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Systemic Reform in Undergraduate Engineering Education: The Role of Collective Responsibility*

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The aggregate of individual faculty member accomplishments—however well done or prolific—seldom fulfills all collective curricular and instructional obligations of an academic program or department. The purpose of this paper is to help those attempting reforms in undergraduate engineering education to better understand the array of systemic factors likely to affect the long-term success of their efforts. We identify the reasons underlying the difficulty in achieving the necessary level of collective responsibility, describe the tensions within academe that affect an individual faculty member's contributions to collective responsibilities and discuss strategies that can be used to meet these collective obligations.

INTRODUCTION

INDIVIDUAL AUTONOMY is a hallmark of academic work life, valued highly by faculty members everywhere. Autonomy and its variant, academic freedom, are deemed essential to productive scholarship, effective teaching, and some forms of professional service. Formal assessments of faculty work, whether in promotion and tenure decisions or salary allocations, reinforce this belief by focusing on the accomplishments and productivity of each individual faculty member. Left out of this perspective are many of the *collective responsibilities* of the home department, especially ones involving other departments in the college, the university, and external constituent groups. These collective responsibilities cannot be met solely by aggregating the contributions of each individual departmental faculty member.

Consider the following hypothetical department. Faculty members are judged individually as very well qualified. Each person's achievements in teaching, scholarship, and service can clearly be documented as meritorious. Yet the pattern of individual accomplishments may not result in long lasting curricular reform or in the institutionalization of pedagogical innovations because these collective responsibilities fall outside of the 'job description' for individual faculty members. An individual might reform an existing engineering course in a manner highly valued by students, external funding agencies, peer institutions, and employers. Yet time and again we have seen these innovations lost once this person is no longer the course instructor. This paper suggests how to coordinate faculty autonomy and collective responsibility in the pursuit of systemic reform in undergraduate engineering education.

Early in 1997, a group of faculty in the College of Engineering at Michigan State University formed a task force to review the roles of courses in undergraduate engineering degree programs. The task force came to recognize that engineering service courses were often overlooked and their potential educational value discounted. By and large, members of MSU's engineering faculty viewed their service courses as a longstanding engineering curricular mandate, promulgated by ABET with the following requirement: 'In order to promote breadth, the curriculum must include at least one engineering course outside the major disciplinary area' [1].

The task force began to look beyond this cryptic requirement to add breadth to engineering programs and asked the question: How might engineering services courses at MSU be transformed to genuinely reflect the educational program outcomes mandated in *EC2000's Criterion 3* [2]?

Since mid-1997, an interdisciplinary team of faculty members and graduate students has promoted educational reform within engineering service courses through a grant from the GE Fund. Although we started with a typical focus on improving the instructional practices and student assessment methods in selected service courses, we have found that *sustainable improvement* requires much more than knowledge of pedagogy, recruiting committed faculty members, and socializing students. It requires a comprehensive conceptual model of systemic reform in undergraduate education—one applicable beyond engineering service courses—and a set of strategies based on this model.

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A critical element of systemic curricular reform is the development of a program or departmental sense of collective responsibility. In particular, the aggregate of individual faculty member accomplishments—however well done or prolific—seldom fulfills all collective curricular and instructional obligations of an academic program or department. The purpose of this paper is to help administrators and faculty attempting reforms in undergraduate engineering education to better understand the array of systemic factors likely to affect the long-term success of their efforts. Toward this end, we identify the reasons underlying the difficulty in achieving the necessary level of collective responsibility. We describe the tensions within academe that affect an individual faculty member's contributions to collective responsibilities. We then discuss strategies that administrators and their faculties can use to meet these collective obligations and simultaneously raise the departmental faculty's awareness of group commitments.

EFFORTS TO REFORM UNDERGRADUATE EDUCATION

Most undergraduate educational reform efforts focus directly on improving teaching and learning. The immediate goals usually are improved pedagogy and assessment. The longer-term goal, if expressed at all, is to promote a cultural shift from teacher-centered to learner-centered environments. *Teacher-centered environments* support and reinforce the faculty, particularly in their instructional role. Faculty members are the knowledge experts, lectures are the primary tool for teaching undergraduates [3], and the student's role is to absorb the required information [4, 5]. Conversely, *learner-centered environments* hold learning as the central aim of the educational enterprise [6]. In this paradigm, students collaborate in the learning process. Faculty members are 'learning facilitators' who help integrate learning experiences across the curriculum, in and out of the classroom [5, 7]. Instructional styles change from lecture to active and collaborative learning.

