SYSTEMIC REFORM IN UNDERGRADUATE ENGINEERING EDUCATION: THE ROLE OF COLLECTIVE RESPONSIBILITY

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Abstract *— Traditionally, members of a department faculty value their autonomy. But their home department has a set of collective responsibilities involving other departments in the college, the university, and external constituent groups. Consider the following scenario. In a certain department faculty are judged individually to be very well qualified. Each person's academic and other scholarly achievements can clearly be documented as meritorious. However, the collective activities and achievements of these individuals fall measurably short of their department's collective responsibilities. More specifically, an individual might bring highly innovative concepts into an existing engineering course that are highly valued by external funding agencies, by peer institutions, and by the employers of the department's graduates. Yet these innovations are lost once this person is no longer the course instructor. This paper examines the relationships among faculty autonomy, the collective responsibility of the department faculty, and systemic reform in undergraduate engineering education.*

Index Terms — Teaching and learning models, faculty autonomy, collective responsibility, systemic reform.

INTRODUCTION

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 primarily as a longstanding engineering curricular mandate, promulgated by ABET with the following requirement [1]:

> 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 so that they genuinely reflect the educational program outcomes mandated in *EC2000's Criterion 3* [2].

Since mid-1997, an interdisciplinary team of faculty and graduate students has sought ways to bring about sustainable educational reform within engineering service courses through a grant from the GE Fund. We have come to recognize that this effort 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.

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. In this paper, we identify the reasons underlying the difficulty in achieving the necessary level of collective responsibility. We describe the traditional tensions that exist within academe that affect an individual faculty member's "Collective Responsibility Quotient." We then discuss strategies that administrators and their faculties can use to meet these collective obligations and simultaneously raise the departmental faculty's Collective Responsibility Quotient.

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. The faculty 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. The faculty 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*

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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 faculty 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].

MODELS OF SYSTEMIC REFORM

We believe that institutionalizing instructional innovations 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 [11]-[13], models of faculty work [4], [14]-[16], and our experiences in the GE Fund project [17]-[19]. 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

Faculty Work
Teaching
↓
Student Learning

FIGURE. 1
MODEL # 1—FACULTY AS INDIVIDUALS

Departments
Rewards
Composition of the Faculty
Diversity of the Students
Admissions Policies
Workload Policies
↓
Faculty Work (Including Motivation and Socialization)
Teaching
Research
Service
↓
Student Learning

