

AC 2007-2912: GOING GLOBAL: IMPLEMENTATION OF A COLLEGE-WIDE INITIATIVE TO PREPARE ENGINEERING AND TECHNOLOGY STUDENTS FOR THE 21ST CENTURY

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Going Global: Implementation of a College-wide Initiative to Prepare Engineering and Technology Students for the 21st Century

Introduction

Engineering is a global enterprise. Markets are global. It is not uncommon for engineers to design products which will be manufactured in Asia and sold in the United States, Europe and many other countries. The design process itself may be a round-the-clock operation, with teams coming on-line across various time zones. Supply chains commonly stretch across the world.

Competition is also global. Perhaps ironically, the technology created by engineers now allows engineering to be done virtually anywhere. The rise in Asia and India of a well-educated and highly motivated workforce willing to work for lower wages means that many routine or easily transported engineering activities will shift to these countries.

But, global competition is also intensifying in innovative new product and process development. Cutting edge research and analysis is now also performed at research centers across the globe. The technological leadership enjoyed by the United States since World War II will be increasingly challenged as the educational and research institutions of formerly less developed countries continue to mature.

How will the United States meet these challenges? We must develop engineers with abilities and skill sets that prepare them to be the innovative leaders in this paradigm. As stated by Ron Barr, President of ASEE, “We have to produce American engineers who are not only obviously technically well-grounded but more talented at things like creativity, leadership, communication and professionalism so that when a company hires an American engineer it expects him or her to lead that company or an international group of engineers¹. ” This same view was emphasized in a recent study by the National Academy of Engineering on the required attributes of an engineer for the year 2020. Besides technical excellence, the attributes include creativity, communication skills, leadership abilities, integrity, flexibility, and a commitment to lifelong learning².

In this paper, we describe the strategy that the Ira A. Fulton College of Engineering and Technology at Brigham Young University (BYU) is taking to meet these challenges. The strategy involves five key areas of focus: **1) Technical Excellence** with a systems emphasis, **2) Leadership**, **3) Character Development** (including ethics), **4) Global Awareness** and **5) Innovation** that address the attributes needed for success in a changing global environment. The paper addresses the attainment of faculty consensus and ownership, the empowerment of a college committee to develop strategic outcomes and recommendations, the strategy that was developed for implementation, and the results of efforts to date.

Faculty Consensus

Having identified what the college administration viewed as both a challenge and an opportunity for growth, the ideas, support, and consensus of the faculty were sought. Efforts began with the department chairs who were asked to read “The World Is Flat³” in preparation for the annual

college retreat. Discussion at the retreat centered on challenges facing engineering and technology, and the opportunity that these challenges presented for engineering and technology education at BYU. Subsequent discussions used the principles taught in “Good to Great⁴” to formulate a plan for moving ahead in a direction aligned with our strengths and the university mission. Additional activities aimed at encouraging faculty involvement included presentations to the faculty, faculty workshops, and the involvement of key senior faculty members on a college strategic initiatives committee.

Strategic Planning Initiatives Advisory Committee

A college committee was formed to direct the development of educational outcomes that characterize graduates capable of meeting the opportunities and demands of engineering and technology in the 21st century. This committee was also asked to make recommendations on how these outcomes might be achieved. The Strategic Planning Initiatives Advisory Committee (SPIAC) consisted of seven senior faculty members who were selected based on previously demonstrated interest, leadership, and activity within the five focus areas of focus. By design, all five academic units in the college were represented on the committee. A subcommittee was formed for each of the five focus areas. Each subcommittee was chaired by a member of the SPIAC committee; the other two members were the SPIAC chair and a member at large. The structure of the SPIAC committee and its relationship to the subcommittees is shown in Figure 1. The subcommittees consisted of three to four individuals with particular interest in the corresponding focus area. Development activities therefore involved approximately 20 people within the college; the SPIAC committee itself served to integrate the forthcoming ideas into a vision of the whole.

