999	Evaluation and interfacing of new courses with the rest of the curricula.	9.0	Some upper level faculty raise concerns about skills.	3.0

changing the curriculum. (This team was not composed of members who had authored textbooks).
2. Charging the new team to investigate more flexibility in the options in the new curricula.
3. Assessing the best approaches to gain the value of the new curricular approaches without overburdening the faculty or students.
4. Clearly presenting the administrative costs and tradeoffs for the new curriculum.
5. Targeting all majors in engineering and establishing a timeline for decision for any new options by 1996.

With these efforts, many of the people who had been resistant became more open to the possibility of changing, however, many faculty who had not previously perceived the new curriculum as being a concern of theirs, now became concerned. Thus, 1995 did not see a reduction in resistance, but there was a shift in the causes of the resistance. As the team aspiring for institutionalization of the new pedagogical approaches continued to attend to multiple sources of resistance, significant reduction in the resistance was finally perceived in 1996. By the time of the vote for adoption, in mid-1996, the momentum for change was significantly greater than the resistance. With a positive vote for change, many more faculty, who had been 'on the fence', became involved and contributed to wider implementation efforts. As more faculty gained interest and participation in the courses, the commitment to change grew.

Currently, all or some of the courses are required for all engineering majors. Over forty faculty members, out of approximately 300 in the college, have been engaged in teaching the new courses. We are currently focused on the growth in resistance to the new courses that arose in 1998 and 1999. However, our investigation of this resistance indicates that as the large number of students now completing the courses enter upper-level courses, even more faculty become more interested, and by default participatory in the new curriculum.

We are attending to the need of the faculty to better understand the advantages and disadvantages in the development of skills and knowledge for students who came through the new curriculum. In addition, we are providing workshops on demand, expanding the number of workshop leaders, and facilitating dialogs to help the upper-level faculty members to take advantage of the skills and knowledge developed in the new curriculum. Departmental curriculum committees have become more proactive in the processes of curriculum change. Furthermore, more faculty members are recognizing the value of teaching innovation and are writing proposals to support curriculum innovation. All these changes are creating more pedagogical changes in the upper-level courses.

THE FIRST-YEAR ENGINEERING CURRICULUM

In 1990, the National Science Foundation (NSF) imagined changing the culture of engineering education. The result of that vision was the Engineering Education Coalitions Program, whose three goals reflected its ambitious, far-reaching nature, namely to:

1. Design, implement, evaluate, and disseminate new structures and approaches affecting all aspects of undergraduate engineering education.
2. Generate a dramatic increase in both the quality of engineering education and the number of degrees awarded in engineering, including those to women and underrepresented minorities.
3. Establish new linkages among all types of US engineering institutions, large and small.

In the fall of 1993, Texas A&M partnered with six other institutions to form the Foundation Coalition (FC) [15, 16], the fifth engineering education coalition supported by the National Science Foundation. In 1993, the other six partners were Arizona State University, Maricopa Community College District, Rose-Hulman Institute of Technology, Texas Woman's University, Texas A&M University-Kingsville, and the University of Alabama.

FC partners proposed to accomplish the goals of the Coalitions program through four guiding principles in restructuring their curricula:

1. Helping students build links between topics, across the curriculum, and to career goals.
2. Encouraging and sustaining development of teams and learning communities involving faculty, students, and industry inside and outside the classroom.
3. Improving learning through routine student use of computing hardware and software.
4. Continuous improvement through assessment, evaluation, and action.

Further, Foundation Coalition partners agreed to build upon their existing innovations including the second-year engineering curriculum at Texas A&M.

At the initiation of the FC, the College of Engineering at Texas A&M had a common first-year curriculum for all engineering programs. However, several departments were not satisfied with the curriculum. In general, engineering departments had become concerned about the declining financial support for the instruction of the freshman problem solving and programming course. Further, engineering and non-engineering departments had increasing concerns about which first-year course was responsible for which topics. Some of the more specific concerns with the freshman curriculum were:

- ENGL 104 (freshman rhetoric and composition

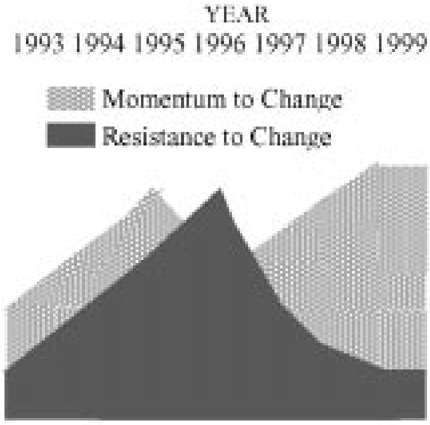

Fig. 3. Relative resistance to momentum to change: first-year curriculum.

course) did not provide enough seats for all entering first-year students.

