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A major change in the structure of the basic engineering curriculum and the way it is evaluated by the Accreditation Board for Engineering and Technology (ABET) has commenced, bringing together teachers from engineering, science, and the humanities in a new learning community. ABET will be accrediting all engineering curricula by the year 2000 on new criteria that encompass objectives not now easily assessed. Drexel University has responded with a new program called, "An Enhanced Educational Experience for Engineers (E4)."

A Learning Community for Professionals: The New Engineering Curriculum

For engineers, recognition of the profession's rapidly changing technology and ever increasing demands for both analytical and communication skills has led to a major change in the structure of the basic engineering curriculum. Naturally, the way it is evaluated by the Accreditation Board for Engineering and Technology (ABET) must reflect those changes. In the vanguard of the innovative basic engineering curricula is the internationally emulated program at Drexel University, "An Enhanced Educational Experience for Engineers (E4)," which won the first ABET award for Excellence in Curriculum Innovation. Several of Drexel's program emphases are now incorporated in ABET's "Engineering Criteria 2000." These, like the Drexel Engineering Curriculum, emphasize humanistic and process-oriented goals (available at http://www.abet.ba.md.us/EAC/eac 2000).

ABET's "Engineering Criteria 2000"

Programs graduates must demonstrate:

- an ability to apply knowledge of mathematics, science, and engineering;
- an ability to design and conduct experiments, as well as to analyze and interpret data;
- an ability to design a system, component, or process to meet desired needs;
- an ability to function on multidisciplinary teams;

- an ability to identify, formulate, and solve engineering problems;
- an understanding of professional and ethical responsibility;
- an ability to communicate effectively;
- the broad education necessary to understand the impact of engineering solutions in a global/societal context;
- a recognition of the need for and an ability to engage in lifelong learning;
- a knowledge of contemporary issues; and,
- an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

In the new criteria proposed by which to evaluate engineering colleges, ABET acknowledges the interdependence of engineering expertise and the people it serves, because engineers cannot build something without recognizing its impact on its end users and the limitations imposed by personal biases. To meet the new criteria, curricula are being revised to allow for an interdisciplinary process that brings together teachers from engineering, science, and the humanities in a new learning community. An appropriate response for educating the people who will build our cities, our transportation, and our communication systems in the next century is to create learning communities that foster the ability to acquire knowledge and the reflective practice of considering its impact on our acquisition and disposition of it. Learning communities have gained wide currency in educational reform efforts and the title alone bespeaks their importance in Thomas Angelo's 1997 article, "The Campus as Learning Community: Seven Promising Shifts and Seven Powerful Levers." One of the most powerful levers that may hasten the shift is assessment, particularly in engineering, which relies on the content of science and mathematics.

The engineering professionals who build their expertise on a base of science and mathematics have begun to recognize that a community of learners may be better equipped to cope with "open systems," which are the norm, rather than fixed solutions. Engineering professionals have actually tacitly built learning communities as they acknowledged the need to involve their clients as well as a myriad of other professionals in their design projects, from bridges to environmentally safe pharmaceutical factories. Now, engineering colleges are undertaking the task of educating the new engineer by creating learning communities in the first year. Preliminary evaluations of the effectiveness of these communities for engineering students indicate that they are good conduits for fostering creative thinkers attuned to the nuances of the community as defined and redefined with each new encounter or project.

Drexel's Learning Community

At Drexel University, evaluations of the trailblazing E4 program (1987-1994) identified an *esprit de corps* felt by faculty and students (Haslam, 1993). The program's success in retaining students and meeting several of the objectives now identified in the ABET 2000 criteria evidently derived from the learning communities it had established. The freshman engineering class is approximately 550, with 60%

residents and 40% commuters. Given this size and distribution, and the fact that students come from disparate backgrounds, it is not easy for them to identify immediately with other learners unless they are grouped within courses. The E4 program revealed that teamwork, which students engage in for design projects and which faculty engage in for interdisciplinary teaching, built a strong learning community. As the hallmark freshman design project and the integrated approach to engineering education became institutionalized, a conscious effort to foster learning communities was articulated. The College of Engineering approved the Drexel Engineering Curriculum, with a design that includes grouping freshmen in sections of 25 and maintaining that core for all subjects for the entire year, if feasible. At the upper levels, departments identify ways to incorporate tenets of the program so that the entire undergraduate population, approximately 2,000 students, meets its objectives.