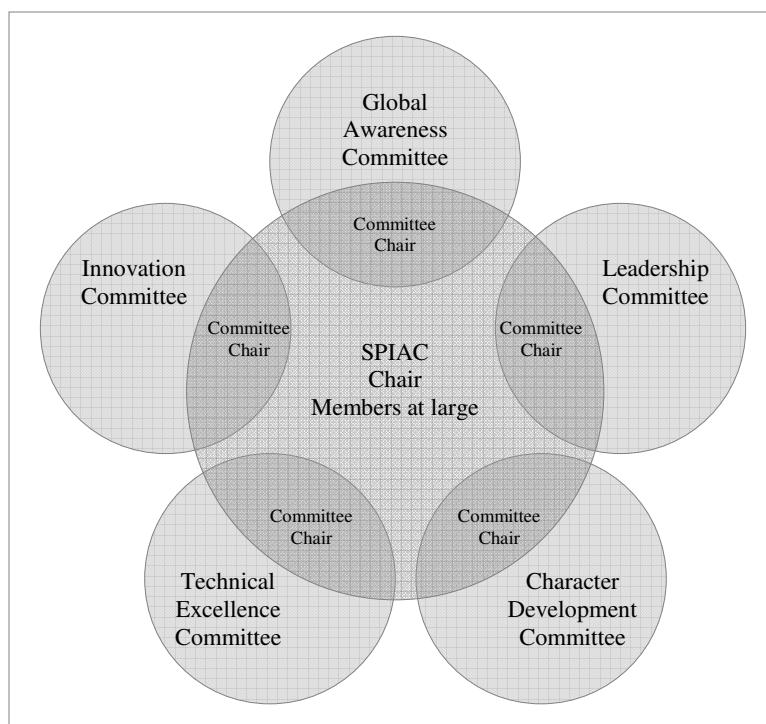


Figure 1. Make up of SPIAC committee and relationship to subcommittees.

Specific objectives were intentionally not given to SPIAC, but the instructions, focus and budget given to the committee made it clear that the results obtained were to be central to the college's response to the changing professional environment. This level of commitment to the committee was empowering and vitalizing. The lack of specific directives was, in hindsight, key to the commitment and energy developed within SPIAC as it was obliged to develop its vision within the context of the foundational principles of the institution and the broader educational outcomes of the university.

Definition of outcomes was the first task of SPIAC, and occupied the committee for more than one semester. In so doing, SPIAC considered carefully the inherent attributes of the institution and its students with a determination to leverage those strengths. The development of character including high moral, ethical, and fairness standards is a foundational aim of the institution, which is owned and operated by The Church of Jesus Christ of Latter-day Saints. In addition, language abilities and skills in teaching and working with peoples of different cultures are developed by many BYU students through two-year church mission experiences; these abilities were considered to be an institutional strength upon which additional global engineering practicum could be built. SPIAC sought a holistic vision connecting the five components as a means for raising the cognitive behavior and attributes of its graduates.

The overall vision developed by SPIAC was couched in a form similar to Bloom's taxonomy⁵ as illustrated in Figure 2. In this model, the base level, "information", is remembering of facts, terms, formulae, principles, etc. The second level as defined by SPIAC, "knowledge", is characterized by an ability to solve standard or traditional engineering problems. This level encompasses the comprehension and application levels defined by Bloom⁶. Standard textbook and exam problems are often effective methods for assessing this level of cognitive learning. SPIAC's third level, labeled "understanding", involves the higher cognitive skills in the Bloom taxonomy of analysis and synthesis. This level is characterized by innovation and personal