FIGURE. 2
MODEL # 2—MINIMALIST ARCHITECTURE

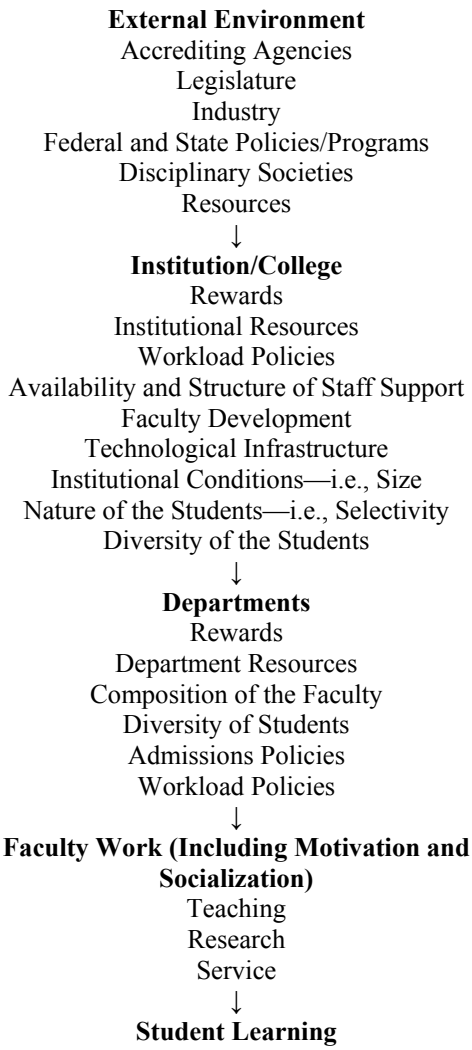

FIGURE. 3
MODEL # 3—HIERARCHICAL ARCHITECTURE

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), the **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 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 [20]. 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 [21], Angelo and Cross' models of classroom assessment [22], 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. In addition to teaching, depending on the type of institution faculty are expected to carry out research and scholarship, improve curricula, and contribute to institutional, community and public service [23]. 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 [24]. 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 responsibility. Traditional models of faculty work assume that departmental or collective responsibilities can be met by aggregating the efforts of individual faculty members [25]. 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.

LESSONS LEARNED FROM THE GE FUND PROJECT

The GE Fund Project, *Reforming the Early Undergraduate Experience*, which began in January of 1998, is now in its fourth year [26]. The stated purpose of this five-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 [26].

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 [26]. During the initial three years of the

project, we began to augment two core introductory engineering science courses with innovative instructional approaches, including cross-disciplinary experiences and teamwork, design, and the use of advanced teaching technologies. Evaluation activities focused on student learning outcomes, faculty development, institutionalization and dissemination. We demonstrated that we improved student learning outcomes in these two courses [17]-[19]. For over three years, we have been observing these and other courses, surveying students, assessing student learning outcomes, and interviewing deans, department chairs, faculty members, and heads of department and college curriculum committees. Through these activities we have developed a better understanding about ways to encourage faculty use of innovative instructional techniques that improve student learning. We developed strategies to achieve systemic change by institutionalizing these reforms. 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.

Collective Responsibility and Curricular Reform

As mentioned previously, the aggregate set of accomplishments of individual members of the faculty seldom fulfills all collective curricular and instructional obligations of an academic unit. Two recent case studies at Michigan State University demonstrate this concept.

- **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—e.g., an environmental engineering or computer engineering course taken by students majoring in mechanical engineering. We have observed that faculty members in the department offering the course strongly prefer not be involved with the course. Instead, their teaching and curricular development preferences align with the needs of their own department's majors or areas of specialization within these majors. Interestingly, faculty members in the other departments generally do not closely at how well these engineering service courses contribute 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.
- **Sustaining EC2000 initiatives**: Nine undergraduate engineering programs at Michigan State University were reviewed by ABET using *Engineering Criteria 2000* during the 1998-99 accreditation cycle. Two of these programs were the Computer Engineering (CpE) and Electrical Engineering (EE) programs. The CpE program is jointly administered by faculty in the Electrical and Computer Engineering (ECE) Department and by faculty in the Computer Science and Engineering (CSE) Department. The EE program is administered solely by ECE. As part of this review relevant faculty members prepared a self-study report for ABET. The report contained a comprehensive assessment component, including outcomes-assessment and continuous-quality-improvement (CQI). ABET reviewers judged this assessment component "excellent." Yet three years later the proposed assessment activities have yet to be carried out. Once the faculty had completed their collective obligation—preparing the self-study report—they retreated to their individual work patterns. These patterns did not include carrying out the proposed assessment reforms so the effort languished.

Each of these examples illustrates how a very well qualified and productive departmental faculty can fall short in meeting its collective responsibilities. An individual faculty member (or a small group of faculty members) might step forward spontaneously to reform an engineering service course or to prepare for initial accreditation under EC2000. However, these reform efforts will be short-lived without policies to support their implementation. The faculty must accept **collective responsibility** for these reforms. The departmental administration should expect it.

Tensions Involving Collective Responsibility in Academe

In their paper, "Improving Productivity: What Faculty Think About It—And Its Effect on Quality," Massey and Wilger make the following observations related directly to an individual faculty member's values about collective responsibility [24]:

> Faculty try to economize in their own teaching and research activities. This is particularly true of their own time, which they see as a very scarce resource. They leverage their time with graduate student assistants, with secretaries and technicians, and in some cases with technology.