The result is dramatically different from traditional engineering education both in the type of courses delivered and in the way they are delivered. "For the core experience in the freshman and sophomore years, Drexel focuses on the interdisciplinary mathematical and scientific foundations of engineering, the transcendent role of the computer and the pivotal role of experimentation in professional practice, the imperative for superior personal communications skills, teamwork and vigorous, life-long learning for continued personal success and finally—design as the defining constant and universal element of the profession" (Quinn, 1993). The program affects the way students learn and, just as significantly, how faculty teach. Students learn physics, calculus, chemistry, and even biology while engaging in engineering projects and laboratories from the first day of classes. Both groups, faculty and students, participate in weekly meetings to assess how the program is doing and to respond to problems in efforts to maintain continuous quality improvement. Throughout the program, the humanities sequence of courses for freshman English is integrated and acknowledged as a vital part of a professional engineer's life.

The students quickly develop study groups and an identity with their section. In the engineering design and laboratory sequence, ED&L, they function in design teams on a sequence of projects moving from assigned teams to self-selected ones. The ultimate step, the freshman design project, is integrated into the humanities curriculum, which stresses communication skills and audience analysis. The iterative process of engineering design coalesces with the stages of the writing process in humanities. Given that engineers must perform their work for the public, they need to recognize the public in its totality.

In fact, the definition of design that is generalized from a report completed for the National Research Council goes even farther and stipulates that "public participation is important throughout the design process." Freshmen awaken to the reality that engineering happens in a social setting. Whether the design requires an environmental impact statement or a market analysis, today's engineering design team must know its audience. For a college freshman who is just a summer removed from being a high school student, the public is their hometown and family. For an engineer, the public means a variety of audiences—people of different generations, cultures, and race.

Of the several innovations occurring in engineering education nationwide, E4 is the only one that involves the humanities component as an integral—in fact, central—part of the curriculum. Humanities faculty have been instrumental in designing the entire program and in training faculty from all the disciplines needed for the interdisciplinary project. The pivotal role of the humanities has been explained in several articles and presentations (Arms, 1994), and, in a recent review of Drexel's College of Engineering, ABET evaluators expressed particular praise for the unique integration of the humanities in the freshman program. At the 1993 Asheville Institute on General Education, a panel of experts cited it as "a paradigm" among exemplary interdisciplinary programs. It has become the stated foundation for innovation in the Gateway Coalition of ten schools. In California, the Liaison Committee of state schools of engineering recommended, after hearing a presentation on E4, that the undergraduate curriculum consider a humanities link similar to Drexel's.

A Tool for Assessing Outcomes

Since faculty from engineering and humanities work as teams in mentoring the design projects, they have formed another learning community. The project deliverables, including the problem definition statement, proposal, oral presentation, and final report, are discussed in both humanities and ED&L classes, with ED&L emphasizing the engineering requirements and humanities emphasizing the communication skills. For 1997-98, the joint faculty have developed assessment sheets for the deliverables, in which the core objectives for each deliverable remain the same for both courses, but the technical competencies reflect the specific goals for ED&L and for humanities.

The worksheets for the deliverables of the design project specify common program objectives directly related to the desirability and efficacy of learning communities, with desired outcomes that are matched with the ABET criteria. For example, communication skills are a specific item to be judged by all faculty; teamwork and research are similarly identified as program objectives. For example:

Teamwork.

- Each member contributes a fair share to the completion of the project.
- Everyone participates, listens, and cooperates with other members.
- Members share information and help reconcile differences of opinions when they occur.

Faculty have available the teams' journals, minutes of weekly meetings, conduct and attendance at meetings with faculty advisors, and oral presentation performances for use in making an assessment of teamwork.

Another goal is designated as systems thinking, and its intent is to make obvious the need to integrate knowledge from the fundamental courses in an engineering curriculum.

Systems Thinking:

- Understands how events interrelate and demonstrates an ability to take new information and integrate it with past knowledge.
- Integrates and uses knowledge from various courses, including engineering, physics, mathematics, and sciences, to solve technical problems.

