Document: 2002-367
Division: Engineering Management

Strategic Planning for OU Engineering Education

Donna L. Shirley, Jeffrey H. Harwell, Sr., Hillel J. Kumin
College of Engineering, University of Oklahoma

Abstract

The College of Engineering at the University of Oklahoma has developed a strategic plan which it is currently implementing. This paper describes the plan and the activities underway to implement it with respect to engineering education. The vision of the College of Engineering is to "produce the engineering graduates most sought after by industry and investors". This overarching vision devolves into three goals, which can be summarized as: 1) Provide a cutting edge education, 2) Get, retain and market job producing and creating students, and 3) Perform cutting edge research. These goals have been fleshed out in the form of a work breakdown structure for the purposes of assigning responsibility and defining assessment processes. Each of the discipline areas within the College has developed plans congruent with the overall College plans. The ABET 2000 process, which has been adopted by the College, is also in synchronicity with the overall plan. The paper outlines the means by which the strategic plan is used to provide guidance to the day-to-day activities and directions of all elements of the College, with a specific focus on the application of engineering management techniques to engineering education. Concrete examples of this are presented.

Vision and Goals of the College of Engineering

Strategic Planning for the College of Engineering began in 1998 with the leadership of a new Dean of Engineering, Dr. W. Arthur (Skip) Porter. By the year 2000 the vision of the College was defined to be: " To produce engineering graduates sought among the first by industry and investors for excelling in a rapidly changing, technology-driven world, both as engineers and technology managers in existing companies, and as leaders in starting new, technology-based companies."

Three major goals were defined to achieve this vision:

1. Cutting Edge Education - Enhance the traditional role of teaching excellence and mentoring by becoming a leader in the demonstration of technological innovation and personal creativity in the knowledge delivery and learning process.
2. Cutting Edge Research - Expand traditional faculty research through leadership in the creation of new technology and processes, industry partnerships in product development, and economic development through the spin-off of new technology-based ventures.

3. Job Excelling and Creating Graduates - Attract and retain the very best students by our leadership in producing graduates widely known for not only being in great demand for existing jobs, but for their understanding of, and unique preparation for, creating jobs.

These goals led to the definition of specific educational objectives for the College, such as:

1. Cutting Edge Education
   a. Improve the student/faculty ratio to at most 15/1 in every school, which will require increasing the faculty by 40-50%.
   b. Increase project-based, multidisciplinary educational opportunities.
   c. Increase our focus on technology-based learning to enable educational innovation.
   d. Improve the educational infrastructure.

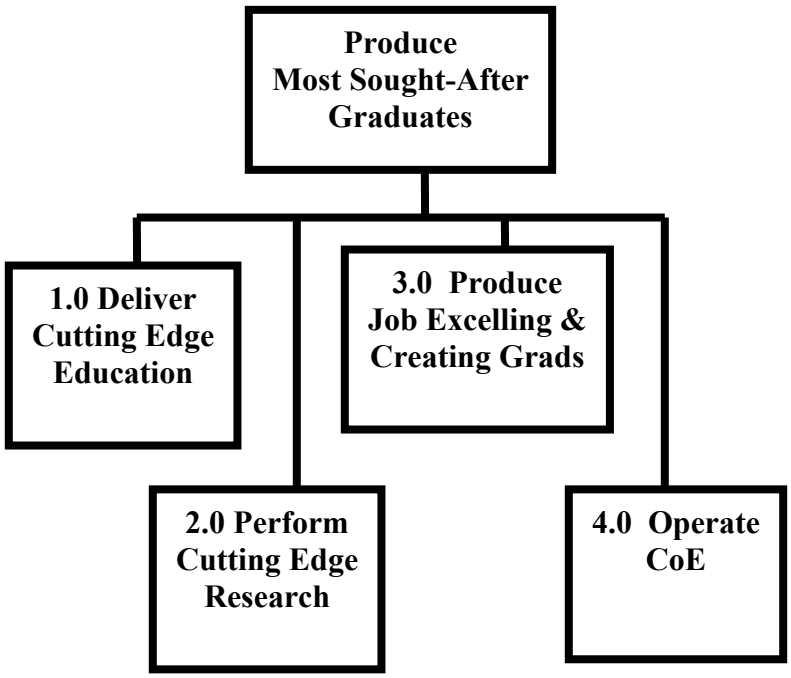
2. Cutting Edge Research
   a. Increase the participation of undergraduate students in research.
   b. Provide education in business and entrepreneurship.
   c. Provide opportunities for student participation in the development of commercializable technologies.
   d. Increase opportunities for participation in industry-focussed or sponsored projects.

