ILLUMINATING BARRIERS TO CHANGE:
CURRICULUM INTEGRATION IN THE FOUNDATION COALITION

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Abstract *-- Since 1988 a major component of reform in undergraduate engineering education has been curr icular integration. What integration means and what form it takes varies from institution to institution, and some efforts have been more successful than other s. In the Foundation Coalition, several forms of curricular integration were implemented, but ov er time the degree of integration has shrunk, sometimes to zero. Without intentional, sustained efforts to maintain an integrated curriculum, curricular structure, student's understanding of disciplinary connections and curricular coherence deteriorate over time. From a qualitative study of the change processes used by FC partner institutions to institutionalize innovative freshman and sophomore curricula, we found several factors that may have contributed to increasing "curricular entropy." Some of these factors were increased faculty workload, insufficient training for faculty new to the curricula, rigid separation between the disciplines, and the absence of a management structure focused on coordinating and maintaining integration. Curricula are manife stations of collective faculty beliefs about learning and teaching. Using the findings from our study as well as the literature on curricular change, we will examine the barriers to sustaining curricular integ ration the FC encountered, and discuss the implicit and explicit values and beliefs that challenged the sustainability of the curricula.*

Index Terms *– curricular change, curricular sustainability, faculty beliefs, integration*

INTRODUCTION

Since 1988 a major element in the call for curricular reform in undergraduate engineering education has been the advocacy of an "educational structure that integrates subject matter and shows relationships among subject areas from the beginning of each student's program" [1]. In the Foundation Coalition (FC) integration of subjects was accomplished through the development of new freshman and sophomore curricula. For the freshman programs, pilot FC curricula focused on improving connections and linkages between mathematics, physics, chemistry, engineering and English. Sophomore curricula organized engineering science courses within a common framework based on conservation of extensive problems and accounting for the flow of extensive properties across the boundary of a system as well as generation and consumption of the properties within the system.

These integrated curricula were more structured than traditional curricula and required teaching faculty to coordinate their content delivery and often classroom activities as well. For the faculty members who were involved in developing these programs, and then stayed with the project to teach the new courses during the pilot stages, coordinating with each other across disciplines and across colleges came as a natural extension of how they had been working together while creating the courses. During the development stages, they worked in teams and together experienced the excitement and challenge of building something new from scratch. As these curricula moved toward institutionalization and became available to greater numbers of students, additional faculty members who were new to the program were required. Collaboration between faculty members decreased and the curriculum integration began to deteriorate, and for some programs disappeared altogether.

From a qualitative study of the change processes used by FC partner institutions to institutionalize innovative freshman and sophomore curricula, we found several factors that may have contributed to this "curricular entropy." Some of these factors were the increased faculty workload, insufficient training for faculty new to the curricula, the traditional rigid separation between disciplines and the absence of a management structure focused on coordinating and maintaining integration.

Using the findings from our study as well as the literature on integration and curricular change, we will examine the barriers to sustaining curricular integration that the FC encountered. In the following section we will we briefly discuss the different forms of integration found in higher education and then focus on the concept of curricular integration as it has been advocated in the reform movement in engineering education. The next section will relate the story of the FC's development and implementation of integrated curricula. We will follow that with a discussion of the barriers the FC experienced in

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institutionalizing and sustaining integration, and follow with a discussion about the nature of curricular development and the associated values and beliefs of faculty. We conclude with suggestions for further research.

CURRICULAR INTEGRATION: WHAT DOES IT MEAN?

Engineering programs were not the only target for curricular reform in higher education during the 1980s. The Carnegie Foundation, National Endowment for the Humanities and the National Institution of Education all called for extensive curricular improvement. These voices argued for curricula that addressed a more diverse student population, promoted an understanding of the impact of increasing globalization and interdependence, and in general helped students see how their studies related to their real lives outside of the classroom [2].

Some believe these issues can be addressed through greater *coherence* , a curriculum where courses are held together by a vision of a whole and some broader purpose [3,4], a concept often used interchangeably with *vertical integration* . The issue of coherence stresses how courses build upon and relate to each other as a student progresses through a four-year program. Another way of reforming curricula was by decreasing the emphasis on specialization in curricula (especially found in programs for the professions like engineering), and a stronger emphasis on *connectedness*, and *integration* within and among different disciplines. *Core curricula* are intended to help the student connect discipline-specific knowledge to the broader body of knowledge [3]. *Curricular infusion* is an approach that organizes the curriculum in such a way that boundaries that separate subject areas or disciplines are eliminated completely. The seamless presentation of topics is achieved through use of such devices as "thematic units, literature circles, investigative reports, and journal writing" [5]. *Integrated curricula* can be manifested in many ways but the goal is common -- helping students see the connections between apparently separate bodies of knowledge, and connecting their learning to their lives outside of school [6].