A recent evaluation of the many projects funded by NSF's Undergraduate Course and Curriculum Development Program demonstrated the difference between the implementation of an educational reform—often a short-term goal—and the institutionalization of that reform. The positive effects of many instructional and curricular innovations seldom are accompanied by dissemination and adoption of innovations beyond the principal investigator, much less beyond the host institution [8]. Rarely do these efforts result in a learner-centered environment. As one example, consider the engineering professor determined to improve the lowest-rated (by students) course taught in his institution by incorporating active learning principles into it. The professor invested many hours in learning to use group instruction, portfolio assessment, and open-ended design exercises. He found these practices both more time consuming than the traditional lecture/discussion format and more effective in enhancing student achievement. The students responded by rating the course very highly and extolling its virtues to other students. Other faculty members and staff from industry were impressed by the preparation of students and by the quality of their design work. By all accounts, the innovation was a success. Yet the departmental faculty rejected a petition to revise the traditional course format permanently because of the extra time commitment and the belief that such an investment was not important in promotion and tenure decisions. Faculty members teaching the course the next year returned to its traditional lecture format [9].

As another example, consider the NSF-funded Engineering Coalition of Schools for Excellence and Leadership (ECSEL). Established in 1990 as part of the NSF's effort to foster 'big change' in engineering education, ECSEL focused on infusing design into engineering curricula, shifting the emphasis from faculty work to student learning, and increasing the recruitment and retention of women and under-represented minorities in engineering education. Initially, coalition leaders and the NSF viewed systemic reform as culminating from putting in place a sufficient number of individual projects carried out by a large number of the faculties and students in each of the participating institutions. The sum total of these individual efforts was to lead to systemic change. This view of systemic reform proved ineffective. Instead, the 'success' of an individual project was not limited to what happened in a single classroom or even in several of them. In addition to improved classroom-level outcomes, success meant the *institutionalization* of these successes at each school, the *dissemination* of these innovations to other schools within the coalition, and the *adoption of these innovations* by faculty and administrators and students beyond coalition schools. In other words:

> ultimately, the progress of ECSEL will be judged by the extent that student learning experiences change, whether or not the faculty roles and institutional reward structures at participating schools change in line with an increased emphasis on teaching and learning, and whether or not the coalition affects schools and colleges beyond its own boundaries [10].

THE PROJECT

The GE Fund Project, *Reforming the Early Undergraduate Experience*, which began in January of 1998, is now in its sixth year. The stated purpose of this six-year project is:

> to substantially revise the instructional approaches used in the engineering science core courses that

most engineering students take, to institutionalize these changes in engineering curricula and to disseminate lessons learned—both internal and external to MSU—so others can benefit from the outcomes of this educational research project.

The project's website (http://www.egr.msu.edu/reform) provides background information on the project, a list of selected project outcomes, and the assessment tools developed and used. During the initial three years of the project, we focused on two engineering service courses. An engineering service course may be defined as a required or elective course taken by engineering students outside their principal field of study.

- *Civil Engineering CE 280: Introduction to Environmental Engineering*, offered by the Department of Civil and Environmental Engineering, is required for students in three engineering majors and in Environmental Science (College of Agriculture and Natural Resources). CE 280 is a technical elective for students in other engineering majors. Students are introduced to the elements of hydrology; groundwater and surface water supply and contamination; and treatment systems for drinking water and various forms of waste.
- *ECE 345: Electronic Instrumentation and Systems*, offered by the Department of Electrical and Computer Engineering (ECE), is required of students in four other engineering majors and is an elective for the rest. Students in ECE do not take ECE 345. Its students are introduced to electrical and electronic components, circuits, and instruments. ECE 345 includes a three-hour per week laboratory.