3. Job Creating and Excelling Graduates
   a. Increase undergraduate enrollments in selected disciplines.
   b. Increase graduate students by 50%.
   c. Focus on recruiting students with both high academic and leadership capabilities.
   d. Increase scholarships and fellowships.

Figure 1 puts these major elements of the strategic plan, plus an element to implement and coordinate the day-to-day operations of the college, into a work breakdown structure. A very detailed work breakdown structure was developed from this top-level structure, which was used to allocate functions among the College's administration.

Figure 1

OU College of Engineering
Top-Level Work Breakdown Structure



Implementation Plans and Goals for Educational Elements

"Cutting Edge Education" in the Strategic Plan includes improving the curriculum and the means by which the students are educated, and adding elements to create engineering entrepreneurs. "Producing Job Excelling and Creating Graduates" means that students must be recruited, retained and supported in getting excellent jobs or starting companies when they graduate. (The College is, of course, also committed to readying students for advanced degree programs.) These two elements of the Work Breakdown Structure are the major foci of the educational elements of the College's planning and implementation activities.

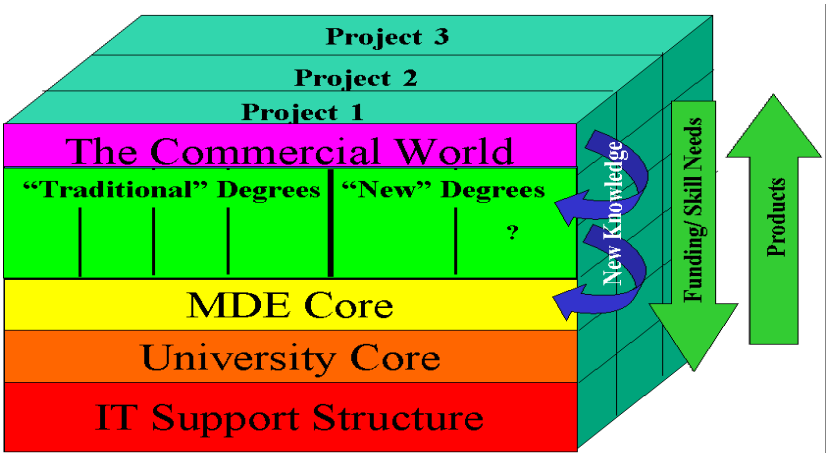
Multidisciplinary Engineering

Curriculum improvement activities are focussed on Multi-disciplinary Engineering. In 1998 a committee comprised of faculty, administrators and advisors recommended an innovative approach to engineering education focussed on providing opportunities for students to understand and participate in the interplay of engineering disciplines[i]. Engineers in each discipline must, of course, be technically competent in their field. But today's engineers are also expected to be capable of working within modern

environments. Ability to use information technology, work in teams, understand business and global culture, communicate, and continue to learn throughout a career have been defined by prospective employers as vital for success in engineering.

Figure 2 illustrates the various components of a holistic engineering education.

Figure 2: The MDE Concept



Multi Disciplinary Engineering (MDE) will allow seamless, cross-disciplinary interactions between various areas of engineering, which are imperative to the success of project-driven learning. MDE builds on a core of university general education (including math, science, social science and humanities). Effective education in the modern world is increasingly dependent on a foundation of information technology. A core curriculum of multi disciplinary engineering which comprises information that all engineers need builds on the university core. Multi disciplinary projects provide "hands on" application of the engineering principles learned in the core. As students move into their disciplinary specialties, multi disciplinary engineering is maintained by projects involving more than one discipline. Ideally, these projects are commercially- and research-based, while at the same time expanding beyond technical expertise to incorporate the critical interaction skills (e.g., communications and teamwork) needed by today's engineers.

