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The Center for Engineering Education and Practice: Rethinking Engineering Education

Engineering faculty should have close contact with those in business, industry, and government who are practitioners, yet the university typically rewards research publications as opposed to collaboration with practicing engineers. To counteract this problem, the University of Michigan-Dearborn's School of Engineering has established a Center for Engineering Education and Practice that has the goal of combining teaching, research, and practice in a joint effort with industry. Multiple projects are funded each year that serve to answer real questions in the engineering community, enhance the school's curricula, and provide hands-on experiences for students. The Center has made a dramatic impact on the school, both in terms of relevance of the program, and in increased student enrollment.

Engineers, unlike physicians, are taught in an environment quite different from the environment of practice. Over the years this has caused distortions in values, attitudes, and, ultimately, curriculum that have negatively affected the engineering profession. Design and manufacturing have suffered the most. In addition, a reductionist model of knowledge acquisition has made a large body of emerging research useless. A mythology has developed that defines engineering as applied science, devaluing the fundamental research issues that engineering offers through its very complexity.

During the last several years, information has been obtained through meetings with over 200 industrial stakeholders at professional and management levels in large and small companies. The following observations can be made:

- Currently, expenditure by industry on in-house education is more than the total expenditure in the United States on post-secondary education. While many programs in industry are unique and

justifiably customized to specific company needs, most are generic among industries and often overlap or duplicate offerings available at universities.

- Engineering education is a continuum that starts with the basics at the undergraduate level, followed by practical education, in-house training, on the job training, and continuing educational experience in either degree or nondegree programs.
- In Michigan, a transition is taking place in which engineering tasks traditionally done by the Big Three auto companies are gradually being shifted to suppliers of varying size. The need for versatile engineers, especially those who can make the transition from design to manufacturing, is going to be greater.
- Engineers are also working increasingly in an internationalized environment. Often, teams consist of engineers from various countries. Many U.S. companies have strong engineering and manufacturing links to Europe.

The Problem

Universities have not questioned existing paradigms in education and have become of marginal benefit to the education of working engineers. Apart from the colossal waste of duplication of educational capabilities between industry and university, there are significant detrimental effects in how engineers are educated. Education in industry, when isolated from universities, often becomes merely training; education of engineers in universities, when isolated from the practice of engineering, becomes sterile, irrelevant, and obsolete, especially toward the final year of undergraduate education and for most of graduate education and continuing education at the noncredit level. A particularly pernicious effect of this separation is poor quality-of-design education. Finally, owing to the dominance of models and incentives within universities directed toward liberal arts education, most engineering faculty cease to be engineers and pursue models of creativity irrelevant to engineering practice. What is needed is a structural change in how engineering education is delivered and by whom.

The Clinical Model as a Possible Solution

An approach to addressing some of the existing pathologies is to combine traditional concepts of continuing education, off-site programs, and cooperative education offered by universities with practice in teaching companies. The concept is analogous to the clinical education of physicians that includes practice in teaching hospitals. A joint industry/university center that combines teaching, research, and practice is an attractive solution. Clearly, this is easier to implement at universities that are in heavily industrialized locations. The conceptual structure is shown in Figure 1.