- Most engineering students were required to take CHEM 101 (first semester chemistry but not a prerequisite for second semester) before CHEM 102.
- Some engineering faculty members were not certain of the value of ENGR 109 (a problem solving and programming course).
- Several engineering programs were inquiring about the need for ENDG 105 (a design graphics course).
- Only 50–60% of incoming first-year students placed into MATH 151 (first semester of engineering calculus), while 35–40% placed in a lower course.
- Student retention of information from PHYS 218 (mechanics) was not adequate.

To respond to these concerns and improve first-year learning experiences, Texas A&M, as part of its participation in the FC, piloted a new freshman integrated curriculum in the fall of 1994. A team of faculty members from engineering, mathematics, physics, English, and chemistry designed the new curriculum. The first offering of the FC first-year curriculum generated a tremendous amount of energy and enthusiasm among students and instructors. Initial assessment and evaluation data showed that students participating in the FC outperformed the comparison group in every assessed category [17]. Due to this perceived success of the pilot, there was a tremendous momentum for change. However, resistance to the FC curriculum began to appear (Fig. 3). Table 5 summarizes the events used to assess the change situation. Some of the factors generating the resistance were:

- The size of the piloted sections was questioned. The original pilot was delivered in two sections of 50 students each. This section size was not acceptable to any of the departments. All administrators questioned the motivation for the small section size.
- The physics instructor thought that dividing the four hours of PHYS 218 into two semesters was not a good idea. Students seemed to pay more attention to the MATH 151 course because it was a four-hour course.
- Physics laboratories were done in-class using a 'studio-like' approach. The main concerns about this approach focused on the cost to deliver laboratories using this format to larger sections.
- The availability of opportunities to students to 'leave' the integrated curriculum without major penalties. An intervention program was offered to students who were failing in some of the subjects [18] but the cost and energy required to run this program was also questioned.
- The lack of participation by the pre-calculus, honor students, and students who placed out of courses in the integrated program.
- Faculty and administrators were very concerned about the 'platform independence' of the piloted program. The impression at this point was that those 'zealots' involved in the development and initial offering of the integrated curriculum were the only faculty willing and able to teach in such a high-commitment program.

Table 5. Relative momentum and resistance for change of the first-year curriculum

Year	Momentum for change	Rel. Max.	Resistance to change	Rel. Max.
1993	NSF Foundation Coalition is funded.	5.0	Faculty is concerned about the feasibility of an integrated curriculum in a large institution.	2.0
1994	Pilot with two sections of 50 students is offered. Assessment and evaluation program is implemented.	7.0	Students and faculty express concerns about time commitment requirements.	4.0
1995	Pilot sections expanded to 100 students. Additional classrooms are renovated.	9.0	Change agents collect data on resistance from broader constituency.	7.0
1996	A Pre-calculus program model is piloted.	5.0	Broader constituency develops institutionalization plan.	9.0
1997	Pre-calculus program is piloted as part of the integrated first-year.	7.0	Academic departments vote for adoption of FC models into the freshman year.	5.0
1998	Integrated first-year curriculum is implemented as part of the Inclusive Learning Communities.	9.0	Team teaching is implemented for new first-year engineering courses.	3.0
1999	The concept of Inclusive Learning Communities is better understood by the teaching faculty. More industry gets involved.	10.0	Team revises engineering courses. Institutionalization team is formed with members from math, science, and engineering.	2.0

The FC first-year curriculum was offered for the second time in the 1995–1996 academic year. Faculty changed the second offering to respond to concerns about the first offering. Two three-hour physics courses (electricity and magnetism was brought to the first year) were included in the first year, and a new chemistry course was included in the curriculum. The size of the pilot was also doubled to 100 students per section so that the pilot section size was similar to the standard section size. The size of the faculty team was also doubled not only to accommodate the increase in section size but also to reach out to more faculty in each of the academic departments. The momentum for change achieved the highest point due to the fact that the assessment results showed that the FC cohort outperformed the comparison cohort in all categories—and this time with a more realistic section size. The resistance for change was even lower than the previous year especially after the announcement of a pre-calculus program planned to begin in the following year [19].

After 1995–96, concerns about the FC curriculum included:

1. The reduction of PHYS 218 and PHYS 208 material from two four-hour courses to two three-hour courses.
2. The ability of first-year students to handle this load of sciences, mathematics, and engineering courses.
3. Opportunities for students, who did not place in MATH 151 and, consequently, were not eligible for the curriculum, were still an issue raised by many faculty members.
4. The Chemical Engineering faculty was not satisfied with the new chemistry course.