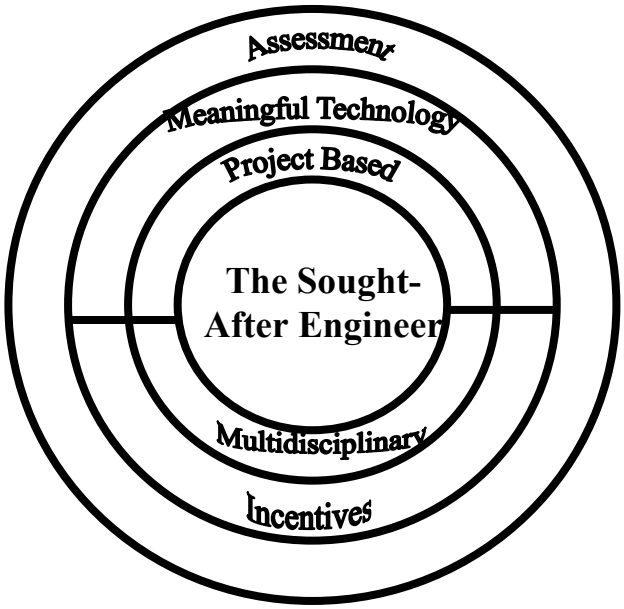
A multidisciplinary core will more efficiently cover the functional core of engineering and allow time to incorporate people and communication skills. The goal is to interface with the commercial world throughout the entire curriculum. In this model, industry provides design- or research-based projects that integrate across disciplines and throughout all four years of study: a concept that will provide synergism for knowledge creation and integration. The projects should generate products of value to the client and also provide a natural feedback mechanism for new knowledge to be disseminated throughout the curriculum.

Activities are underway to implement this approach. A committee was formed in 2000 to address cross-college integration of MDE.

A key element of the MDE approach has been to develop an integrated vision for its applicability to the College of Engineering. A schematic of this vision is shown in Figure 3.

Figure 3.

The CoE Educational Vision



The following are the characteristics of the Vision:

The "Sought-After Engineer" corresponds to the CoE Strategic Vision: "Produce the most highly sought-after engineering graduates".

Having the Sought-After Engineer at the center of the diagram ensures a student focus.

A Student focus pays attention to and takes advantage of:

- Individual learning styles
- Student excitement about learning
- Student retention

Project Based education includes projects which are:

- Available for student participation all four years
- "Real World" either in research or applications
- Funded, preferably by industry.

Multidisciplinary Engineering requires collaboration and teamwork

- Of faculty within and across schools
- Of engineers and non-engineers
- Of students

Incentives are to both faculty and students and include:

- Rewards
- Resources
- Strictures (enforced rules)
- Standardization to some degree so that assessment is possible and rewards/demands are equitable
- Cross-College
- Benchmarkable for ABET

Meaningful Technology means the use of technology which is meaningfully integrated into education

- Integrated via a systematic plan
- Innovation is diffused throughout the CoE
- Technology results in more, better or different learning, and is not just inserted for its own sake or for novelty.

Assessment: The entire system of producing The Sought-After Engineer must be validated through assessment

- Benefits must be provable, demonstratable, and measurable.
- Actions must be cost effective
- Actions must be affordable

In order to implement the vision, all elements of engineering education must be modernized in conjunction with each other. It does no good to require all students to use laptop computers in the classroom if the infrastructure cannot support them and the instructors don't teach so that laptops are useful for instruction.