The nature of 'service' differs substantially between CE 280 and ECE 345. Some departments require ECE 345 to fulfill the 'general breadth requirement'. A few list it as one of three or four courses among which the students must choose. Mechanical Engineering sees ECE 345 eventually as a prerequisite for its course on Control Systems. This variation in expectation and in the breadth of service exerts considerable pressure on the faculty teaching ECE 345 to include a large (and growing) amount of material. In contrast, CE 280 is both an elective to fulfill the general breadth requirement *and* a required course of Civil Engineering majors with an environmental specialization. Faculty members who teach this course must simultaneously address the needs of majors and non-majors.

In both courses, we added innovative instructional approaches, including cross-disciplinary experiences and teamwork, design, and the use of advanced teaching technologies. We incorporated complex critical thinking and design applications to assessments of student learning. We promoted a seamless link between lectures and laboratory sessions.

METHODS AND COURSE-LEVEL OUTCOMES

Assessment activities focused on:

- within-class achievement;
- effect on curricula in client departments;
- institutionalization and dissemination of results within the MSU College of Engineering;
- dissemination beyond MSU.

All data collection instruments and statistical comparisons can be referenced at our GE Fund project website. For within-class achievement, we adopted an instrument developed by Patrick Terenzini and colleagues at Penn State University to assess changes in student learning outcomes in the service courses [11]. This instrument focused on increased student knowledge of the engineering profession, increased ability to carry out complex designs, increased problem-solving ability, improved competency to analyze and assess alternative solutions, increased ability to apply theory to practical problems, improved communications skills, and increased ability to work with others. Consistent with Terenzini *et al.*, we found the innovative service course sections for ECE 345 and CE 280 more successful in promoting beneficial student learning outcomes than traditional courses [12–14].

For ECE 345, as of spring semester 2000 the 221 students in three innovative courses fared significantly better in their self-assessed knowledge than the 62 students in the baseline course. They were significantly more likely to express knowledge of the engineering profession ($t = 2.12$, $p < 0.05$), design ($t = 2.55$, $p < 0.05$), problem solving ($t = 2.71$, $p < 0.01$), assessment of alternative solutions ($t = 2.68$, $p < 0.01$), application ($t = 2.68$, $p < 0.01$), and communication skills ($t = 2.55$, $p < 0.05$). Similarly, the 73 students taking the reformed version of CE 280 were significantly more likely than the 68 students in the baseline course to express greater confidence in their ability to do design ($t = 2.45$, $p < 0.05$), assess alternative solutions ($t = 2.54$, $p < 0.05$), communicate ($t = 2.59$, $p < 0.01$), and work with others ($t = 2.85$, $p < 0.01$).

Once we found the innovations effective, we developed interview guides to gather data about a variety of factors likely to affect both classroom teaching and institutionalization of reforms. Relevant within-class constituencies included faculty who taught the course as part of the GE Fund project, other faculty members who had taught or expected to teach the course, faculty members who refused to teach service courses, laboratory assistants, and teaching assistants. To assess the effect of service course reforms on curriculum reform and on long-term institutionalization we interviewed all engineering department chairs, chairs of engineering curriculum committees, and deans and associate deans. We also examined curriculum documents to assess both the fit of service courses

in existing student programs and any changes to these documents over time. Finally, to determine the likely effect of the GE Fund project beyond MSU we carried out a benchmark analysis of peer institutions asking them about the equivalent service courses, including credit requirements, fit with other curricula, and instructional practices.

In all, we interviewed more than 50 faculty, administrators, laboratory staff, teaching assistants, and students at MSU. After conducting the interviews, each an hour or so in length, we developed coding protocols to place each respondent's answers into a common analytical framework. We analyzed these interview data to identify strategies to encourage faculty use of innovative instructional techniques that improve student learning. We further identified actions to promote systemic change by institutionalizing these reforms.

COLLECTIVE RESPONSIBILITY AND CURRICULUM REFORM

Despite improving student learning outcomes and better aligning the courses with constituent needs—students, other departments, peer institutions, and industry—we found that faculty members in the departments offering the two service courses strongly preferred not be involved with the courses. Instead, their teaching and curricular development preferences aligned with the needs of their own department's majors or areas of specialization within these majors. When assigned to teach the service courses, these reluctant faculty members invariably returned to teaching with traditional approaches and materials.