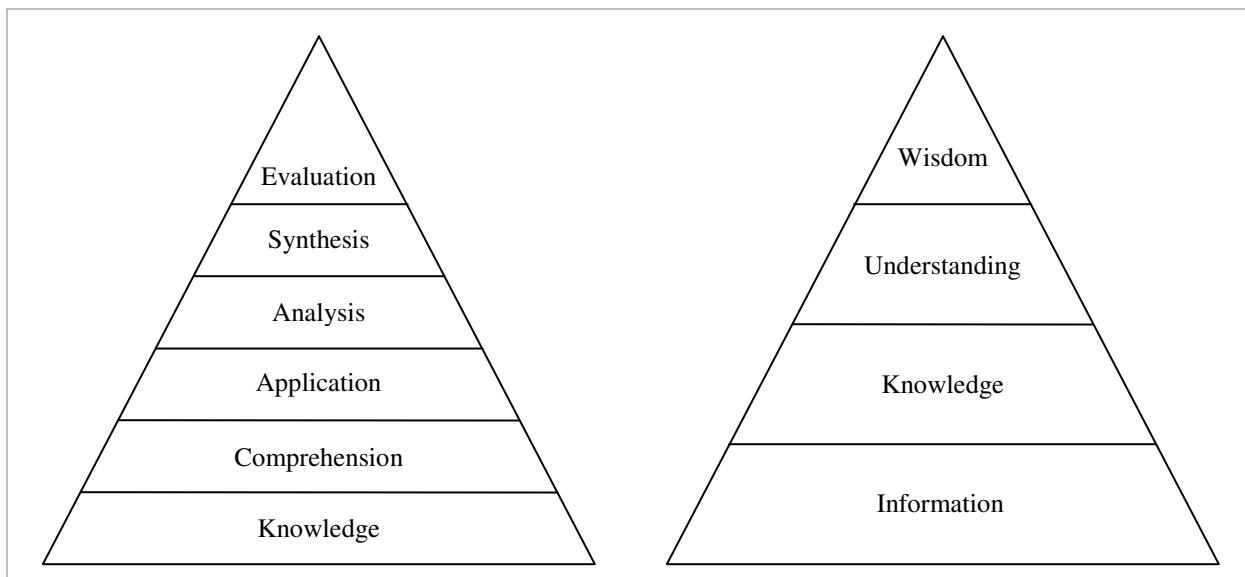


Figure 2. Bloom's taxonomy for cognitive development (left) and the SPIAC-defined levels (right) of outcome.

creativity in applying knowledge to model, design, develop, or create useful processes and products. It involves leadership and critical decision making skills. The highest level in the SPIAC model borrows some of the metacognitive characteristics identified in Fink's taxonomy of significant learning⁷. In addition to foundational knowledge, application, and integration, Fink includes human dimensions, caring, and learning how to learn. Fink suggests that significant and lasting learning is developed by significant learning-living experiences connecting problems to life. Development of "wisdom" is a life-time pursuit characterized by value-based decisions that are insightful, correct, and beneficial to the human condition. It involves learning to learn, an understanding of humanity, and the incorporation of responsible and ethical engineering practice for the benefit of society and the welfare of others. This higher skill naturally manifests itself in utilization of engineering problem solving skills, leadership, integrity, ethics, and service because of its metacognitive blend with the other dimensions of understanding. The epiphany in adoption of this model by the SPIAC committee was the realization that the five focus areas are not separate objectives, but a means to achieve the overall outcome of developing wisdom in students. Permeation of these five focus areas into the educational culture at BYU was viewed by SPIAC as a means to move students to a higher cognitive plane, key to addressing the challenges of engineering in the 21st century.

The specific outcomes defined by SPIAC in the five focus areas are shown in the sections that follow. The recommendations made by SPIAC to achieve these outcomes are also provided.

Technical Excellence

Outcome: Students think critically and creatively in solving problems. They understand fundamental principles appropriate to their discipline and are able to apply the principles in solving real, open-ended problems. They are able to distinguish real technical, environmental, safety, and societal constraints from historical or perceived constraints to optimize the solution.

Recommendations:

- Identify and provide college seminars and resource material on best practices in engineering education.
- Increase student curricular use of problem-based, non-scripted learning to approximately 30%.
- Provide all students with at least one opportunity to analyze a developing technology in terms of fundamental engineering principles.
- Ensure that every graduate was engaged in at least one mentored project with a faculty or graduate student in discovery mode.
- Ensure that each graduate had at least one opportunity to discuss their technical work with a leader or a competent practitioner in their area of expertise.

Leadership

Outcome: Students understand the characteristics of a good leader, the principles of good leadership, and have had a chance to practice leadership in a professional environment. Students are prepared to assume leadership responsibilities.