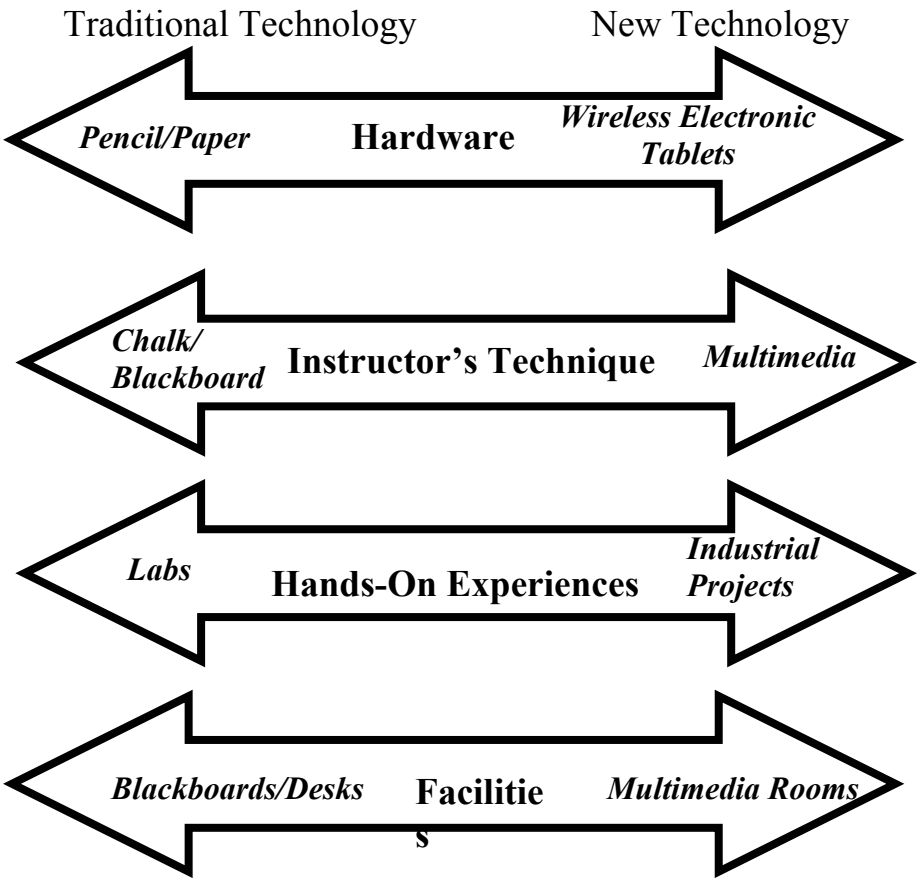
Figure 4 is a schematic of how educational elements can be brought forward synchronously. This does not mean that pencil and paper or research labs will be abandoned, but that as modern technologies or techniques are introduced, they must be supported by other elements.

Committee Actions

Based on the vision, the committee has initiated or completed a number of actions. The committee's activities are documented on the MDE web site (http://coecs.ou.edu/mde/opening.htm). They include:

- Development of an MDE web site.
- Defining what it means to be a "laptop college".
- Implementing facility improvements to support MDE

Figure 4.
Elements in Engineering Instruction



- Implementing training and support programs for faculty in the use of information technology for education.
- Support of faculty development of innovative education techniques.
- Review of courseware used for engineering courses
- Development of a laptop loan program
- Defining the College's computing requirements
- Restructuring the Introduction to Engineering class for efficiency
- Retention data analysis and development of models for retention of engineering students.

Examples of successful activities include the refurbishing of three classrooms from blackboards and "chesks" (the standard classroom chairs with built-in desks) to configurations which provide opportunities for student teamwork (tables) and information infrastructure support (i.e. power and ethernet connections, multimedia presentation capabilities).

An early committee activity was to evaluate the College's laptop program. A survey was conducted in 2000 of courses whose class descriptions included use of the laptop. In particular, laptop instruction was required for Introduction to Engineering, the first course taken by engineering majors. In addition to the faculty, students in laptop classes were surveyed to cross-check against the instructors' responses. Questions addressed what the laptops were used for, how they were used, how well the infrastructure (e.g. wireless network) worked, and whether the laptops' use was effective in teaching the material. Results were mixed, with the faculty ascribing more value to the laptops than the students. Issues included the relatively high first cost of laptops compared to desktops and the inadequacy of their capability to support computer science requirements, some lack of satisfaction with the way the laptops were used (e.g. to show power point slides vs. active classroom interaction), and problems with the infrastructure.