In grading a final report, faculty considering systems thinking might note that the students had taken care to calculate percentages rather than saying "there is a great need," or that they had developed a mathematical model to represent the failure of a mechanical system rather than saying "there are frequent breakdowns." Another example might be that students had tried to find new applications for shape metals and calculated the cost/benefit ratio to see if the expense of a shape metal replacement for a car bumper would be warranted.

These assessment worksheets appear in the Manual for Humanities, on the website for ED&L and on the website for the Gateway Coalition, a group of schools committed to implementing the innovations in engineering curricula (www.gatewaycoalition.org). The Gateway Coalition recognizes the impact of learning communities in educating engineering students and has included plans for assessing them and disseminating the results via the Internet, CD-ROM's, and traditional means.

The National Science Foundation funds the Gateway Coalition, which itself provides the basis for a larger learning community of faculty as successful innovations are promulgated within the coalition through faculty development workshops, newsletters, software, and assessment tools. When the pilot run has been completed and evaluated, those results with recommendations for revision will be reported on the website. It is crucial that data on assessment be gathered and reported broadly if the academic culture is to be changed. "The teacher is the key in educational reform. Until the teacher understands the learning process, reform efforts will take much longer. Traditionally, university faculty treat knowledge as static, a concept that has influenced how teachers view students' ability to learn: mere possession of knowledge is valued and faculty often disregard the dynamic process of how one comes to know. Clearly, there is a need for faculty to understand more about the learning process and to redesign their curricular, instructional, and assessment methodologies so they are congruent" (Haslam, 1997). A learning community of faculty who share program goals for student development is integral to effecting such change.

Challenges to Faculty

Faculty in the sciences and mathematics have had the most difficulty in accepting the constraints of the integrated curriculum, which necessitated delaying delivery of some of the content taught in the first two years of a traditional program. In the inverted curriculum used at Drexel, upper-level interdisciplinary courses should compensate for the earlier omission. Additionally, the program seeks to instill an awareness for lifelong learning that recognizes that no college program can provide all the knowledge that an individual will need for any job. From the earliest independent evaluations of E4 to the most recent of the expanded Drexel Engineering Curriculum, faculty teaching calculus, chemistry, and physics have expressed dismay at the loss of content. The design project, for some of the them, has been an interruption of the delivery of content in their discipline. Others have seized the opportunity to act as advisors to student projects that involve their subject matter. For example, the chemistry professor has advised fruitful design projects that require applying chemistry to find an engineering application for shape metals. A sampling of E4 faculty, in extensive interviews with an outside evaluator, have commented on "the positive student-faculty relationships, small groups, teamwork, and the productivity and creativity of student thinking throughout the year. They described how they were using newer methods of providing depth. They concluded that the development of student learning is the future for university educational reform" (Haslam, 1993). However, the faculty who remain locked in their discipline need more than experiential evidence to change entrenched pedagogies.

The assessment forms described here are being used as a pilot in 1997-1998. Student and faculty response will be assessed in the summer of 1998 and further revision and implementation will be considered, an activity that is integral to continuing both this program and others emulating it, because the program expense, in faculty time and in laboratories, is greater than delivering a traditional curriculum. In addition, the effort is considerably more intense and requires more faculty development and cooperation.

To outsiders, a learning community sometimes seems to function chaotically; to its members, there is a discernible rhythm. Since process-oriented coursework and team activities are new to some faculty and students, both groups have expressed malaise because of the lack of clear-cut problems with well-defined answers. Open-ended problems are contrary to much of the students' previous school experiences and are more difficult for faculty to grade. Grades for team projects pose the additional dilemma of adequately rewarding individual effort. Good reason to overcome the problems posed is obviously necessary; otherwise faculty and students are justified in preferring an orderly, passive lecture system. The value of the learning community must be documented if it is to be widely adopted in engineering education.

Efforts to document the effects are fairly new in engineering; however, the assessment of cooperative education is well-documented in general. A meta-analysis of studies of small-group learning in science, mathematics, engineering, and technology (SMET) found that small-group learning had a significant effect on improving undergraduates' achievement, persistence, and attitudes (Springer, 1998). Surveying the results of such studies in a major engineering magazine, the authors conclude: "As cooperative learning should lie at the heart of any classroom, cooperative teaching teams should lie at the center of any instructional program" (Johnson, 1998). Faculty are unaware of such results, perhaps because research in pedagogy is not deemed necessary for an experienced teacher to stay abreast of the disciplinary field. Those who themselves engage in classroom research are often viewed as suspect.