A CLINICAL MODEL FOR ENGINEERING EDUCATION

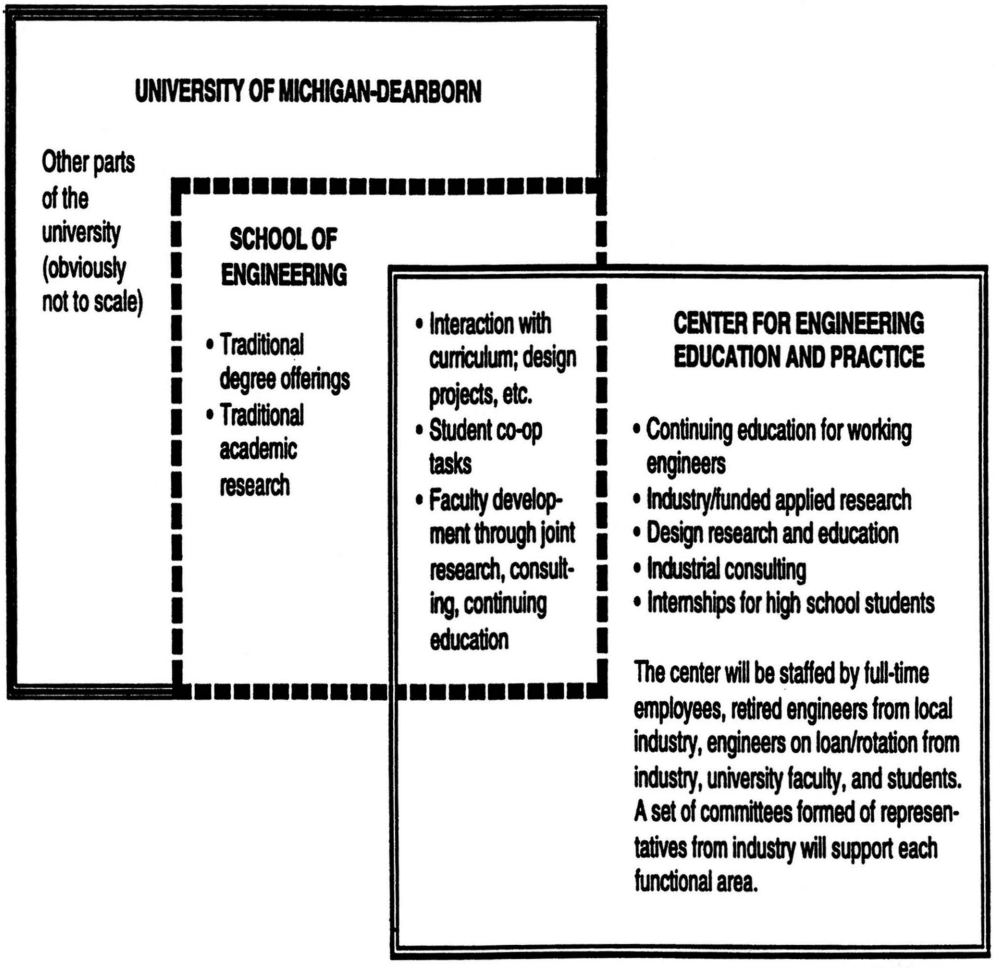

Figure 1. The Conceptual Structure for the Center for Engineering Education and Practice

The Center for Engineering Education and Practice (CEEP) at the University of Michigan-Dearborn (UM-D) was founded in 1992 with support from the Ford Motor Company and the Chrysler Corporation. The Center's mission is to be a leader in incorporating engineering practice, design, innovation, and concepts of manufacturing technology at all levels of engineering education, by integrating the teaching environment with the world of practice. The Center consists of the following groups:

- A continuing education group for engineering with participation from both university and industry, including on-site personnel from both sides.
- A group for graduate degree programs for working engineers. This is managed by university personnel with advisory boards from industry.
- A group for design education and research. This is staffed by faculty, graduate students, and engineers from industry on loan on part-time or short-term bases. Activities focus on design curriculum development and design instruction for undergraduate, graduate, and continuing education courses. Applied research projects will be a major emphasis.
- A consulting group consisting of faculty, full-time engineers, and retired engineers from nearby industries. The last group is a resource to be used and nurtured. Most of these people serve on a part-time or as-needed basis. They can also serve as institutional memory and cushion the shock of losing expertise acquired once long-time employment ends.
- Offices, classrooms, and design studios are housed in the same building, ensuring physical proximity of diverse personnel.

Benefits

The benefits of the Center are the following:

- Innovative courses and curriculum, especially in design, that can be tested and made available to other institutions.
- Enhanced education opportunities for working engineers, integrated with undergraduate and nontraditional programs.
- A quantum jump in design education at all levels.
- A fundamental enhancement of faculty quality and orientation by interaction with engineers in industry. Faculty become and remain engineers.

- Availability of trained retired personnel for consulting services, providing institutional memory for affiliated companies and ensuring that findings from practice are integrated into teaching.
- Teaching of students by experienced engineers from industry.
- Continual exchange of ideas between students, teachers, and practitioners;
- An environment for applied research in which industrial and university personnel work together.

Collaboration with Industry

The components required to develop the Center were already in place in various forms at UM-D:

- Metropolitan Detroit represents an area where challenges from foreign competition are very strongly felt.
- Historically, UM-D was created by support from the state of Michigan and Ford to provide graduate engineers for the growing industry. This is a purpose that the university has served well, and it will continue to be an important part of its mission.
- Ninety-five percent of the graduate students at UM-D are practicing engineers.
- On-site degree programs at industrial sites are already being delivered by UM-D.
- Numerous noncredit courses are offered by UM-D for practicing engineers. An advisory committee consisting of industrial representatives provides guidance for the program. Often, customized courses have been developed for industrial clients.
- The Manufacturing Systems Engineering Laboratory, funded mostly by industry, has served as a provider of unique educational programs. It is an essential resource to the education of working engineers seeking master's degrees and has changed the school by providing a facility for applied research. Support has come from Ford, Chrysler, United Technologies Automotive, Tenneco, ASC, and Craft Line.
- Many projects have been completed by UM-D faculty for local industries, both as research projects and on a consulting basis.
- Many industrial researchers from local industries serve as adjunct instructors for UM-D graduate, undergraduate, and

continuing education courses.