Nonetheless, all engineering majors allowed students to opt to take the FC curriculum. However, if students did not complete the entire year in the FC curriculum there were some difficulties placing them in appropriate courses to finish the year and lose as few hours as possible.

The new Chemistry for Engineering course was adopted as the course required in the first year curriculum; however, Chemical Engineering was not satisfied with this being the only required first-year chemistry course. They were allowed to make a footnote on the next year's catalog to require their majors to take a higher chemistry course in the first year.

At this point the concerns of administrators became a source of resistance to the program. We realized that the effective implementation of the new curriculum was heavily affected by the proper handling of administrative details [20–22]. Administrative details are important issues to the administration but often faculty, especially the faculty involved in the development and delivery of the pilots, ignore them. Several of the most important administrative details dealt with in the early phases of the implementation of the FC were:

1. While none of the faculty had difficulty gaining approval for teaching FC courses, the College of Engineering Dean's Office was approached by almost all of the departments providing faculty to discuss the plans for the FC. (The Associate or Assistant Deans and FC leaders visited all of the departments to discuss concerns. In addition, FC leaders attended faculty meetings in the Aerospace, Agricultural, Chemical, Civil, Computer, Electrical, Industrial, and Mechanical engineering programs.)
2. The engineering, science, mathematics, and English departments did not want the program to continue to grow until more discussion was conducted on the effectiveness and costs of the program. (Data was provided on student outcomes and some data was provided on costs.)
3. The costs of supplies and time demands on technical support for the FC computers were under-estimated.
4. Laptop computers, which were used in the newer classrooms, were significantly harder to maintain compared to desktop computers.
5. The undergraduate advisors were not comfortable on what to advise students to take if they left the FC after one semester, and what to do about being 2 hours short in physics hours, due to the FC physics courses. (FC leaders kept the advisors informed about students who were leaving the FC, and Physics described an existing course which would allow students to make up the two hours.)
6. Block enrollment of the students in FC courses was time demanding for staff. (Alternatives were discussed with the Registrars Office, however an acceptable alternative was not found.)
7. Chemical engineering was not satisfied with the new chemistry course for engineers. (The FC leaders and faculty attended a faculty meeting with Chemical Engineering to discuss the course content of the chemistry course and its perceived deficiencies.)

To deal with the resistance generated by the perceived inattention to the administrative details, an institutionalization plan was developed.

The College of Engineering adopted the FC-developed Chemistry course, and the Mathematics department modified the syllabi of FC mathematics courses to be the syllabi for all MATH 151 and 152 courses. The adaptations in the mathematics courses changed the ordering of material, and in some cases it has moved some material from one course to another. The FC also worked to develop a curriculum for students who were not calculus ready.

The key administrative concerns dealt with during this phase of the program were:

- Facilities for teaming and technology-enabled instruction were too scarce. Even with the two

Fig. 4. Typical model for circular institutionalization.

new large rooms we could not handle the current first and second year loads.
- Faculty recruitment and training was crucial if the program was adopted across the programs.
- The curriculum was becoming required. (The Engineering College formed a first-year curriculum team with representatives from all engineering departments, mathematics, physics, and chemistry.)

At the beginning of the 1997–1998 academic year the final decision for full adoption of the freshman integrated curriculum was made by all academic departments after the College committee on the first-year curriculum made its recommendations in the Spring of 1997. This created some problems in dealing with the recruitment of students for the FC pilots since most academic departments wanted to wait and see how the final integrated curriculum would be implemented for all freshman engineers. The lack of enthusiasm by the faculty teaching in the pilot became apparent. This was the fourth and final year of the pilot and the teaching faculty was concerned about the potential loss of aspects that they considered vital to the integrated program.

In the fall of 1998, the freshman integrated curriculum was offered to all incoming freshmen. Students enrolled in cohorts of one hundred. Some cohorts took common sections of calculus, physics, composition and engineering while other cohorts took common sections of combinations of two or three of the four first-year courses. Industry case studies were added to the freshman engineering courses with industry representatives delivering the case studies and facilitating classroom discussion. Inclusion of industry to the integrated curriculum and emphasis on the importance and appreciation of diversity constituted what we have called an **Inclusive Learning Community** [23]. During this period the momentum for change was at an all time high while the resistance for change was at an all time low (Fig. 3 and Table 5).