Chairs in the 'home' departments were reluctant to contribute substantial resources to service courses even when these courses produced a high percentage of undergraduate credit hours for the department. Interestingly, faculty members in the other departments generally did not closely look at how well these engineering service courses contributed to the educational learning objectives of their programs. These faculty, too, seem preoccupied with courses and curricular issues directly associated with their discipline or areas of specialization within the discipline.

These examples illustrate how a departmental faculty can fall short in meeting its *collective responsibilities*, embodied here in the service courses provided to students in peer departments, *regardless of their individual qualifications or productivity*. An individual faculty member (or a small group of faculty members) might step forward spontaneously to reform an engineering service course. However, these reform efforts will be short-lived without policies to support their implementation.

Our research strongly suggests that the actual level of success in systemic course and curricular reform hinges upon subtle factors intrinsic to faculty culture and the institution's academic environment. In their paper, 'Improving Productivity: What Faculty Think About It—And Its Effect on Quality,' Massey and Wilger describe the effects of research-oriented reward structures and the larger system in which faculty work [15]. The authors see faculty as 'satisficing' on teaching and service; i.e., '. . .doing enough to meet a quality standard—but once the threshold has been achieved, turning one's attention elsewhere.' Faculty members then invest their 'free time' on more highly valued activities, especially research.

Autonomy means discretionary time—time that can be invested in research. Professors will 'earn' their discretionary time by teaching, and they will try to do a good job of it, but for most, the real definition of productive behavior lies in the area of research.

In the next section we examine curricular reform in the context of the larger academic social system.

MODELS OF SYSTEMIC REFORM

We have found that institutionalizing instructional innovations—even for single courses—and transforming academic departments and programs into learner-centered environments requires a *systemic perspective* of educational reform that depicts the interrelationships among the array of external, institutional, departmental, and individual factors influencing academic departments, faculty work, and student learning. Failed efforts to transform academic environments also reflect a dearth of strategies for translating theory and research in practice. We developed a theoretical framework for educational reform based on systems theory and principles of learning organizations [16–18], models of faculty work [4, 19–21], and our experiences in the GE Fund project [12–14]. We focus on academic departments and programs to develop a new architecture or architectures for faculty work, models that seem most likely to increase student learning.

Academic departments and programs are the focus of the *collective work of the faculty*. The model in Fig. 1, the first conceptualization, *presumes no architecture or system*. It focuses solely on the individual faculty member and his or her instructional responsibility and represents the most common underlying 'model' of undergraduate educational reform. The second, which we call *minimalist architecture*, is illustrated in Fig. 2. This model acknowledges a wider range of faculty work responsibilities and places the faculty member in a departmental context. The third model (see Fig. 3), *hierarchical architecture*, incorporates additional institutional and external factors. In both the minimalist and hierarchical architectures, student learning lies at the end of this chain, the most proximate event being classroom teaching.

Strategies to enhance learning and create learner-centered environments based on limited

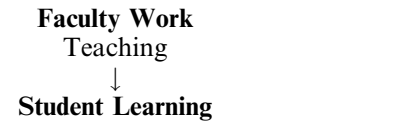

Fig. 1. Model #1—Faculty as individuals.

architectural concepts fail for many reasons. Reshaping complex faculty roles requires reorienting institutional reward structures and examining the interrelated components of the institutional structure in which the work takes place [22]. Without incorporating a more systemic approach, most change efforts are relegated to the individual level—enhancing learning and learning productivity through improving classroom pedagogy. Weimer's work on effective teaching [23], Angelo and Cross' models of classroom assessment [24], and many other types of instructional development programs focus on improving the individual professor's instructional style without addressing the academic architecture directly. The underlying assumption here is that the academic culture can be transformed from teacher- to learner-centered by the cumulative effects of reforming individual teachers and teacher beliefs in their classrooms.