- UM-D location is proximate to many sites, and within a radius of 20 miles there are approximately 100,000 engineers.

Implementation

The approach to causing change was to identify and support faculty and projects that would catalyze the existing institutional processes. The Center formed an advisory board to review progress and to help determine future direction. Board members represented Ford Motor Company, Rockwell International Corporation, General Motors Corporation, TRW, Inc., United Technologies Automotive, Detroit Edison Company, and Chrysler Corporation.

The dean of the School of Engineering, the author of this article, has served as director of the Center since 1992. A search for a full-time director is nearing completion.

Personnel

The director to be hired for the Center will be an engineer with substantial experience in industry. Other personnel consist of:

- the participating faculty of the School of Engineering at UM-D;
- visiting faculty from other institutions; engineers on short-term or part-time loan from industry;
- exceptionally qualified retired engineers;
- graduate research assistants;
- co-op undergraduate students;
- motivated high school seniors on summer jobs.

Faculty Internships in Industry

The most effective way of adding elements of the culture of practice into the academic environment is to have faculty spend time in industry. The Center funds salaries of faculty who work in industry. It often facilitates internships that are completely industry funded. It also matches federally-funded faculty internships through the Grant Opportunities for Academic Liaison with Industry (GOALI) program of the National Science Foundation. One popular program has been to add a half-year paid industrial internship to a half-year paid sabbatical.

These internships not only widen faculty perspective, but allow the hosting industrial partners to value faculty participation. Industry-funded projects have re-

sulted in several continuing relationships. Joint university/industry proposals for federal support have also been successful.

Collaborative Projects with Industry

The Center supports collaborative projects with industry. A competition is held every year for the school's faculty, with projects selected by external (largely industrial) reviewers with relevant expertise. The following criteria are used:

- industrial relevance, as demonstrated by existing, ongoing activity in a company willing to participate in the project;
- active collaboration with practitioners, as evidenced by joint investigations, data sharing, joint publications, and presence at each other's sites;
- long-term technical merit, essential in order to avoid the temptation of doing well-funded but routine tasks;
- impact on the curriculum, as evidenced by changes in existing courses, new courses for credit, and not-for-credit programs;
- funding from external sources as clear evidence of a successful convergence of relevance and quality.

Projects can be supported solely by the Center, jointly by the Center and an industrialsponsor, or completely by an external industrial sponsor. Those projects with sole support through Center funds are limited to two funding cycles.

Senior Design Contest

The Center sponsored a school-wide senior design contest in 1997, after several years of discussion and changes in the senior design experience. Competitions held within each department resulted in the selection of three nominees for the school-wide contest. External juries awarded the prizes.

Interdisciplinary Student Projects

For several years the Center has supported student projects that recruit students from various disciplines for team participation in national design competitions such as the Natural Gas Vehicle Challenge, the SAE Formula Car Competition, and the Automated Guided Vehicle Competition. Financial support from the Center has leveraged substantial extended support in many cases.

Continuing Education for Practicing Engineers

A natural corollary to the clinical model is the integration of continuing education within the school. Continuing education activity at the University of Michigan started as a centralized program administered by an associate dean who reported directly to the provost. The School of Engineering participated in this program, providing courses taught by tenure-track and adjunct faculty. In an effort to make the process more productive, there was a reorganization that brought the engineering professional development component into the Center for Engineering Education and Practice in April 1996 as part of the original vision of the Center. Since then, the revenue stream in engineering professional development (EPD) has doubled, with over 1,000 yearly participants.

Dissemination

The Center holds a yearly meeting to review project results, a "Technology Day" during which the faculty and their industrial collaborators present the results of their work. Recently, Technology Day has been structured to include an industrial panel followed by a poster session of projects that have industrial collaborators. The panel discusses issues relevant to increasing cooperation and publishes an abstract of proceedings. The meeting is open to the public. The Center also publishes a newsletter twice a year highlighting achievements.