Levers for Change

To borrow Angelo's (1997) imagery, two levers are pushing faculty to shift their stance: technology and student response. In the first case, technology has so changed the way course material is delivered that faculty must make adjustments not only in teaching style but also in content. In the second case, student response to learning communities has been so overwhelmingly positive that it would be foolhardy to ignore their potency in retention as well as in intellectual development.

Technology

The lever of technology is pushing change in many such obvious ways as electronic delivery of course work via the Internet, but a more subtle change is occurring in classrooms. Consider the experience of one professor in mechanical engineering. Professor ME teaches a junior-level course in Thermoanalysis. Historically, he has given problems that require iterative solutions of 3rd-order equations and nonlinear simultaneous equations for students to demonstrate a logical approach to complicated problems about the chemical equilibrium of a system. Today's students enter class with a graphing calculator that allows the solution of such problems with a single keystroke. Professor ME could refuse to allow the calculators in class, but that would deny the reality of the work experience. The students will use calculators and must develop an understanding of their power and their limitations, i.e., they need a sense of the right answer, a way of intuiting correctness, and a checking of technology, not a denial of it. Professor ME acknowledges that he has had to examine his educational goals for the class and is teaching it very differently in 1998 than he did in 1996. The year 2000 will bring more than new ABET criteria to bear on how teachers present material.

Challenges to Students

The second lever, student response, both pushes and portrays the emotional and intellectual development of the freshmen who progress through fifteen weeks of a design project. Students are required to write in journals throughout the entire year and to reflect on changes that they see in themselves as emerging professionals. Some of the responses are predictable for freshmen and pertinent to any professional who engages in collaborative work.

> There are many things I learned about myself during the time of the freshman design project. In this new atmosphere of teamwork and different people, it overwhelmed me and changed me in some ways. When a person like me steps into an atmosphere of team work it is kind of scary....I learned many things to help me with future projects. I learned how to be patient with other people, Also not to panic so quickly. One person can't always do all the work. Other people are there to help, not to pull you down. Others sometimes try their best even though you may not think so. I have to think of every assignment as a real one because it will prepare me for the future.

Students are learning not only the content of engineering, but also the leadership and group dynamics skills that they will need to function in a complex, public arena. These lessons match the ABET criteria in a genuine engineering project, so they should have outcomes that can be measured. Certainly, the students recognize their value:

> I've tried to touch on some of the things that I think will help me in my quest to become a productive engineer. O.K., sure, I've also learned some technical things. I've certainly learned a lot about group dynamics—our group I believe has functioned well together. I've seen my role as a group leader develop in ways that have benefited me but have also made me realize that a group leader is not one who is worth more or who plays a more instrumental role, but rather one who functions as a synthesizing site where the ideas of the group can be centralized and formalized in a coherent manner.

On the negative side, students are not accustomed to responding to different audiences simultaneously, i.e., how to get an A when two teachers, or at least from two different fields, must be pleased. For the record, the team leaders of the various disciplines meet weekly to plan and appraise each other of the status of the existing syllabi and assignments, and the humanities team meets weekly to discuss such information and various approaches to the forthcoming topics. However, even with that extensive coordination, simply using the different vocabularies of the English teachers and the engineers causes confusion. That and the difficulty of working with other people for a grade generated the following student criticism:

> What I've learned about myself as a learner is that I cannot trust people in regards to their credibility as a good student. I don't feel that the system currently employs a way of ensuring good credibility....There are other things that bother me with freshman design though. There needs to be better communication between the humanities teachers and the group advisors.

Freshmen are still in the process of finding themselves and sometimes they do find out what it means to be an engineer only to discover that they are not suited for the profession. It is arguably good, even though negative, that they make the discovery before investing more time in the wrong curriculum. The following student comment illustrates their ambivalence when they experience the joy of creativity and the annoyance at not being self-sufficient:

> Nothing teaches better research and teamwork skills than doing research and working in a team. I learned much about people while working on this project. I learned how overly self-assured some people are and how they will defend their ideas to the death instead of admitting someone knew something they didn't. I also learned that people can be lazier than I ever imagined even when a four-credit grade is on the line. Not all was negative, however; I learned how to better research any topic I want. I also learned design skills. Creativity

> is far rarer than logic. Both are indispensable in the design process and one is worthless without the other. That fact is great support for teamwork; unfortunately, my team didn't work together enough for our skills to complement each other like they might have. Overall, I think the design project can be one of the greatest learning experiences of the freshman year and it only falls from this by the lack of seriousness of the students.