The history of two curriculum changes at Texas A&M illustrates innovations driving change, sources of resistance to change, and how the engineering college, by responding to both innovations and resistance, created improved learning experiences for all engineering majors. These experiences can be abstracted into a model for facilitating curriculum change. The model, presented in the next section, was developed not only by examining the history of curriculum change, but also by analyzing how businesses are responding to change. In particular, the model was developed by adapting models of change management in business.

THE CURRICULA CHANGE MODEL (CCM)

In this section, we will describe the curricular change model (CCM) at Texas A&M University that we have synthesized from our survey of the literature on change management and our experiences in college-wide curriculum change. First, we will describe what we see as a traditional model for curriculum change. Next, we will describe the CCM that we have extracted from our research and experiences. Differences between the two models are subtle and may be difficult to describe. However, we will attempt to highlight the differences with examples from our curriculum change experiences.

What we label the traditional model for curriculum change is illustrated in Fig. 4. In the traditional model the focus of change is on the curriculum. First, a pilot group of faculty plan the curriculum, then they prototype, assess, evaluate, and revise the curriculum until it is adopted, or perhaps rejected, by the entire faculty. We recognize that at each stage various constituencies may be engaged, but the focus of the change effort is the curriculum. We also recognize that various iterations may be required in most developments. The focus is clearly on the development and refinement of the ultimate product to be adopted.

In higher education, often because of the tenure system, there is an assumption that faculty members are empowered and that administrators have much less power than CEOs of private corporations. However, often faculty members do not feel empowered to lead change in their institution. On the other hand, faculty members can be extremely powerful in resisting change, especially in curricular areas. Figure 5 attempts to picture efforts to change and resist change to the curriculum.

This figure adapts Peter Senge's archetype of an organization in a growth situation [24], where natural limitation will eventually have influence,

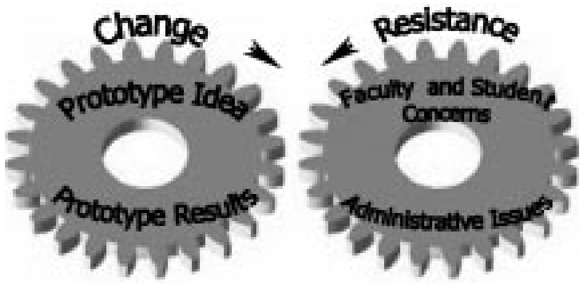

Fig. 5. Relationships between energy for change and energy to resist change.

if not control, on the rate of growth. In the adaptation we have changed growth to the institutionalization of change and the limitation has been modeled as the resistance generated by faculty members and students [25]. In Fig. 5, faculty members who are developing curricular reforms may often spend a great deal of energy in the feedback loop, where they continually refine the prototype programs under development. This would represent pouring more energy into the left wheel in Fig. 5.

In this model, energy that is poured into processes for creating and improving prototype curricula generates equal or greater amounts of energy to resist the change (represented by the right wheel). However, since balancing mechanisms that cannot be depicted connect the two wheels, increasing energy in the right wheel decreases the rate at which change occurs and slows the left wheel. Therefore, the most effective strategy is usually to divide the efforts and devote some energy to identifying and reducing resistance. Reducing resistance reduces energy in the right wheel, decreases the resistance to change and allows the change to proceed at a greater rate. Thus, institutionalization efforts have to focus both on the desired change and the natural resistance to change. Efforts cannot be focused on the desired change alone; the momentum of the resistance must be reduced as part of the change effort.

We have developed an approach where we have 'champions' focused on pushing the changes desired in prototypes, and change agents who focus on reducing the resistance to change. A change agent focuses on:

- shepherding the change;
- maintaining the focus of the change;
- removing barriers;
- rewarding effectiveness.

The change agent may also enhance the communication and trust among different people and be a catalyst for action.

Reducing the resistance as any change is attempted is essential. Here we utilized an approach developed by Lewin [26] where we 'unfreeze' people's attitudes by identifying the individual and organizational barriers. Then we address the needs, fears, beliefs, and values of the people in order to create a more acceptable change for the people involved. After this unfreezing activity we make the actual change action. Then we stabilize the change by rewarding the new behaviors.

The curriculum change model that aids our team in understanding the process we are engaged in is shown in Fig. 6. The box where we are focused on unfreezing any resistance also allows a good opportunity to find out if we are actually wrong in any of our assumptions about the change we are planning. Thus, we recognize that resistance is not always unfounded. Further, the focus of the CCM is the behavior of people, not the new curriculum. By focusing on people, we create the role of a champion who focuses on the people who are developing the new curriculum and the role of a change agent who focuses on the people who will be impacted by the new curriculum and may be the people who may resist the curriculum change. The CCM, with its focus on people and their behavior, encourages a broader perspective than the traditional model, with its focus on the new curriculum and its improvement.