The authors see faculty as "satisficing" on some of their activities; i.e.,

> …doing enough to meet a quality standard—but once the threshold has been achieved, turning ones attention elsewhere.

Moreover, they believe that faculty value "autonomy;" i.e.,

> 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.

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. In the first model 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. In the second model (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.

The **Hierarchical Architecture** illustrated in Fig. 3 places faculty work, as well as the faculty member's academic department, into a larger context (environment). Hence, faculty work might be influenced in part by factors external to the department. For example, returning to the "engineering-service-course" case study 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. The key, which we discuss below, is encouraging individual members of the faculty to accept collective responsibility as part of their own expectations. In the EC2000 case study cited previously the pressure comes not from another engineering department but from an accrediting body (ABET) and the employers of the program's graduates.

We understand that faculty value their autonomy. We believe that highly productive people need to pick-and-choose how they spend their time, which leads them to "satisfice" on certain activities. Here lies the dilemma—or set of tensions—which obstruct a department from satisfying its collective responsibilities. These tensions include the following:

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

We believe that both the faculty and administration must acknowledge these tensions. Once acknowledged, they must be openly discussed and approaches found that simultaneously satisfy the collective needs of the department without destabilizing the faculty.

Dealing with These Important Tensions

We offer several recommendations for dealing with these fundamental tensions within academe.

- **Strategic planning**: The faculty needs to be involved in the department's comprehensive planning process. The faculty needs to be made aware of the department's collective responsibilities and the faculty'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.
- **Leadership role of college deans and department chairs**: Strategic plans provide a vision for the department and college. Deans and department chairs occupy the nexus between organizational and individual faculty member goals. These leaders help manage these tension by motivating faculty to understand and act upon their collective responsibilities. Rather than mandating specific actions, these leaders should encourage the faculty to socialize amongst themselves to discuss and understand the department's overall needs in the context of the department's system of individual faculty rewards.
- **Faculty planning, assessment, and autonomy**: An individual faculty member's work has three basic components—i.e., teaching, service, and scholarship. The basic teaching load is assigned and relates to the teaching of courses during the academic year. Service assignments most often relate to specific committee or administrative duties. In contrast, the work associated with scholarship typically is defined by each faculty member taking into account personal motivation and the department's system of rewards. In short, only a portion of a faculty member's work is actually planned for at the outset of an academic year or calendar year. We believe that the tensions described in the previous section would not be as severe if faculty became more involved with planning their own use of time during the coming year, and if these plans were shared with the department chair. This plan would include teaching, service and scholarship and how each faculty member's planned activities will be evaluated. We believe that individual faculty planning is an essential component in helping the department meet its collectively responsibilities. It need not adversely affect faculty autonomy.
- **System of 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. If faculty do not automatically move toward meeting these needs then the system of values and rewards may need to be adjusted to provide the necessary incentives. This effort could be accomplished in part by adjusting teaching loads of individuals or adjusting the teaching-load model within the department.

- **Identifying and sustaining classroom innovation**: We believe that it is important for a department to identify and recognize faculty innovative practices. Specific innovations might lead to improving the quality of course content, improving the quality of student learning, or improving faculty efficiency with respect to classroom instruction. The department does not generally institutionalize these innovations. These best practices should be discussed and evaluated by the faculty. Best practices should then become "planned innovations" by the department and should become part of the overall department's culture.
- **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.

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REFERENCES

[1] *Criteria for Accrediting Programs in Engineering in the United States: Effective for Evaluations During the 1998-99 Accreditation Cycle*, Engineering Accreditation Commission, Accreditation Board for Engineering and Technology, Baltimore, MD, 1999, pp. 5-7.

[2] *2001-02 Engineering Criteria, ABET's Engineering Accreditation Commission* (EAC, URL: http:/www.abet.org/eac/eac.htm, 2001.