Many strategies to improve pedagogy also fail to take into account the complexity of faculty work. Depending on the type of institution, faculty members are expected—in addition to teaching—to carry out research and scholarship, improve curricula, and contribute to institutional, community and public service [25]. Strategies to improve teaching that do not account for the potential effects on other aspects of faculty work are likely to fail. Improving instructional productivity also requires understanding the complex relationships between other types of faculty productivity and how these relationships play out within departments as organizing units [15]. Without a systems perspective, interventions impact singular aspects of complex problems and often result in unintended outcomes unrelated to the actual goal.

The department is the crux of undergraduate educational reform because it forms the nexus between individual faculty work and collective

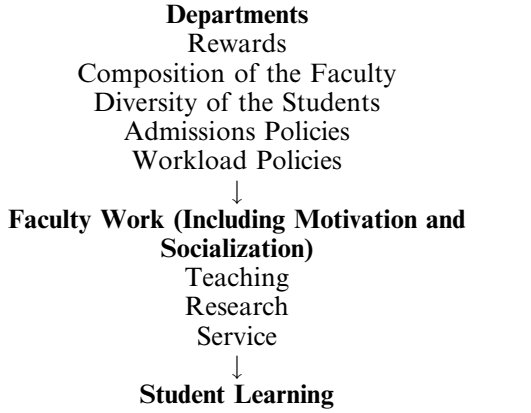

Fig. 2. Model #2—Minimalist architecture.

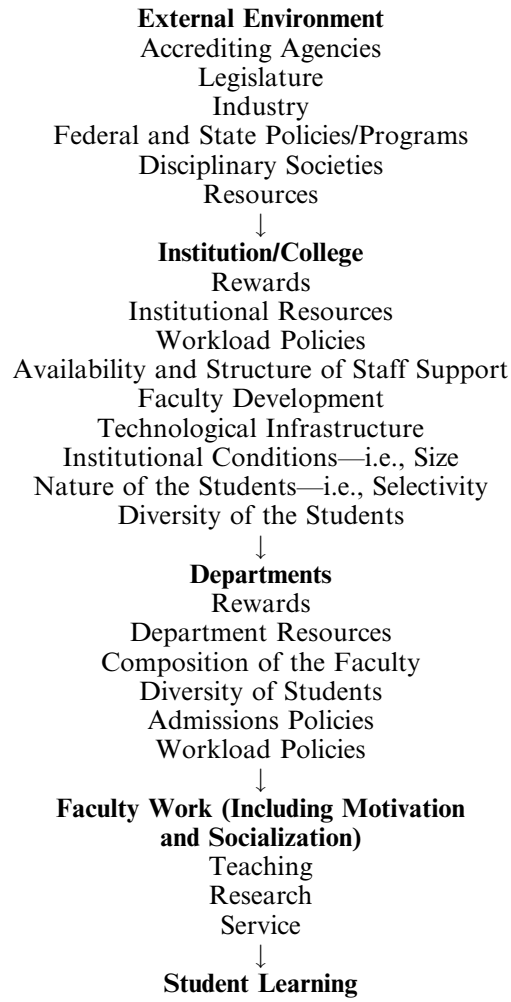

Fig. 3. Model #3—Hierarchical architecture.

responsibility. Traditional models of faculty work assume that departmental or collective responsibilities can be met by aggregating the efforts of individual faculty members [26]. As we discuss below, this belief is not supported empirically. Instead, meeting many collective responsibilities requires the faculty and department chairs to do more than carry out their individual assignments.

We can see that the three teaching and learning models illustrated in Figs 1–3 differ in how well they encourage faculty to think and act collectively:

- *Model #1 (Fig. 1) Faculty as Individuals:* Faculty work related to teaching is viewed in isolation from the rest of the person's activities or academic environment. It treats the faculty member as an autonomous individual.
- *Model #2 (Fig. 2) Minimalist Architecture:* Work is recognized as being composed of three components, i.e., teaching, research, and service. How faculty choose to spend their time would depend upon department rewards, workload policies, and the individual faculty member's motivation. This minimalist architecture focuses on the department and its faculty, suggesting a certain autonomous relationship between the department faculty and outside influences.