Impact on Faculty, Students, and Curriculum

The clinical model of engineering education advanced by the Center envisions a collaborative atmosphere among participants, faculty, and students that has impact on research, curriculum, and teaching. Indices that measure these outcomes through the fourth year are:

- number of funding cycles - 5
- number of projects - 60
- collaborating practitioners - 95
- faculty involved - 22
- undergraduates involved - 34
- graduate students involved - 32
- high school students - 39
- number of new courses planned - 19
- number of modifications to courses - 83

Over the years, the Center has been involved in about twelve externally-funded projects with industrial collaborators per year. Examples of projects include:

- "Air- and Structure-Borne Noise Reduction for Vehicle Dampers," which involved Monroe Automotive Equipment Corporation, with an impact on the program in that two courses were modified, case studies were created, theses were developed, and a research assistant was employed (1996);
- "Development of Thermoplastic Composite Stamping Processes for Automotive Applications" with Siemens Automotive and Allied Signal Plastics, with an impact on the program in that a course was modified, demonstrations were offered to students, and a visiting research scientist was available (1995);
- "Evaluating Sensors for Object Detection" involving Ford Motor Company and U. S. Army TACOM, with the result that modules for two courses were created, undergraduate capstone design projects were carried out, and undergraduate internship opportunities were made available (1994, 1995);
- "Massively Parallel Processing Technology for Industrial Machine Vision Applications," involving Applied Intelligent Systems, Inc., with an impact on the program in that a graduate course was created and a research assistant was employed(1993);
- "Exhaust Emissions and Their Control in Lean Burn Natural Gas Engines," with Ford Motor Company and Diesel Controls Limited, with an impact on the program in that a fuel systems course for Ford Motor Company was created (1993).

The Center was started in January 1992. Currently, over $3 million in unrestricted gifts has been obtained, and several times that amount has come from specific project funding from industry and government to support projects seeded by the Center. Some of the changes fostered by the concept of the Center and the growth in interdisciplinary programs led to a reorganization of the school. The critical role of the Center in supporting faculty and building external relations is evidenced within the new structure.

Unrestricted grants provided by many corporations include those from: Applied Intelligent Systems, Aries Technology, Craft Line, Inc., Chrysler Corporation,

Detroit Edison, Ford Motor Company, Michigan Bell Telephone (Ameritech Michigan), Rockwell Automotive, Royal Design and Manufacturing, Siemens Automotive, TRW, and United Technologies Automotive.

Other projects have been supported by funding and personnel from: ASC, Inc., Cincinnati Milacron, Hewlett-Packard, The Budd Company, CIMLINC, Ford Motor Company, Michigan Consolidated Gas Company, Diesel Controls Ltd., United Technologies Automotive, Wisdom Systems, and Royal Design and Manufacturing.

Additional accomplishments of the School of Engineering include the completion of a new 53,000-square-foot engineering complex, which houses the Center as well as nine new laboratories for teaching and research. There are another 15,000 square feet of space in an attached continuing education building where noncredit engineering programs are offered. The new laboratories are as follows:

- Automotive Electronics Laboratory
- Plastics Processing Laboratory
- Specialized Design Studios
- Ergonomics Laboratory
- Rapid Prototyping Laboratory
- Networking Laboratory
- Artificial Intelligence Laboratory
- Hypermedia Laboratory
- Ingenuity Laboratory

Office space is available for industrial partners for the duration of the projects. This helps in casual, but effective, interaction with our faculty.

The Center has catalyzed a capital campaign generating over $8 million in private funds for projects and equipment, and over $5 million from the state for building construction.

Conclusions

The impact of a single initiative on a complex organization such as a university or school is difficult to assess with firm causal connections. However, qualitative connections can be identified and overall outcomes assessed through the indices enumerated above.

The Center enhances the appreciation by faculty and the university administration of our connectivity to our local industrial community. A keen awareness of our stakeholders' needs and wishes now permeates the faculty at an individual level, and is the key to many positive outcomes.

While nationwide engineering enrollment has dropped by 20 percent in the 1990s, the School of Engineering at the University of Michigan-Dearborn has grown by 70 percent. In 1990, the school had 950 undergraduate students and 250 graduate students. Today there are 1,300 undergraduate students, 900 graduate students, and over 1,000 students in our noncredit programs. What is most telling is that the entire growth in the school has come from new programs. If the school had only the programs today that it had in 1990, the enrollment would have been 20 percent lower! But since 1990, new graduate programs include:

- master's degree in Engineering Management (interdisciplinary with the School of Management);
- master's degree in Computer Science;
- master's degree in Computer Engineering;
- master's degree in Automotive Engineering (interdisciplinary, involving all departments in the school);
- Participation in the Doctor of Engineering degree in manufacturing at Ann Arbor (interdisciplinary, with all departments in the school).