As a result of this survey the policy for requiring laptops to be purchased by incoming freshmen was revised to require them to have access to a laptop if it is required for a course. Support is being provided for instructors to develop web sites that will enable effective use of laptops. The cost of laptops is decreasing and their performance is increasing, which has improved student attitudes. In addition, the University of Oklahoma has instituted a purchase and lease program which further decreases the costs. The infrastructure is being improved. A follow-up survey will be conducted next year.

Other committees are addressing the issues of the core curriculum. Activities initiated or completed to date include:

- Revitalization of syllabus control and assessment for core courses.
- Definition of new engineering core courses, including those with a focus on computational architectures and software.
- Development and delivery of specific courses and experiences for educating engineers (and others) in MDE skills.
- Recommendations for improving the efficiency and applicability of basic math and science education for engineers.
- Suggestions for streamlining the traditional engineering core curriculum (e.g. Introduction to Engineering, Statics, Fluids, Dynamics, etc.)
- Recommendations for the University General Education curriculum (the University Core in Figure 2).

Project-Based Education

The University of Oklahoma requires that every student complete a "capstone" project in her or his field in order to graduate. Typically, engineering capstone projects have been discipline-focussed and single-semester. Some projects have been conducted incorporating multiple disciplines in the senior capstones. The School of Civil Engineering and Environmental Science has taken the lead in this area, involving mechanical and electrical engineers in their projects. Other "teaming" arrangements between Schools (primarily Mechanical and Electrical Engineering) allow students from one school to participate for credit in another school's projects.

In addition, plans are underway to incorporate lower level students into the capstone experience, for instance, to allow freshmen taking Introduction to Engineering to have a role in capstone projects. Some capstones are being extended from one to two semesters.

The College plans to broaden the project experience. A committee of alumni advisors, working with administration and faculty, have proposed an internship program to give college credit for work experience. Like many colleges, the College of Engineering has seen a downturn in the number of graduate students in the economically prosperous 1990's. Consequently, the College has increased its emphasis on facilitating undergraduate research experiences. Undergraduates are matched with faculty doing research in areas of interest. Policies are being developed to allow college credit for this research.

Credit for other projects is also being explored. For instance, the College of Engineering has many student-managed projects for national competitions such as a formula racing car, a solar-electric car, robots, and concrete canoes. Some of these activities, when conducted within the scope of a class, are allowed credit. Others are not. Policies are being developed to ensure that projects proposed for credit meet the College's accreditation criteria.

Professional Skills Education

Surveys of companies who hire CoE graduates reveal that they want increased emphasis on "professional skills" such as team work, communication, understanding of business processes, and ability to function in a global culture. In addition, the goal of producing "job creating graduates" calls for education in entrepreneurship. In addition to the University's General Education requirements for Social Science and Humanities courses, the College of Engineering currently offers four undergraduate courses which emphasize professional skills. These are taught by CoE deans and adjunct faculty whose work experience allows them to bring a strong basis of reality to these courses. They include:

- Leadership, taught by a retired 2-star Air Force General who is an alumnus of the CoE
- The Role of Technology in the Wealth of Nations, team-taught by the Deans of the CoE and of the Honors College
- Managing Creativity, taught by the Assistant Dean of the CoE based on her wide experience in management in the aerospace industry
- Entrepreneurship, team-taught by the Executive Associate Dean of the CoE and a member of the Industrial Engineering faculty, both of who have successfully started and managed businesses.

All of these classes feature additional lectures by experienced industry people, class projects, and the participation of non-engineering students. The CoE plans to extend availability to these courses, add a specific communications element (based on a graduate level course currently taught in Civil Engineering and Environmental Science), and propose at least one of the courses for the University General Education curriculum.