- *Model #3 (Fig. 3) Hierarchical Architecture:* Places faculty work, as well as the faculty member's academic department, into a larger context (environment). In this scheme faculty work might be influenced in part by factors external to the department. For example, returning to the 'engineering-service-course' case study that was cited previously, faculty work would involve teaching and reforming engineering courses designed for non-majors. This task can be viewed as part of the department's collective responsibility.

Collective responsibility is better portrayed in the hierarchical architecture than in either of the other two perspectives. We can identify a set of tensions not obvious from more minimalist architectures. On one side we have faculty autonomy, a mainstay of the academic culture. In this culture, highly productive people pick-and-choose how they spend their time, which leads them to 'satisfice' on certain activities. On the other side we have collective responsibilities that do not easily fit into a faculty role so defined. Here lies the dilemma—or set of tensions—which obstruct a department from satisfying its collective responsibilities. These tensions include the following:

1. The tension between collective responsibility and the system of *individual faculty rewards*.
2. The tension between collective responsibility and the boundaries of *academic freedom*.
3. The tension between collective responsibility and the faculty member's desire to maximize his/her *autonomy*.
4. The tension between collective responsibility and *faculty collegiality*.

STRATEGIES FOR REFORM: A SYSTEMIC PERSPECTIVE

In this section we use our systems perspective to discuss strategies likely to address these tensions, and to promote the achievement of both individual and collective goals and responsibilities. We focus here specifically on curricular reform.

External constituencies

- *Leverage accreditation:* Department chairs and deans can view upcoming ABET reviews or responses to ABET findings as opportunities to promote needed curricular and course reforms rather than simply as hurdles to attain or retain accredited status. Instead of telling their faculties that they must respond in writing to criticisms, deans and department chairs can argue that some current practices—say those related to active and collaborative learning—must change to make the department credible to ABET reviewers.
- *Use benchmarking to leverage peers:* Benchmarking increasingly is valued as a method of identifying the status of an academic program in relation to comparable programs at peer institutions. We recommend that deans and department chairs and their faculties view benchmarking from a more strategic perspective. In particular, faculty may respond to reforms based on peer practices when they will ignore the same appeal made to them solely as members of a department or program. Deans that argue for reform because a respected peer institution follows certain practices have more success than deans who argue that their faculty should employ particular instructional practices based on the pedagogical literature.
- *Industry advisory groups:* Many engineering colleges and departments have advisory groups from industry. Most often these groups focus on fundraising, forming employment links for students, and the like. Yet these advisory groups can also assist in curriculum reform. At MSU we have found that members of Industry Advisory Boards serve as effective reviewers of course content and student learning experiences. This feedback often is useful in getting faculty members to reconsider their instructional practices.
- *Funding sources:* Most Colleges of Engineering are dependent to some degree on external research funds. Course and curricular reforms that require increased faculty time spent on teaching can conflict with faculty funded research productivity [9] and threaten departmental and college financial health. Educational reforms that become more efficient over time are more likely to be institutionalized because they reduce this conflict. One alternative is to spread obligations for funded research over a department or college rather than requiring each individual faculty member to acquire a certain amount of funding. Another successful reform model is to rotate faculty members in and out of labor-intensive curricular and course reforms to minimize the reduction in funded research generated by individual engineering faculty members over a protracted period of time. The dean and department chairs may even decide to reduce their dependency on external funds, but such a decision requires support from the central administration.

Institution/college

- *Identify appropriate interventions for leaders at distinct organizational levels:* One key to successful curricular and course reform is to identify the appropriate leadership roles for program heads, department chairs, deans, and central administrators. Department chairs cannot resolve problems resulting from service courses because these courses have a college-wide audience, not a departmental one. ECE 345 serves students in all other departments within the College of Engineering except the home department. In this circumstance, the dean is the appropriate

administrator to turn to for leadership. Similarly, program heads within large departments cannot solve resource allocation issues without the support of their department chairs.