All of these forms provide an alternative to the way knowledge has been delivered in the traditional classroom. The separate-subject approach to education has been so pervasive and enduring at all levels of our educational system that it is rarely questioned as an appropriate way to educate children and young adults. Yet the notion of connecting subject areas has considerable appeal. As Czerniak et al [7] comment, our lives are not separated by school subjects or academic disciplines. In the real world we must apply knowledge learned in one area (e.g., simple mathematics) to common activities that are part of everyday living (e.g., grocery shopping). And indeed, many advocates for curricular integration stress that all schooling should be fashioned around the problems and issues posed by life itself. Others assert that integration helps students think critically [7] and is more compatible to the way we learn. New research has shown that the brain functions in such a way as to support coherent, patterned and connected knowledge [8].

It must be stressed that these curricular enhancements are only aids or tools that help foster connections and linkages between subject areas and topics.

> The basic recurring concept of curricular integration is mistaken. Curriculum does not integrate *for* individuals. Only individuals integrate; only individuals make their meanings. [9]

The work of integration is not done by the faculty or the curriculum but by the student. It is the student who must integrate the new learning into his or her personal knowledge base.

INTEGRATION IN ENGINEERING EDUCATION

One of the pillars on which the new paradigm of engineering education is based is curricular integration. Much of the rationale for advocating a more integrated curriculum comes from the concept that since the practice of engineering is an integrative process [10], the education of the engineer should be an integrative process as well. Engineers synthesize information and expertise from disparate sources into a solution for the client. The very nature of design is integrative. Not only does industry need graduates with coherent, integrated knowledge; but industry needs graduates who can integrate. Many of the ABET "a through k" outcomes involve integrative activities, including the following:

(b) an ability to design and conduct experiments
(c) an ability to design a system
(d) an ability to function on multi-disciplinary teams
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context
(j) a knowledge of contemporary issues

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(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice [11]

Within the engineering education community, as is within other groups of educators, the term *integration* has been used so loosely as to be synonymous with many other terms, e.g., interdisciplinary, coordinated, multidisciplinary, foundational, and broad-based, etc. For us to understand why curricular integration is difficult to sustain within a new and innovative curriculum, we need to have a common understanding of its meaning in any particular context.

In the "next steps" paper that reported on the progress of NSF's Action Agenda for Systemic Engineering Education Reform [1], John Prados describes the integrative character of the "new engineering education paradigm." He writes that this new paradigm must have "an educational structure that integrates subject matter and shows relationships among subject areas from the beginning of each student's program" [p. 1]. Quoting from the NSF program guidelines, the goals for the curriculum are described thusly:

> Create engineering curricula, through a combination of learning experiences not limited to traditional course structures, that maintain a solid mathematical and scientific knowledge base and also: *integrate subject matter* by introducing fundamental principles in *the context* of applications; *integrate* the development of teamwork, communication, and group project definition and problem-solving skills *in learning experiences* throughout the curriculum; *address issues* of cost and timeliness, quality, social and environmental concerns, health and safety, etc., *in the context of engineering practice*; recognize diverse learning styles and career goals; increase opportunities for international experience, possibly taking advantage of distance learning technologies; and *integrate* research and education. [p. 3] (emphasis added)

Clearly, Prados and the NSF are speaking directly to curricular activities that are aimed at combining traditional subject material with new types of learning experiences that facilitate students making the connections. For some educators struggling to improve undergraduate programs in engineering, integrating topics and subject matter within curricula was seen to solve many problems. For example, curriculum integration could:

- eliminate duplication of material and other redundancies between the engineering sciences found in the traditional curricula
- make the delivery of course content more efficient, thus saving resources
- accommodate various learning styles of students [12]
- overcome discipline-oriented "compartmentalization" found in traditional engineering curricula [13]

Engineering educators have tried several methods of integrating curriculum, from the lone capstone design course that prompts students to draw on knowledge and skills learned earlier in the curriculum, to Sooner City [14] that threads a common design theme throughout the four-year curriculum, to Drexel's E^4 program that integrates freshman and sophomore courses into four themes oriented toward preparing students for the profession of engineering [15]. In the Foundation Coalition, faculty focused on restructuring the "foundation years" – the first and second years in order to facilitate integration.

FOUNDATION COALITION CURRICULA INTEGRATION

Integrated courses and curricula were in existence at three of the future Foundation Coalition (FC) partner institutions at the time the FC proposal was written. At Rose-Hulman Institute of Technology, two professors had led the development of a 12-credit Integrated Freshman-Year Curriculum in Science, Engineering and Math (IFYCSEM) [16]. Assessment of the program seven years after it was first implemented showed that IFYCSEM students were retained at a higher rate and had higher grade point averages than students in comparison group [17]. At Arizona State University, an innovative freshman-year engineering course was developed that incorporated design and cooperative learning [18]. And at Texas A&M University, a set of four four-credit sophomore-year courses were being taught that presented engineering science topics in a unified framework organized around the concepts of conservation, accounting and systems. "Engineering science courses such as statics, dynamics, thermodynamics, fluid mechanics, strength of materials and circuits were taken apart, and the 'essential elements' that all engineers should command from these traditional courses were carefully reassembled into four core courses" [19].

The proposal writers identified students' inability to integrate concepts from different academic disciplines as being out of step with the needs of industry.