Recommendations:

- Provide regular meaningful opportunities for faculty and staff to strengthen personal leadership characteristics, and gain increased understanding of how to effectively teach leadership principles and skills.
- Provide opportunities for each student to receive instruction about, and practice in, leadership through leadership workshops and retreats, student organizations, capstone courses, team-based projects and classes, and seminars.
- Develop and offer an engineering course focused on leadership, character, and enhancement of global and cultural awareness.
- Develop a website for faculty, staff, students and alumni to provide leadership resources including reading lists, discipline specific leadership links, seminars, workshops, and class materials.
- Establish opportunities for joint efforts in leadership development with other domestic and international education and industry institutions.

Character Development

Outcome: All students, faculty, and alumni cultivate their personal characteristics of integrity, responsibility, impartiality, and charity, constantly pursuing and exemplifying impeccable character as they engage in professional and scholarly pursuits that enhance the honor and dignity of their professions and provide service to society.

Recommendations:

- Provide and continually improve curricula that effectively strengthen individual character including an engineering offering focusing on leadership and character that fulfills general education credit, modular courseware of ethics examples and case studies from across the engineering and technology curriculum, and K-12 development experiences.
- Sponsor life-long learning functions involving students, faculty, and alumni that support the character development and leadership vision of the college.
- Present an annual prestigious, internationally recognized award to a prominent individual, acknowledging exemplary character and leadership in moral and technological issues.
- Provide scholarship support to students, based on character and leadership criteria
- Confer official academic recognition on students who complete specified requirements in character building, leadership, innovation, and global awareness.

Global Awareness

Outcome: Students appreciate how cultural differences affect how people think, live and work in at least one other culture. Students are able to lead within a global context. At least half of the graduates have had a global technical experience.

Recommendations:

- Establish a faculty abroad program.
- Begin a technically oriented study abroad program.
- Establish a certificate or international option program to recognize student curricular and experiential work in global engineering.

- Refocus college lecture series on global technology and develop an international engineering visitor seminar series.
- Establish a 500-level (mezzanine) course on global issues and technology.
- Establish a professorship on global issues and technology.
- Start one or more sister institution programs for faculty exchanges.

Innovation

Outcome: Students understand the processes by which innovation can be enhanced and have had a chance to practice these in a technical environment. Students are ready to guide innovative change from within an organization.

Recommendations:

- Develop consistent terminology used to describe creativity and innovation. This terminology should be used in all departments, in addition to any discipline-specific terminology used for these topics.
- Establish a formal Innovation Initiative that will raise the consciousness of faculty and students in the college concerning innovation and creativity.
- Instill Innovation across the curriculum (that is, within the teaching environment of all departments in the college).
- Continue to support and further enrich the innovation-oriented classes that are currently in the curriculum of the college.
- Establish an Innovation and Creativity Laboratory.
- Establish an annual product innovation contest (with prize money) that encourages students to develop their own product ideas.

In addition to the outcomes and recommendations listed above, SPIAC also crafted a matrix of the student characteristics exemplified at each of the four learning levels (shown previously in Figure 2) for each of the focus areas. Our intention is to use these characteristics as part of future assessment activities.

Implementation Strategy

Development of a viable implementation strategy was critical to our efforts to move the college forward in a strategic direction. Implementation at the college level at an academic institution, where departments and individual faculty members have a great deal of autonomy, is particularly challenging. Consequently, a set of principles was developed to guide our efforts.

1. It is the role of the Deans' office to work with departments to develop a vision for the college as a whole. Strategic directions are intended to encourage lasting changes in the education of our students, and represent an opportunity for the college to be truly excellent.
2. The primary implementation role for the college is to provide resources to the departments to facilitate accomplishment of the department/college vision.
3. Departments have the stewardship and responsibility to effectively and efficiently educate students, preparing them to excel. To do this, departments should plan

- strategically and implement those plans in order to constantly improve. Strategic changes made by departments should be reflected in learning outcomes defined for their students and should be included as part of regular assessment cycles.
4. Departments are accountable to the college for their stewardships.
 5. Faculty members are accountable to the department for their stewardships. This accountability should include the contribution of the faculty member to the strategic mission of the department.
 6. In order to best accomplish our primary mission of undergraduate education, faculty members at BYU are expected to be involved in improvement of the educational process. This includes familiarity with the “best practices” for their discipline, etc.
 7. Change for the sake of change is not desired. Only lasting changes that have a significant, measurable impact on the education of students should be considered.