At the graduate level a new Masters degree in Engineering Management has been established by the School of Industrial Engineering. This MS focuses on the skills necessary to manage engineering projects. It is a specific, technically based, alternative to an MBA. It includes courses in "professional skills" (e.g. Managing Creativity) as well as business courses, and allows various options for a technical emphasis in operations research, logistics, etc., which are derived from the traditional MS in Industrial Engineering.

Individual Faculty Educational Research

In addition to the committee activities, individual faculty educational research is being coordinated through an Engineering Education Network. This network provides information dissemination on educational activities, proposal opportunities and publications, both internally to the College of Engineering, and externally. For example, a list of over 50 technical publications on engineering education by OU College of Engineering faculty has been posted on the MDE web site.

An example of a specific educational research activity is Sooner City[ii]. This project-based approach to Civil Engineering education is funded by the National Science Foundation. Sooner City fosters an integrated approach to design where a series of Civil Engineering courses build on each other through the design, over a student's educational program, of a virtual city. The design is captured electronically. The Sooner City approach has been codified in a multi media format for dissemination to other disciplines and universities[iii]. Multi media is being used in a variety of formats for both in-house and distance education. For example, courses are being taught using web-based formats[iv], CD ROMS[v], and interactive graphics where an instructor can manipulate the student's work[vi].

Cooperative learning techniques are also being studied and new tools developed[vii]. The above are merely examples of engineering educational research at the university level.

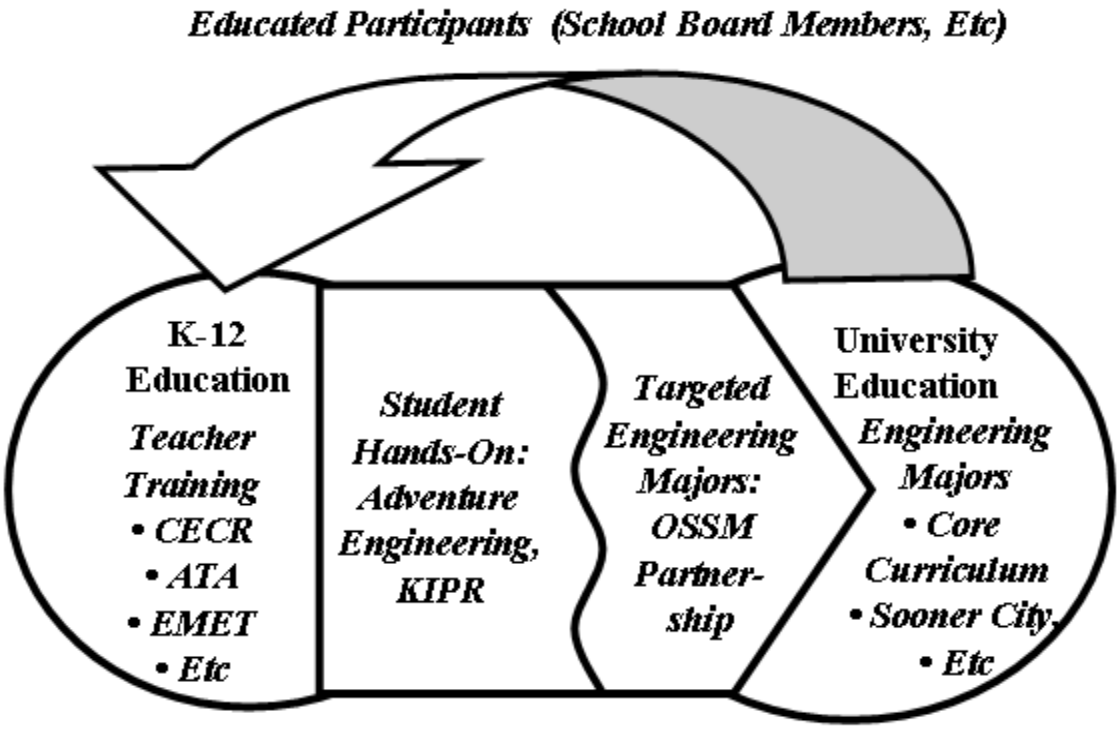
K-12 Education

Why should a College of Engineering be concerned with K-12 education? Figure 5 illustrates the "K-12 Pipeline" which is the basis of the CoE's K-12 program. Obviously, colleges of engineering need well-prepared students. But society also needs for its citizens to be aware of and capable of dealing with technical issues as they impact their lives.