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Existing engineering curricula present students with discipline-oriented “containers of knowledge” called courses. Integration of concepts is often left entirely to the students, and coordination of topical presentations is left entirely to individual faculty. Students frequently fail to integrate concepts from different disciplines, e.g., mathematics and physics. Similarly, faculty members frequently fail to coordinate topics. For example, in a typical first-year curriculum at A&M, a student would see three separate introductions to vectors. Such discipline-oriented curricula encourage students to “build boxes” and visualize the world in terms of compartments. This orientation is out of step with approaches required to solve multi-disciplinary real-world problems. [20]

An example of a student's failure to integrate the same concept taught in two different courses is described by a mathematics teacher in the interview from the study of the curricular change process.

> We were doing projectile motion when one day a young man walks into my office and says to me, “Do you mind if I use the physics formula to model this?” And I looked at him and I said “Do you think gravity is different over there? What is it that you think is so different?” And he goes “Well, these are physics formulas.”

The plan was for each partner institution to develop integrated freshman and sophomore-year curricula, using the existing curricula described above as models. The FC proposal identified "key strategic issues", including the following two:

- Development of site-sensitive prototype lower-division curricula at each Coalition school of engineering, utilizing existing experimental Coalition programs and instructional technology as appropriate.
- Development of academic climates which are conducive to change so that prototype programs may be accepted willingly beyond the initial faculty teams. Each prototype curricula will be carefully and thoroughly evaluated so that the performances of the students in these programs can be analyzed by faculty who did not participate. As the prototypes are being implemented, faculty will be kept abreast of innovations that are being employed, reactions of the students, performances of the students, and experiences and reactions of participating faculty. [20]

Once formed, the curriculum development teams received training on how to work effectively on teams. The result was an open, creative and collaborative environment not often found in academia. Though these faculty teams had members from different disciplines inside and outside engineering, they had similar characteristics: a commitment to students, learning and teaching; a willingness to try new things; and a willingness to support the team process that required individual professors to suspend judgment of each others’ contributions. Participating in this early stage of curriculum development was special to many of the faculty we interviewed. One participant told us the most important thing to come out of the process was “that we talked to each other.” Another said it “was when the flame was burning the brightest. That was the essence of innovation right there.”

The process with which these curricular development teams worked was similar across the institutions. Teams included faculty members that represented disciplines traditionally taught in the freshman year: engineering, graphics, mathematics, physics, English, etc. What follows is a description of how the freshman team at A&M went about designing their curriculum. This occurred during the summer of 1994.

The faculty leader of the team asked the members to list by topic everything they taught in their freshman class. As a group they reviewed the lists and then, the leader asked the team to justify why the topics were in the course:

> Why is it there? What are you trying to teach?...we had this idea that there should be a reason why you’re teaching them something….so then they would go off and they’d come back and we would take them, one at a time, each course, and we’d say, “OK now everybody understand this…nothing’s sacred anymore. [they all understood] until you start pulling their sacred cow…– a good example would be in mathematics/calculus one. Why are you covering epsilon delta proofs? Well because you can’t be a real good mathematician if you – Oops stop right there. OK. We don’t want them to be good mathematicians. We want them to be good engineers. So why are you covering epsilon delta proofs? …Well [if they didn’t] have a good reason…out it goes! Well at the end of this process…we realized…there’s going to be two reasons why you’d put something in a course. One is it’s got to be there in order for you to use it for something, and two, there’s got to be a little bit of something in there or else a faculty will not teach it. (laugh) OK? So then we said, “OK. We understand a little bit better how this works then.”

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The team examined every topic from every course, and if its inclusion in the curriculum could not be defended it was eliminated. By the end of their first semester working together they were ready to decide how the topics would be integrated. They decided to choose a "pacing" course around which the rest of the topics would be organized. The pacing course was the one with the least flexibility:

> ...and of course engineering has a lot of flexibility. We can do whatever… whenever you feel like it... English, very similar …but the one that became the pacing course was physics. And the reason was because [the physics professor] wasn't a total believer in [integration]…we said "can you rearrange the way you teach physics?" "No." "Well you know surely you could put one topic in front…" "No." "But isn't there something that can be done with?" "No." So we said physics is the driver.

> Now at the time, I don't think we believed [the physics professor] was telling us the truth. I think we just felt like he wasn't quite up on the vision yet… anyway, we went into this room. We said, "OK physics is the driver…put the first concept up on the wall." So he goes and sticks this thing up on the wall. "All right… tell us what mathematics you need in order to teach that subject." "I need this and this and this."

The team built the curriculum scaffolding in this manner by letting the physics topics direct the placement of mathematics. As they "filled" the "thirty weeks" of the freshman curriculum, the English and engineering professors would suggest topics and projects that were connected to the topics on the wall. Through debate and discussion, arguing "as a team," (i.e., coming to consensus) and doing some "micro-movement of topics.

> But that's kind of how we laid the thing out. That took us two days. And we went in there, I mean it was fantastic. Everybody showed up at 8 o'clock. You lock the door...you don't leave…lunch was delivered and …it was really fantastic. And at the end of those two days, 16 hours, we had designed the entire freshman year….but then we had to worry about the details.

They took the rest of the summer to flush the program out week by week, deciding on classroom activities, homework assignments, who would do what, and there was "some little horse trading." By the end of the summer they were more than halfway through the fall term. "And then they went in and did it…in the meantime, we had people working on the technology and renovating the classrooms." The team leader coordinated and managed communication between the teaching faculty members making sure people had what they needed to teach and facilitate the integration.