Using the CCM, faculty and administrators could recognize the growing resistance to the new sophomore engineering science curriculum and take actions to understand and reduce resistance. If faculty and administrators used the traditional model of curriculum, they would only take actions to improve the proposed curriculum without necessarily seeking to understand the sources of resistance. Using the CCM, faculty and administrators could recognize concerns about the facilities and resources required for adoption of the FC first- and second-year curricula across the entire engineering college. Then, they could take action, involve all the interested constituencies, and develop a plan that addressed the concerns. If faculty and administrators used the traditional model, they would attempt to either improve the pilot first-year curriculum or communicate positive assessment results more broadly. By focusing on desired behavioral changes of all faculty, the CCM encourages champions and change agents to broaden their perspective for institutionalization efforts.

In curricular and pedagogical changes, one of the ultimate goals is to change the behavior of instructors, which should result in the change of the behavior and performance of students. Products, such as syllabi, texts, projects, assessment data, need to be developed in order to motivate and aid instructors in changing their own behavior. Now, behavioral change, rather

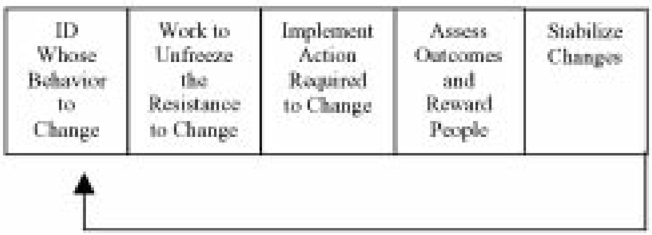

Fig. 6. Model for facilitating behavior change.

Fig. 7. Model for growth in cognitive commitment.

than products, is the ultimate focus of an institutionalization effort. In a nutshell, assessment and evaluation of the results of a prototype are *necessary but not sufficient* to cause the change. This change in focus from proving that a product, or prototype, is valuable to a focus on what will motivate faculty members to change is important, if not essential for the institutionalization of curricular changes.

One of the important elements in motivating change is to foster a cognitive commitment from the constituencies for the change. In the past we have tended to make faculty members aware of an idea for curricular change and of data that supports this change, then we expected them to support the change. This paid no attention to the fact that most of the faculty members had no cognitive commitment to the change. In other words, their only real involvement was trying to guess how this change would affect them, and in the absence of this information, then they would opt for no change.

In our FC efforts we began to have change agents who attended to the cognitive commitment of the decision makers for any change. Our model for enhancing such commitment is a staged model that is illustrated in Fig. 7.

Faculty do not move from ignorance to accountability in one step. Instead, they move through each stage in the model at different rates and in response to different data. In each step of the model in Fig. 7, the change agent will work to increase the number of constituents at this level. Careful attention must be paid to the fact that different people are at different points in the model. The move for a decision about change should be made when there is sufficient commitment to believe that the decisions are based on facts rather than fears.

CONCLUSIONS

This paper examines in detail the processes involved in two major curriculum changes at Texas A&M. Trials and successes in these changes have led to a better understanding of change processes for any major curricular activity. The team that went through these learning experiences is more adept now at managing change, and could potentially accelerate any new curricular change because of these understandings. Specific lessons that the team has learned from these changes include the following:

1. Time and energy must be invested both in initiating and sustaining curriculum change efforts and in identifying and responding to sources of resistance.
2. Administrative issues are crucial to curriculum change and faculty must learn to pay attention to the administrative issues.

Knowledge that has been gained through two significant changes in the engineering curricula at Texas A&M has been synthesized with change models described in the literature to create the change model described here. However, lessons about change that have been drawn from the A&M experiences may be culturally dependent. It appears that the need for change and the inevitability of resistance, as well as the need to manage both, are universal. More detailed issues regarding how to initiate and sustain change, how to identify and respond to sources of resistance, and how to recognize and pay attention to critical administrative issues will depend on the culture of the institution and the country in which the institution is embedded. Literature has acknowledged that culture can be defined according to four common vital signs, which are universal to every organization: *power, identity, conflict, and learning* [3]. Once these vital signs are characterized, educational institutions can determine interventions necessary, e.g. faculty involvement and 'excitement' for the innovative, to make the 'new' implementation a success. Despite the immense diversity among educational institutions, we are convinced that other teams could learn from our experiences and accelerate their own campus changes.

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