The preponderance of interdisciplinary programs is quite telling, and their nature was strongly influenced by the interaction with our external industrial stakeholders.

The influence on the faculty has also been quite dramatic. Today, over 80 percent of our faculty work on industry-related research, a dramatic difference from a few years ago when only a handful were involved. External funding levels have increased manyfold during this period.

The Center for Engineering Education and Practice has made a dramatic impact on a long-existing School of Engineering. The successful pursuit of the clinical model for engineering education will continue as a strategy for the school.

Lessons Learned

The most difficult part of our experiment has been the ongoing process of convincing faculty that the Center's purpose is not simply to obtain industrial support for academic research and publications. The notion that the complex, inelegant problems constituting the reality of engineering practice can contribute greatly to curriculum and research is difficult for some faculty to accept. At least several generations of faculty came into universities after the Sputnik milestone when the paradigm of sci-

ence was accepted as an ideal. Simplicity and reductionism triumphed, and synthesis and complexity suffered. Those holding intellectual values of hiring, tenure, promotion, and all the other incentives and environmental support systems that constitute engineering education today looked with suspicion, at least at first, to the intrusion of practice into academe. The centrality of practice in engineering education must be articulated clearly, repeatedly, and consistently, which is the core value of the Center.

However, it is important not to devalue the importance of reductionist thinking, which is crucial in many academic projects. The purpose of the Center is to enrich the lives of the students and faculty, not substitute one set of dogma for another.

For those who wish to pursue similar endeavors at other institutions, the following do's and don't's may prove useful.

Do's

- Recruit a core group of external, local stakeholders at a very early stage who will support the Center in an advisory capacity and with funding;
- Obtain early support from university leadership;
- Ensure that project selection is influenced largely by practitioners;
- Be inclusive in bringing into the Center's sphere of support the existing research, seminars, student/faculty internships, adjuncts, and other resources and activities that fall within its scope;
- Be inclusive in terms of supporting as many faculty as possible. Even though some faculty will not share in the vision of the Center, as long as they satisfy publicly stated criteria they should be supported;
- Monitor project performance, especially the influence on curriculum. This is a part that is often ignored because it does not have an impact on the usual imperatives of publication;
- Showcase output for external stakeholders. This greatly enhances cooperation by simply increasing the number of contacts and interactions;
- Ensure that activities supported by the Center are recognized in the reward system for faculty.

Don't's

- Do not focus on the success of individual projects. Collective change is the objective;
- Do not expect quick results. At UM-Dearborn, the Center has

functioned for five years. We have seen some important changes, but it takes several years and several hiring and tenure cycles for the changes to be self-sustaining. We have a long way to go.

Acknowledgments

Changing culture is always difficult. Personal gratitude is owed to all those who spent time talking and listening to the author in 1990-91 as the concept of the Center developed. Dr. John McTague and Hank Lenox of Ford Motor Company were initial supporters, as was Robert Marcell of Chrysler Corporation. The advisory board has been an inspiration. Mr. Jerry Rivard of Global Technology Business Development has been extraordinarily supportive with ideas and encouragement. The administration of the university supported the Center from the beginning. Chancellors Blenda Wilson and James Renick provided financial, intellectual, and political support, as has Provost Robert Simpson. Of course, the most important group to whom I am indebted is the faculty of the school and the numerous industrial collaborators. They have defined the Center and in so doing changed the culture of the school. The Center has been administered effectively by Kathryn Tamborino since its inception.

Call for Contributions

Metropolitan Universities continues to welcome the submission of unsolicited manuscripts on topics pertinent to our eponymous institutions. We seek contributions that analyze and discuss pertinent policy issues, innovative programs or projects, new organizational and procedural approaches, pedagogic developments, and other matters of importance to the mission of metropolitan universities.

Articles of approximately 3,500 words should be intellectually rigorous but need not be cast in the traditional scholarly format nor based on original research. They should be *useful* to their audience, providing better understanding as well as guidance for action. Descriptions of interesting innovations should point out the implications for other institutions and the pitfalls to be avoided. Discussions of broad issues should cite examples and suggest specific steps to be taken. We also welcome manuscripts that, in a reasoned and rigorous fashion, are *provocative*, challenging readers to re-examine traditional definitions, concepts, policies, and procedures.

We would also welcome letters to the editor, as well as opinion pieces for our forum pages. Individuals interested in contributing an article pertaining to the thematic portion of a forthcoming issue, or writing on any of the many other possible subjects, are encouraged to send a brief outline to either the appropriate guest editor (addresses available from the executive editor) or to the executive editor. Letters and opinion pieces should be sent directly to the latter:

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