The new curricula were implemented as prototype curricula following the above design process. The plan was similar to the product development process. Once the curricula were designed, the prototypes were tested and data were collected to assess how well the students were learning. It was assumed that if the assessment data were positive the faculty at large would agree to adopt the new curricula and then it would become the new 'default' curricula. This model of change proved to be faulty and its limitations were discussed in [20]. The important point for this paper however, is that the early FC curriculum developers and leaders correctly assumed that creating and implementing prototype integrated curricula would demand significant effort in terms of faculty resources. They also assumed that teaching and maintaining the already-developed integrated curricula would require only slightly more effort than teaching traditional, un-integrated courses, and in some cases believed that they could be taught even more efficiently. Surely if the new curricula could be created, the thinking went, the curricula could be maintained.

For the new FC curricula that were scaled up for institutionalization, changes were required in order to accommodate more students and faculty, and the changes compromised aspects of the curricula that facilitated integration. Integration also was affected by increasing the *diversity* of the students. The pilots had a more homogeneous student group, for example, every student in the pilot curricula were calculus ready. How the more heterogeneous student population effected integration on one campus was described by one of the FC leaders:

> In the process [of scaling up] we destroyed what integration there was between chemistry and anything else because the pre-calculus group took chemistry in their first semester, before anything, and the normal group took chemistry in their second semester with Calculus II….And, as somebody put it,…it's hard to pretend that something's really integral to the program if you can extract it and stick it in two semesters before it starts and not have any bad effects.

In the next section we describe the impact "institutionalization" had on the integrated aspects of the new curriculum.

PERCEIVED BARRIERS TO SUSTAINING INTEGRATION

A lot of papers have been written about innovative integrated curricula and how problem-based activities, or "just-in-time" teaching, or team projects or thematic cores have been used to help students make connections between supposed disparate topics. Faculty members who helped create the pilot curricula and then watched the FC curricula "drift" slowly back to traditional lecture-based, discipline-specific formats are eager to pin the blame on obstacles endemic to higher education:

- An educational tradition that is teacher-centered rather than student-centered,
- A strong academic culture focused on individual, specialized achievement that inhibits faculty collaboration, especially across disciplinary boundaries [1].

In our analysis of the data collected from the qualitative study, as well as our discussion preparing for this paper, we identified what we called "barriers" to attaining the successful adoption of the integrated curricula as developed and piloted. As mentioned previously, many of these became apparent when scaling up the curriculum to accommodate greater numbers of students. This created several sections of the new courses, and more "teams" of faculty coordinating their sections. Each institution faced these issues but at different levels because not all FC partners adopted the new programs for all students. For some, the institutionalized integrated curriculum was an option for students, while for others, it was a requirement, either a departmental requirement or a college requirement. Each barrier will be examined in a separate section.

Teachers unwilling to teach integrated courses

There are several elements that contribute to what we perceived as unwillingness. One was the perception that faculty would be sacrificing their autonomy and independence. Team teaching or working collaboratively was difficult for some faculty who preferred working independently, thus preserving their primacy in the classroom. This is a value characteristic of the wider academic community. A professor who taught in the sophomore program at Rose Hulman said, "I don't think anyone can tell me how I can teach my individual course. I think they can tell me the material to cover... [but] if they prescribed...active learning, no lectures at all...I don't think I could do that." Another aspect was the lower prestige associated with teaching undergraduates, especially freshman. Sometimes faculty were assigned to teach freshman courses who had never taught undergraduate courses at all, and they were forced to sacrifice teaching a graduate course. This created resentment and resistance to the new courses.

Because the faculty that created the new courses were usually the first ones to teach in the prototypes, the level of enthusiasm and commitment to making these innovations work was very high. These faculty members felt like they *owned* the curricula, much like individual faculty members might have *ownership* for a course that they have developed. The follow-on faculty did not feel that way about the curricula, and often, especially those who were assigned by their department heads, rather than volunteering out of their personal interest, were not inclined to spend extra hours during the week meeting with other professors also teaching in the curriculum.

Coordination requires time

In order to maintain integration across courses and different disciplines; teaching faculty needed to coordinate syllabi, tests, and homework. Some courses were team-taught, and sometimes faculty would sit in on a class where concepts were introduced that he or she would build on in the next class period in order to assure facilitating the connections. Ongoing coordination placed an additional burden on faculty, an increase in workload many faculty members were not willing to accept. With several teams of faculty rather than just one, communication becomes more complex. One FC leader felt that once the program was institutionalized, communication started to fail. He said, "I can find that out by simply asking somebody something about another section and find out they don't even know the name of the professor who's teaching that section." A professor teaching in the program said:

> I think as more people became involved... we've lost that camaraderie among faculty. We don't meet nearly as often as we did the first year, so it's almost to the point where—I mean, we still have communications. My team of engineer and physicist, we meet every couple of weeks and talk about how things are going. But it seems like we've lost a little bit of that impetus from the beginning. I think all new programs are like that. At the beginning everybody is excited and you do lots of things and as more people get involved it gets to be a bigger program. It's more difficult to do those kinds of things.