These student comments are typical, and even in the negative responses to interdisciplinary and cooperative learning as it occurs in the design project, students describe the experience as beneficial. An assessment plan that more clearly targets the same areas of faculty concern and alerts the students to their importance has generated the idea of the assessment worksheets discussed earlier in this article. The objective is to help all faculty develop a holistic and consistent grading standard that is clear to all involved, which may be quixotic but is worth striving for. As Peter Senge (1990) claims, "There is something in all of us that loves to put together a puzzle, that loves to see the image of the whole emerge. The beauty of a person, or a flower, or a poem lies in seeing all of it....Systems thinking is a discipline for seeing wholes. It is a framework for seeing interrelationships rather than things....It is a set of general principles—distilled over the course of the twentieth century, spanning fields as diverse as the physical and social sciences, engineering, and management....And systems thinking is a sensibility—for the subtle interconnectedness that gives living systems their unique character."

Academe has the means to provide holistic education, and engineering education, in particular, can benefit from it. Documenting the effectiveness of learning communities may speed their implementation and provide faculty and students with a way of learning that is more satisfying and more appropriate to the complex world of technology.

Conclusion

In retrospect, the Drexel Engineering Curriculum created a learning community in its efforts to improve the education of engineering professionals. The benefits of the learning community have been recognized, but the challenge now is to document these in a standardized way. Data that assess the benefits to students and faculty would facilitate recruiting both groups for the interdisciplinary program. Further, ABET will be accrediting all engineering curricula by the year 2000 on the new criteria, which encompass objectives that are not now easily assessed. Comparisons between programs should also be more balanced. For an urban university, the learning community based on the curriculum assuages the differences between students from different backgrounds and between faculty from different disciplines who are usually housed in buildings that may be blocks apart. Those of us fortunate enough to have experienced the empowerment of a learning community have no doubts about the assessment results, only a desire to welcome newcomers with evidence they can apprehend prior to the experience.

Suggested Readings

Angelo, Thomas, "The Campus as Learning Community: Seven Promising Shifts and Seven Powerful Levers," *AAHE Bulletin 49* (May 1997).

Arms, Valarie M., "Personal and Professional Enrichment: Humanities in the Engineering Curriculum," *Journal of Engineering Education* (April 1994).

Arms, Valarie M., "Joining the Conversation: Drexel University's Learning Community," *Liberal Education* (Winter 1994).

Fromm, Eli and R. G. Quinn, "An Experiment to Enhance the Educational Experience of Engineering Students," *Engineering Education* (April 1989): 424-429

Haslam, Elisabeth, "A Learning Model that Develops Students' Active Learning and Reflective Practices," *Proceedings of Frontiers in Education* (1997).

Johnson, David W., Roger T. Johnson, and Karl A. Smith, "Maximizing Instruction Through Cooperative Learning," *ASEE PRISM* (February 1998).

Quinn, Robert G., "Drexel's E4 Program: A Different Professional Experience for Engineering Students and Faculty," *Journal of Engineering Education* (October 1993).

Senge, Peter M., *The Fifth Discipline: The Art & Practice of the Learning Organization* (New York: Currency Doubleday, 1990).

Springer, Leonard, Elizabeth Stanne, and Samuel Donovan, "Effects of Small-Group Learning on Undergraduates in Science, Mathematics, Engineering, and Technology: A Meta-Analysis," National Institute for Science Education (1997).

Wheatley, Margaret J., *Leadership and the New Science* (San Francisco, CA: Berrett-Koehler Publishers 1992.)

CD-ROM:

"Continuous Faculty Development" and

"Gateway Works: the People and the Products" (available through the web site http://www.gateway.vpr.drexel.edu/Gateway/projects. html# HPD_FD.)

Web sites:

http://www.abet.ba.md.us/EAC/eac2000.html

http://www.gatewaycoalition.org

http://www.tdec.coe.Drexel.edu

http://www.tdec.coe.Drexel.edu/edl_website/ for the "Engineering and Design Lab"