The OU CoE "pipeline" includes teacher training through programs such as the Authentic Teaching Alliance (ATA)[viii], a partnership between the College of Education and the College of Engineering which is educating K-12 teachers in modern teaching practices, including the teaching of technical subjects. Opportunities for hands-on work with technology are provided by programs like Adventure Engineering[ix], in which engineering

students participate directly in classroom activities, and Botball (http://www.botball.org), in which middle and high school students build automated robots.

Figure 5.
The K-12 Engineering Education "Pipeline"



Partnerships with schools such as the Oklahoma School of Science and Mathematics (OSSM) (http://www.ossm.edu), which provides opportunities for high-achieving students, are resulting in a flow of very desirable engineering majors to OU. In the fall of 2001, 4 of the 61 OSSM students who graduated in the spring of 2001enrolled in the OU CoE, up from an average of 1 in previous years. (These students are sought by such institutions as Caltech, Stanford and Princeton). In addition, one of the authors of this paper is administering, through the Oklahoma Space Industry Development Authority (http://www.okspaceport.state.ok.us), ten NASA space education grants. Several of these include collaborations between Oklahoma universities and colleges and K-12 schools.

Assessment of Progress

The College of Engineering achieved ABET accreditation against the ABET 2000 criteria in 1999. This is the main focus of assessment of the quality of engineering education. However, the CoE has also decided to adopt a "Balanced Scorecard"[x] for assessing its progress against the strategic plan, which covers areas and activities beyond the scope of

ABET, although the ABET assessment process is a major input. Measures in the Balanced Scorecard are in four categories: Customer Perspective; Financial Measures; Internal Business and Management Processes; and Innovation, Learning, Improvement and Growth. Measurements include internal and external metrics. Some candidate metrics which are specific to the educational objectives are listed in Table 1.

Table 1.
Metrics for Assessing Progress Against Strategic Plan

Goals	**Objectives/Metrics**
Produce Most Sought After Graduates	Every graduate has at least one job offer, one admission to graduate school, and/or funding to start a business.
Deliver Cutting Edge Education	Every graduate has skills desired by a) employers, b) grad schools, and/or c) investors Every graduate is satisfied with her/his education
Provide Cutting Edge Curriculum	Provide students with skills desired by consumers of our graduates Curriculum is recognized as excellent ABET approval is retained Most courses in first 2 years = multidisciplinary 50% of courses use laptops effectively 20% of courses are on-line 10% of courses use multi-media Discipline courses build on multi-disciplinary curriculum
Ensure Instructional Excellence	15/1 Student/faculty ratio in all schools Faculty trained in new educational technology and incentivized to use it. 4.5 out of 5.0 Student satisfaction with instruction
Create Entrepreneurs	All students have some entrepreneurship training 20% of students take at least one entrepreneurship course 10% of students start a business Every graduate is familiar with state-of-the-art technology in her/his field
Perform Cutting Edge Research	Research integrated with curriculum so that grads understand technology
Produce job excelling & creating graduates	Get students who will be successful engineers Retain students who will be successful engineers Graduate students who will be successful engineers
Effectively operate the CoE	Provide educational infrastructure

Center for Engineering Education

The College of Engineering is developing plans to create a Center for Engineering Education. The Center will provide a formal means for coordination and collaboration of the College's engineering education activities. The Center will have a Multidisciplinary Engineering focus which will allow seamless, cross-disciplinary interactions between various areas of engineering, imperative to the success of multidisciplinary, project-driven learning. To accomplish the ambitious goals proposed for the Center, we will draw together engineering and non-engineering faculty, from our Schools, plus Mathematics, Physics, Education, and Instructional Development. Many of these Colleges and Schools already have faculty members with a history of collaboration and innovative education.