Lack of training for follow-on teachers

Over time, the original faculty members who developed and first taught in the new programs rotated out. Training for new faculty members was inconsistent. During the pilot stages, preparation varied from observing others teach the course to team teaching the course with experienced faculty members. However, once a new curriculum was expanded and adopted, the

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innovations were often difficult to sustain. At the University of Massachusetts at Dartmouth, faculty leaders saw this "drift" back to the way things were as partly a result of inadequate faculty training. Some of the faculty members we interviewed had not received any training in use of student teams, or active and cooperative teaching techniques. An administrator commented:

> My suspicion is that we need a dedicated team of faculty who know what this is all about, and initially we expended a lot of effort and funds to train the faculty in this new way of conducting educational experiences. And the people who came in the first year were very well trained and worked in a coordinated way…[Now] we have tried to train new people, to bring them in. But what I see happening, and this is not the fault of the director or anybody, it's just sort of entropy happening…. people are now just being assigned into that as a normal course of teaching and that will not work. They must be trained in the new techniques, or we will find ourselves slipping back….I think we have to make sure that the faculty that go in are properly trained and they know that this is a different way of delivering engineering education.

Another issue is resources. The first generation of faculty involved in the FC activities received summer stipends and course buy-outs. This was appropriate given the enormous effort and length of time it took to develop, pilot and scale up new curricula. But as we mentioned earlier, a possible underlying assumption held by administrators and FC leaders was that once institutionalized, these curricula would be passed down and replicated year to year through the same process that sustained traditional curricula. Of course there is a basic flaw in this assumption, the new 'paradigm' of engineering education required many changes in the way engineering professors taught in the classroom, and these changes could not just be handed off to the next generation of faculty via a few pages of syllabus or notes.

Teachers unfamiliar with other disciplines

Many courses in the integrated curricula were interdisciplinary, requiring faculty members to "come up to speed" in areas outside their disciplinary expertise. Specialization within disciplines as well as the traditional separation between the disciplines of knowledge have always been the primary obstacle to successfully integrating curricula of any sort [3]. A conflict for new faculty teaching in the integrated program stemmed from the nature of academic disciplines and the values embedded in the concept of curricular integration. One of the main "thrusts" of the FC was integration of subject matter, not only across the sub-disciplines within engineering, but also across disciplines outside the colleges of engineering that were traditionally taught in the freshman and sophomore years, e.g., mathematics, physics, and chemistry. Faculty in the FC spoke about both "horizontal" integration, making linkages across courses taken simultaneously in a semester, and "vertical" integration, assuring continuity with courses that students take before and after a particular semester. Helping students make "the connections" across subject areas and "see the big picture" often required faculty members to form partnerships with engineering colleagues outside their departments and with professors and other teaching staff in Mathematics, Physics, Chemistry and English. One of the FC core values is "partnership," where among other things, "faculty redefine their relationship to the students and to each other across disciplines." When successful, this "redefined relationship" challenged a long lasting and very strong tradition of separation between disciplines, and even departments within a discipline. Due to the intense nature of the curriculum development process, those partnerships were strong for the first generation of faculty. New faculty coming in after institutionalization did not have the opportunity to develop those relationships, so often the integration that was facilitated by working as a team did not occur. The academic structure is set up to support a narrow disciplinary focus:

> Because departments and professorial reward systems are organized to pursue specialized teaching and research, and because each department covets all the enrollments, faculty members and research monies it can get, any change proposal which is perceived by departments or their individual members as threatening these basic interests is in for a rough time. Any innovative program which "borrows" faculty from departments, as many do, soon finds that departmental interests come first [21].

Some faculty members saw both sides of the issue; integration pitted "helping students make linkages across topics" against wanting students to form a "disciplinary identity" from the beginning of their freshman year. The "blurring of disciplinary boundaries" "re-ignited turf issues" and "a lot of the resistance was territorial." The "territory" in many cases was departmental-specific courses that would be eliminated with more generic introductory engineering courses which threatened departments' ability to recruit students. A war metaphor appears in the following excerpt from a professors' interview:

> But there's always a struggle with individual departments. If you're going to be an XYZ engineer, then you need to have them building left-handed widgets as a freshman, because if you don't get it there, you'll never get it. And that's a continual battle.

This "disciplinary parochialism is said to interfere with the aims of undergraduate education"[22] and certainly interferes with cross- or interdisciplinary work. Many of the FC integrated courses depended on engineering faculty to be at least moderately versed in the commonalities among the engineering disciplines. These courses were difficult to staff, they were "too hard to teach," and meant faculty members brushing up on some basic principles in a way that could applied to engineering in general. The new curricula, as illustrated in the following quote from an administrator at an FC partner institution, advocated a much more holistic and unified approach to introductory engineering education.

> And I would like the teachers in the [FC] program to be kind of generic. I would like for them to be faculty of the College of Engineering without a label on them saying "Civil" or "Mechanical." I don't believe the faculty wants to give up that identity, I don't believe we are going to cultivate faculty from programs here who would be content being a general engineering faculty member. So to me, that represents the biggest continuing challenge to departmental acceptance of the [FC] program among our faculty -- looking for a champion who would get in there and play the generic engineering game with the idea that they want to help students.