[3] Pascarella, E., and Terenzini, P., *How College Affects Students*, San Francisco: Jossey-Bass, 1991.

[4] Guskin, A.," Reducing student costs and enhancing student learning restructuring the role of faculty", *Change,* 26, September/October, 1994, pp. 16-25.

[5] O'Banion, T., *A Learning College for the 21st Century*. Phoenix, Ariz.: Oryx Press, 1997.

[6] Barr, R., and Tagg, J., "From teaching to learning—A new paradigm for undergraduate education", *Change*, 27, November/December, 1995, pp. 12-25.

[7] Dirkx, J., and Prenger, S., "A Guide for Planning and Implementing Instruction for Adults: A Theme-based Approach", San Francisco: Jossey-Bass, 1997.

[8] Eiseman, J., and Fairweather, J*., Evaluation of the National Science Foundation Undergraduate Course and Curriculum Development Program: Final Report*, Washington, D.C.: SRI International, 1996.

[9] Fairweather, J., *Faculty Work and Public Trust: Restoring the Value of Teaching and Public Service in American Academic Life*, Boston: Allyn and Bacon, 1996.

[10] Fairweather, J. et al., *ECSEL: The Sixth Year*, University Park: Center for the Study of Higher Education, Penn State University, 1996.

[11] Argyris, C., and Schon, D., *Organizational Learning: A Theory of Action Perspective*, Reading, Mass.: Addison-Wesley, 1978.

[12] Kast, F., and Rosenzweig, J., *Organization and Management: A Systems and Contingency Approach*. 4th ed., New York: McGraw-Hill, 1985.

[13] Senge, P. and Associates, *The Fifth Discipline: The Art and Practice of the Learning Organization*, New York: Doubleday, 1990.

[14] Blackburn, R., and Lawrence, J., *Faculty at Work: Motivation, Expectation, Satisfaction*, Baltimore: Johns Hopkins University Press, 1995.

[15] Braskamp, L., and Ory, J., *Assessing Faculty Work: Enhancing Individual and Institutional Performance*, San Francisco: Jossey-Bass, 1994.

[16] Seldin, P. and Associates, *How Administrators Can Improve Teaching*, San Francisco: Jossey-Bass, 1990.

[17] Fisher, P., Fairweather, J., and Haston, L., "Establishing learning objectives and assessing outcomes in engineering service courses", *Proc. of the 30th ASEE/IEEE Frontiers in Education Conference*, Kansas City, 2000, CD-ROM.

[18] Fisher, P., Fairweather, J., Rover, D., and Haston, L., "Linking engineering service courses with engineering design", *Proc. of the 2000 ASEE 2000 Annual Conference, 2000*, CD-ROM.

[19] Fisher, P., and Fairweather, J., "Transforming engineering service courses", *Proc. of the 29th ASEE/IEEE Frontiers in Education Conference*, San Juan, Puerto Rico, 1999, CD-ROM.

[20] Colbeck, C., "Merging in a seamless blend: How faculty integrate teaching and research", *Journal of Higher Education*, 69, 1998, pp. 647-671.

[21] Weimer, M., *Improving College Teaching: Strategies for Developing Instructional Effectiveness*, San Francisco: Jossey-Bass, 1990.

[22] Angelo, T., and Cross, K., *Classroom Assessment Techniques: Handbook for College Teachers*, 2nd ed. San Francisco: Jossey-Bass, 1993.

[23] Bowen, H., and Schuster, J., *American Professors: A National Resource Imperiled*, New York: Oxford University Press, 1986.

[24] Massy, W., and Wilger, A., "Improving productivity: What faculty think about it—and its effect on quality", *Change*, 27, July/August, 1995, pp. 10-20.

[25] Finkelstein, M., *The American Academic Profession: A Synthesis of Social Scientific Inquiry since World War II*, Columbus: Ohio State University Press, 1984.