Summary and Conclusions

The College of Engineering of the University of Oklahoma is using its strategic planning process to materially improve and modernize its engineering education process. In the three years since the initiation of the strategic planning process considerable progress has been made in terms of achievement of faculty/staff alignment around the goals of engineering education. Many specific activities have been completed or initiated, most notably modernization of facilities and the broadening of the use of modern technology for instruction. Implementation plans are in place or being developed to meet all of the goals of the strategic plan.

The limitation on how far the College gets toward achieving its goals is largely funding-related and a capital campaign is being instituted to raise private funds for faculty, facilities, educational research, scholarships and fellowships. Additional funds to continue educational research are being proposed to the National Science Foundation, the Department of Education, and NASA, as well as to private foundations.

The College of Engineering believes that its Strategic Planning process will result in a major improvement in the quality of education for its students.

Bibliographic Information

[i] The results of this committee are documented most completely in, Fink, L. D., Kolar, R.L., Muraleetharan, Nairn, R.W., Sabatini, D.A., Sack, R.L., Rhoads, T.R. and Shirley, D.L. "Reengineering Sooner Civil Engineering Education", American Society of Engineering Education National Conference, 2000.

[ii] Kolar, R.L., Muraleetharan, K.K., Mooney, M.A. and Vieux, B.E., "Sooner City - Design Across the Curriculum," J. Engineering Education, ASEE, 1999, 89(1), 79-87.

[iii] Sun, Qiuli, Kevin Stubblefield, Kurt Gramoll, "Internet-based Simulation and Virtual City for Engineering Education," ASEE Annual Conf. Proc., St. Louis, MO, 18-21Jun 2000.

[iv] Court, Mary, "A Case Study on the Impact of Web-based Technology in a Simulation Analysis Course," Simulation 76:4, 207-213, April 2001.

[v] Crynes, B, "Rom and Ramble - Combining New Technologies and Old Methods for Better Learning and Use of Time," (with C. Dillon and B. Greene), ASEE 2001, Albuquerque, NM, June 24-27, 2001.
[vi] Sun, Qiuli, and Kurt Gramoll, "Internet-based Distributed Collaborative Geometric Modeling" Engineering Design Graphics Journal, in Press, Dec. 2001.
[vii] Trytten, Deborah, Progressing from Small Group Work to Cooperative Learning: A Case Study from Computer Science, Journal of Engineering Education, Volume 90, No. 1, January 2001, pp 85-92.
[viii] Nanny, M.A.; Proto, C.; Fedick, J. "Integrating the University and Hands-On Activities into the High School Science Curriculum: A Research-Based Outreach Program," ASEE 34th Midwest Section Conference Proceedings, April 16, 1999.
[ix] Mooney, M.A. and Taubach, T., "Adventure Engineering: A Design Centered, Inquiry Based Approach to Middle Grade Science and Mathematics Education", *J. of Engineering Education*, 2002, In Press.
[x] Internal CoE Communication: Dr. Teri Reed Rhoads and Dr. Justin Chimka, July 2001.

Biographical Information

DONNA L. SHIRLEY is Assistant Dean of Engineering for Advanced Program Development and an Adjunct Professor in Aerospace Mechanical Engineering, with foci in intelligent aerospace systems and management. She coordinates engineering education and planning for the College, and teaches multidisciplinary engineering courses.

JEFFREY H. HARWELL, SR is the Executive Associate Dean and Conoco/DuPont Professor of Chemical Engineering. He was formerly Director of the School of Chemical Engineering at OU. His duties include managing the strategic and day-to-day activities of the College. He teaches Entrepreneurship and performs research in surfactants.

HILLEL J. KUMIN is Associate Dean for Academics and Professor of Industrial Engineering. He supervises all activities connected with the recruitment, advising, and retention of undergraduate students. He chairs the Multidisciplinary Engineering Education Committee.