Strong faculty partnerships were formed in the FC programs and they were a source for much satisfaction for the professors involved. But many did not experience support for this kind of work from their "home" departments. A chemistry professor saw it this way, echoing the war metaphor we saw in the last section:

> The university is composed of colleges, call them the nations and the colleges are composed of departments, call them tribes. Tribes, because tribes like to throw spears at each other. And if you cooperate with another tribe then you are an enemy. So I am a dire enemy because I cooperate with the engineering nation and tribes. That's very bad. So the way this university…the departments don't look to see what they can do to improve the university, the departments look to see what they can do to improve themselves, even if that's to the detriment of another department. And you get the same thing with the colleges. And I don't know that anybody wants that….

It is in this area of integration vs. disciplinarity where the FC has experienced perhaps their strongest barrier to reform. The worldview espoused in the academic culture is supported by a very strong administrative and bureaucratic structure. It is not just a value system the reform movement needs to address but a structural system as well.

Coordination difficult across colleges

Integration between engineering, mathematics, and the physical sciences (as well as English at some institutions) was more difficult to sustain because of the organizational barriers and/or departmental differences. At Arizona State University, where incorporating English into their first year program was extremely successful and sustainable, integrating mathematics proved to be difficult. The mathematics department at ASU traditionally rotates faculty assignments so that professors don't teach the same course more than two semesters in a row. The impact of this rotation on the FC freshman program was noted by a physics professor: "It's like a revolving door and it's bad for the students. It's bad for integration…what's the point in putting any integration work in because it's going to be gone next semester anyway." This comment stresses again that much of the work of *integrating* was provided by faculty coordinating with each other. Another issue that affects any type of change in higher education is the unpredicted leave-taking of department heads or deans. In more than one instance in the FC, interim deans or department heads were unwilling to make major decisions that their successors would have to implement. Both department-specific norms and frequent, unpredictable changes in leadership adversely affected efforts to sustain integration.

DISCUSSION

As quotes from the faculty members indicate, the development teams did not work together and watch an integrated curriculum emerge. Rather, they started with a conviction that students needed help in making connections between subjects and they fashioned a curricular structure that they thought would make the connections clearer to students. These faculty members also believed in the value of a cooperative learning environment and helping students learn how to work on teams and these values were also reflected in the new integrated curricula. As members of the development team worked together,

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their collaborative efforts led to new insights about relationships among subjects and these insights led to further changes in the pilot curricula that they were creating.

Curricula are manifestations of collective faculty beliefs and values about learning and teaching. As these new curricula became more widely implemented, the beliefs and values inherent within the curricula challenged the ideas and values that formed the foundation for traditional curricula. Professors primarily identify with their individual disciplines and maintain the differences between individual disciplines rather than stressing the commonalities. The integrated and generalist approach challenged that norm. Faculty members guard their right to choose her/his teaching techniques in their classrooms, and creating curricula that dictated particular pedagogical approaches appeared to question the quality of their teaching. Differences in values were rarely addressed directly in conversations about differences in curricular structures and approaches.

Quotes from faculty members illustrate these types of conflicts, and they also illustrate that the underlying values were rarely made explicit. Conflicts among values might have been resolved through deeper conversations about differences in values and priorities that might be assigned to the values, but deeper conversations about curricula rarely occurred. One way of looking at the new curricula that were maintained as permanent *options* for students may be that it allowed some institutions to avoid addressing the hard questions about conflicting values. The hard questions around values were also avoided when sacrificing mechanisms that facilitated integration in favor of obtaining more widespread implementation of the new curricula. To the extent that deeper conversations were avoided, lost opportunities for improving future change efforts are highlighted.

Initially we assumed that the *dis-integration* that occurred during and after the adoption process was a result of several barriers. Other coalitions and NSF have also named similar barriers and called for "new and innovative" ways of overcoming them. But focusing on the barriers may not be the most fruitful path to follow in the effort to improve engineering education. The barriers are created by the beliefs and values faculty hold about teaching and learning. We saw in the early efforts of the interdisciplinary faculty teams in the FC how collaboration, teamwork and collegiality lead to community. In the push to institutionalize these curricula faculty had little time to reflect about what they were learning. Finding ways to foster conversations among faculty that address the hard questions on beliefs and values about teaching and learning is needed.

Because many of the curricular mechanisms that were intended to provide the integration gradually disappeared, it does not mean that students failed to make the connections. Another way of facilitating integrated learning is collaborative study [23]. Discussions with peers help students connect the new knowledge to his or her personal knowledge. Another study undertaken by the FC discovered that the cohort scheduling – a necessary structure to maintain the integrated curricula – also produced sustained student groupings that over time became *learning communities* through which students helped each other to understand the relationships and linkages between subjects [24].

In writing this paper we were reminded of the Sufi story about a man looking for his lost house keys. It is nighttime and a friend finds him searching under a streetlight for his keys. The friend helps him search but after some time with no success he asks the man where exactly he lost his keys. The man points to the back of his house. Upset, his friend demands why they have been searching in the front of the house. The man replies, "Because this is where the light is."