- *Leaders, not just administrators:* Many department chairs and deans view their jobs as ones of management and administration. These perspectives are useful when the focus is on operations and maintaining ongoing departmental obligations. Promoting and fostering curriculum reform, however, requires deans and chairs to take active leadership roles. Facilitating dialogue, mediating conflict, and introducing future-oriented ideas are important, visible leadership activities. Less obvious but no less crucial is uncovering deeply held (and often tacit) assumptions about curriculum and how it relates to faculty identity, roles, and work. These leadership activities are very time consuming. Effective reform requires a shift in how academic administrators understand their roles and may require reconfiguring administrative tasks to create flex time for leading.
- *Values and rewards:* We have observed wide variation in the incentives/disincentives for faculty to teach various courses, to participate in various planning and assessment activities, and to assist the department in meeting its collective responsibilities in certain areas. Consistent with Massy and Wilger [15], most faculty members will not pay sufficient attention to collective responsibilities without some modification in reward structures. Comprehensive reforms involve challenging promotion and tenure criteria, spelling out the relative value of meeting collective obligations. Less radical reforms include giving release time for course preparation and additional conference travel for faculty members involved in educational reforms. In either case, bringing key administrators from each organization involved in the promotion and tenure into the conversation is crucial.
- *Understanding curricula:* We have found that many service course reforms fail because they are not tied to subsequent courses in client curricula. When the faculty members teaching ECE 345 change content in line with the perceived needs of electrical engineers, the reforms may conflict with the needs of mechanical, civil, and other engineering students. Conversely, when the faculty members teaching CE 280 reform the course to fit the needs of students in other majors the result may conflict with the needs of the home department in preparing its own majors.

Department

- *Workload policies:* Departmental workload policies affect curricular and course innovations directly. Departments, which count each course taught as a 'unit of work,' fail to differentiate between the actual load in teaching a course with 300 undergraduate students and one with five doctoral students. Departmental policies that do not give credit for managing laboratory-based courses increase the actual work load for the faculty members teaching them. Not surprisingly, we have found that faculty are reluctant to teach service courses in part because of these work load policies. Work load policies more conducive to course improvement would give course credit in line with the effort required to teach the course.
- *Strategic planning:* Strategic plans can help a department identify collective responsibilities and the faculty member's obligations in meeting those needs. This goal can be accomplished in part if the department (and college) have in place operational strategic plans. These plans should be continuously reviewed and periodically updated. They should be tied in with resource allocation decisions.
- *Individual faculty planning, assessment, and autonomy:* An individual faculty member's work has three basic components—i.e., teaching, service, and scholarship. We have found that faculty members, especially those teaching service courses, tend to view their teaching and service commitments as 'assignments' made by department chairs or program heads. These same faculty members view the focus of their scholarship as a matter of personal and professional choice, more consistent with autonomy than either teaching or service. We believe that department chairs could reduce the tensions described in the previous section by allocating teaching and service assignments in consultation with their faculties. These assignments could be clearly linked to the overall collective responsibilities of the department, which would enable each faculty member to see how his or her work fit with the whole.
- *Course ownership, collegiality, and academic freedom:* The issue of who owns a particular course is an important one. For example, assume that a certain faculty member is the only person who teaches a course for a long period of time. No one feels comfortable asking this person about course content, course learning objectives, or even the suitability of the course in the curriculum. Under what conditions is this situation in the best interests of the department? If some faculty in the department believe that 'this isn't their course', does this attitude affect the department's ability to conduct its collective instructional obligations effectively? Faculty should discuss and agree on the basic boundaries between collegiality and academic freedom and how interpreting these boundaries affect course quality, program quality, and department efficiencies.
- *The hiring decision:* Ultimately the decision to hire new faculty members affects teaching and curricular directions. Rather than basing the

hiring decision primarily on research and even teaching credentials, department chairs and program heads can make sure that the prospective hire can contribute to the unit's collective responsibilities.

In sum, sustained curricular improvement in undergraduate engineering education requires systemic reform. An essential part of this reform is moving the focus from individual faculty interest, motivation, and activity to collective ownership and understanding of the reform efforts. Long-term success depends on carefully defining the system in which classroom teaching effects other parts of faculty work, departmental and college operations, and external pressures. Ultimately successful reform requires re-orienting the roles of faculty members, department chairs, and deans to achieve both individual and collective success.

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