We believe it is important to understand the context and culture in which efforts to improve engineering education occur, and the barriers we have highlighted in this paper are part of that context. But the keys to furthering our understanding of learning and teaching may be where we haven't looked yet, in the faculty and student learning communities that formed as a by-product of the curricular change efforts.

ACKNOWLEDGEMENT

This material is based upon work supported by the National Science Foundation under grant number 9802942. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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And it was the 'joy of collaboration' that kept Ron Roedel and Sara Duerden working together so long teaching the integrated freshman engineering course at ASU. At UA, the curriculum developers experienced the same joy of collaboration. We mistakenly thought that other teachers following behind us would be energized by the collaborative teaching, but it didn't work that way.¶
¶
Many of the initiatives taken in response to these calls for reform were based on the tacit and unexamined assumption that integration is best fostered through curricular manipulation, that curricula can be designed to accomplish the integration of concepts *for* the student. We challenge that assumption. We also believe that the slow disappea ... [164]

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related to how some degree of integration may have occurred despite the barriers.

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were designed to reflect efforts promoting greater diversity in

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Another way of viewing coherence is related to how students link new knowledge to their existing knowledge, forming coherent knowledge.

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was another way of reforming curricula

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Another type of curriculum that relates to issues of integration is the c*ore curricula* . These represent an effort to help students see the connections between his or her discipline-specific education and the broader body of knowledge.

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in the real world outside of schools

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would have trouble functioning if we could not

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Beane [5] divides these concerns into two realms: "1) self- or personal concerns and 2) issues and problems posed by the larger world." He goes further to state that "the central focus of curriculum integration is the search for self- and social meaning."

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Davis [#] challenges the rationale behind these enhancements,

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> The basic recurring concept of curricular integration is mistaken. Curriculum does not integrate *for* individuals. Only individuals integrate; only individuals make their meanings. (Davis, 1997)

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Integrated curricula produced by the Engineering Education Coalitions took many forms.

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integration became the panacea for what ails the curriculum. I

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improve undergraduate engineering education in many ways: it could

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assumed that integration can be achieved best through manipulating the curriculum. This has been done using several methods

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SENIOR YEAR "CAPSTONE" COURSES INTENDED TO BRING SKILLS AND KNOWLEDGE TOGETHER THROUGH RESEARCH OR DESIGN EXPERIENCE
INTRODUCING ENGINEERING DESIGN IN THE FIRST YEAR AND HAVING IT BE THE "THEME" FOR CONSECUTIVE YEARS
STRUCTURING COURSES AROUND THEMES OR CONCEPTS, E.G., RATE OF CHANGE, CONSERVATION, ACCUMULATION, ETC.
STRUCTURING ENGINEERING SCIENCES, MATHEMATICS AND ENGLISH UNDER AN "UMBRELLA" ENGINEERING COURSE
USING COMPUTER SIMULATIONS OR INTERDISCIPLINARY COURSE MODULES

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At the core of the Foundation Coalition proposal to NSF were integrated lower-division curricula.

> Implementation will focus on creation of Foundation Curricula—integrated, interdisciplinary, design-oriented, lower-division engineering curricula that emphasize broad concepts, student discovery, cooperative learning, problem-solving processes and design.

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Examples of successful integrated curricula existed at three FC partner institutions at the time the proposal was written. At Rose-Hulman Institute of Technology, two professors had led the development of a 12-credit Integrated Freshman-Year Curriculum in Science, Engineering and Math (IFYCSEM) [2]. Assessment of the program seven years after it was first implemented showed that IFYCSEM students had better retention and grade point averages than students in comparison group [3]. At Arizona State University, an innovative freshman-year engineering course was developed that incorporated design and cooperative learning [4]. And at Texas A&M University, a set of four four-credit sophomore-year courses were being taught that presented engineering science topics in a unified framework organized around the concepts of conservation, accounting and systems [5]. "Engineering science courses such as statics, dynamics, thermodynamics, fluid mechanics, strength of materials and circuits were taken apart, and the 'essential elements' that all engineers should command from these traditional courses were carefully reassembled into four core courses."[1]

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Many of the members of these first teams

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as seen in the interview excerpt below.

They sort of locked themselves in a room and redesigned the freshman year from scratch. …And that was the group, that

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Including engineering professors, members of the teams were faculty in the

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described above

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engineering design

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, the idea was to test

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data from assessment of the prototypes, share this data with

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implement the curricula as

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following a successful vote by the faculty.

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, however and we have discussed the

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of this change model

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versions of the new

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that is the core of "curricular integration

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following barriers

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This was a value that emerged from our interviews in the Change study. This is a value characteristic of the wider academic community,

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and is often cited as a barrier to faculty collaboration.

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The traditional separation between the disciplines also made the courses harder to teach, as it required faculty to come up to speed in subject areas they may have had as undergraduates.

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and now we have more sections, I think

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Although some of the newer generation maintained integration, others, whatever their prior preparation, often fell back to what was familiar. A perfect Entropy example?

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From an administrative point of view, departments, consisting of one of more disciplines, are the basic organizational units of academia, and have more authority over faculty behavior than colleges. Larger institutions tend to have greater disciplinary distinctions, thus more departments and greater stress placed on disciplinary knowledge. There is increasing pressure placed on graduate students and new faculty to specialize by focusing on smaller and smaller areas in their research area. A familiar joke about the meaning of doctoral status is that a professor "learns more and more about less and less." The move toward greater and greater specialization has even effected undergraduate education, where core courses or generalist courses give way to discipline-specific introductions to the field, as one professor explained it, "more and more faculty wanted to make a focus of their particular discipline down further and further in all of their courses, and as they began to teach fluid mechanics for chemical engineers as compared to fluid mechanics for civil engineers …it became very specific and narrow" to the point of wanting "to get our majors engaged in the freshman year."

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(Harrington, quoted in Storer, p. 207)

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Block scheduling cannot accommodate all students. Integrated curricula often take the form of "course packages" created to maintain connections between courses. However, individual students may, for various reasons, need or want to take one or more courses within a package. Allowing this addresses the needs of the students, but weakens connections among the courses.

Lack of text books for integrated curricula. In most cases, there were few textbooks or course guides to help maintain topic integration. Instead, faculty members passed down notes to successive generations and the notes were often not sufficient to maintain structure of the course.

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What is your experience around this point?

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Another obstacle was dealing with norms that are departmental specific

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The mathematics department at ASU

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faculty assignments so that professors

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don't teach the same course more than two semesters in a row. The impact of this rotation on the FC freshman program

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was noted by a physics professor: "It's like a revolving door and it's bad for the students. It's bad for integration…what's the point in putting any integration work in because it's going to be gone next semester anyway."

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This last comment stresses again

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that much of the work of *integrati*

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ng was provided by faculty coordinating with each other.

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Integrated pilot curricula emerged from collective beliefs among the development teams that helping students make connections among subjects was important. As quotes from the faculty members indicate, the development teams did not work together and watch an integrated curriculum emerge. Rather, they started with the conviction that students needed to make connections and they fashioned a curricular structure that they thought would make the connections clearer to students. FC pilot curricula emphasized student teams and active and cooperative learning because faculty members on the pilot development teams believed in the value of helping students learning to work on teams and in the value of a cooperative learning environment. As members of the development team worked together, their collaborative efforts led to new insights about relationships among subjects and these insights led to further changes in the pilot curricula that they were creating. Since curricula emergent from collective understanding, changing curricula is not like adopting VCRs or DVD players.

More widespread adoption of the pilot integrated curricula brought ideas that led to construction of integrated curricula into conflict with

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Some of the ideas that formed the foundation for traditional curricula have been show to

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include primary of individual disciplines,

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, and flexibility afforded students of choosing when to take individual courses and in what combinations to take courses.

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Instead, surrogate reasons for often offered in the conversations.

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required more difficult conversations, but the tradeoffs still avoid deeper conversations regarding the conflicting values.

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Many of the change efforts focused on the pilot curricula and various features of the pilot curriculum and whether various features would be retained in the institutionalized version. Conversations about whether to retain certain curricular features avoided conversations about curricular beliefs or values.

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We believe that curricular change cannot be treated like other kinds of innovations. Curricula are not things, they are dynamic systems.

Much of what we have discussed above relates to faculty activity. It is clear that many of the FC leaders believed that integration could be facilitated through manipulating the curriculum and managing or encouraging faculty to coordinate and complement their classroom activities in such a ways as to foster students to see the connections and linkages among disciplines

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And it was the 'joy of collaboration' that kept Ron Roedel and Sara Duerden working together so long teaching the integrated freshman engineering course at ASU. At UA, the curriculum developers experienced the same joy of collaboration. We mistakenly thought that other teachers following behind us would be energized by the collaborative teaching, but it didn't work that way.

Many of the initiatives taken in response to these calls for reform were based on the tacit and unexamined assumption that integration is best fostered through curricular manipulation, that curricula can be designed to accomplish the integration of concepts *for* the student. We challenge that assumption. We also believe that the slow disappearance of several mechanisms within FC curricula that were designed to promote integration does not necessarily mean that integration is not occurring for students. We need not necessarily look at these "watered down" curricula as indicating failure to achieve the integration mission articulated by the FC. "Curriculum does not integrate *for* individuals. Only individuals integrate; only individuals make their meanings" (Davis, 1997).

some efforts have been more successful than others. In the Foundation Coalition (FC) several forms of curricular integration were implemented but over time the extent of integration has lessened, sometimes to there being no elements of integration left at all in the curriculum. The integrated curricula that were produced through the work of faculty teams at the partner institutions of the FC had an unspoken notion of exactly what a curriculum was. We believe it corresponds to the definition that Good (1959), a curriculum theorist, wrote in his book "blah blah",

> **"A general over-all plan of the content or specific materials of instruction that the school should offer the student by way of qualifying him for graudate or certification or for entrance into a professional or vocational field."**

Under this definition of curricula, an *integrated* curriculum would mean that content and materials would be presented in such a way to make apparent their connection with other parts of the curriculum. Integrated curricula are more structured, or ordered, than traditional curricula and can be seen as a system.

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