From these principles, the implementation strategy illustrated in Figure 3 emerged. The strategy includes activity at three levels: 1) College, 2) Department and 3) Individual Faculty Member. Figure 4 describes activities for each of the five focus areas at each level.

College Role

As seen in the Figures 3 and 4, the role of the college is to facilitate development of a joint vision, provide resources needed for the accomplishment of that vision, and provide activities at the college level that are not discipline specific and that benefit from economy of scale.

Establishment and ownership of a joint vision is an essential element of the process as it is impossible to move forward without such a vision. The goal was to obtain strong ownership by the chairs and by a critical number of senior faculty members in the college. Ownership by the senior faculty was effected to a large degree by involvement in the SPIAC committee. Required resources included funding for activities, development of instructional and other resources for use by faculty, and personnel support for activities such as global internships. Possible vehicles for providing funding included professorships, fellowships for faculty and students, grants for curriculum development, direct funding of projects/capstone experiences, etc. Activities targeted for implementation at the college level included the development of a course to teach leadership and ethics in a global environment, and the development and management of global internship opportunities for faculty and students. The role of the college also included the responsibility to provide seminars on “best practices” in engineering/ technology education, and to examine the possibility of a global certificate program for students in the college.

Department Role

The role of the department is to apply the joint vision to the specific discipline and to integrate the vision into the department curriculum. The vision establishes the desired endpoint.

However, it is the purview of the department to establish priorities and a strategy for implementation. It was expected that departments would focus on different aspects of the vision and move forward at different rates. A critical element of the department-level effort is the redefinition of their ABET outcomes to include the strategic elements in order to effect long lasting change. The department is accountable to the college for its strategic plan and progress on the strategic initiatives.

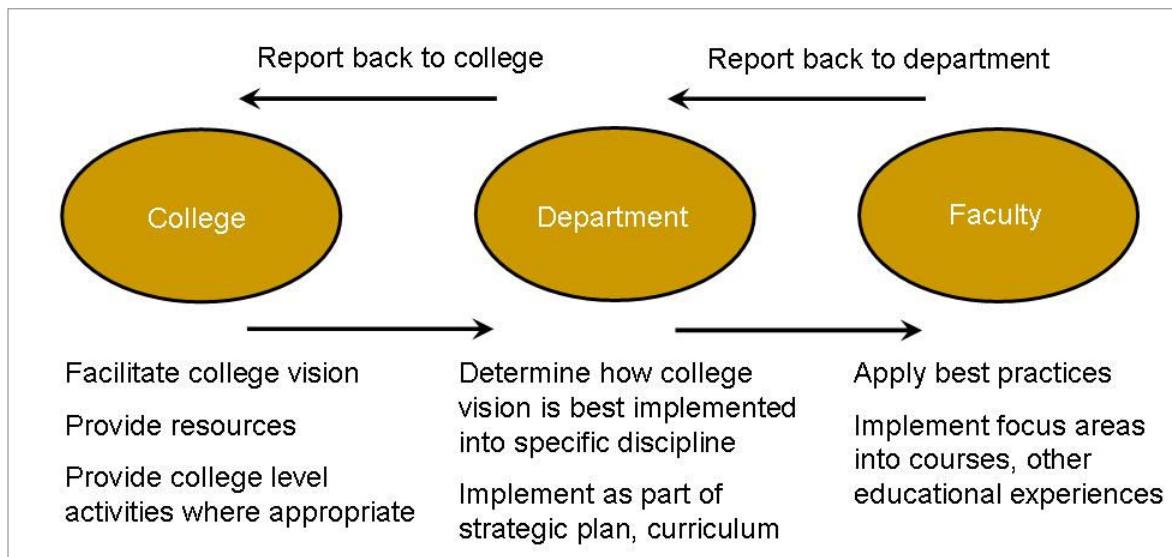


Figure 3. Implementation strategy showing roles at different levels.

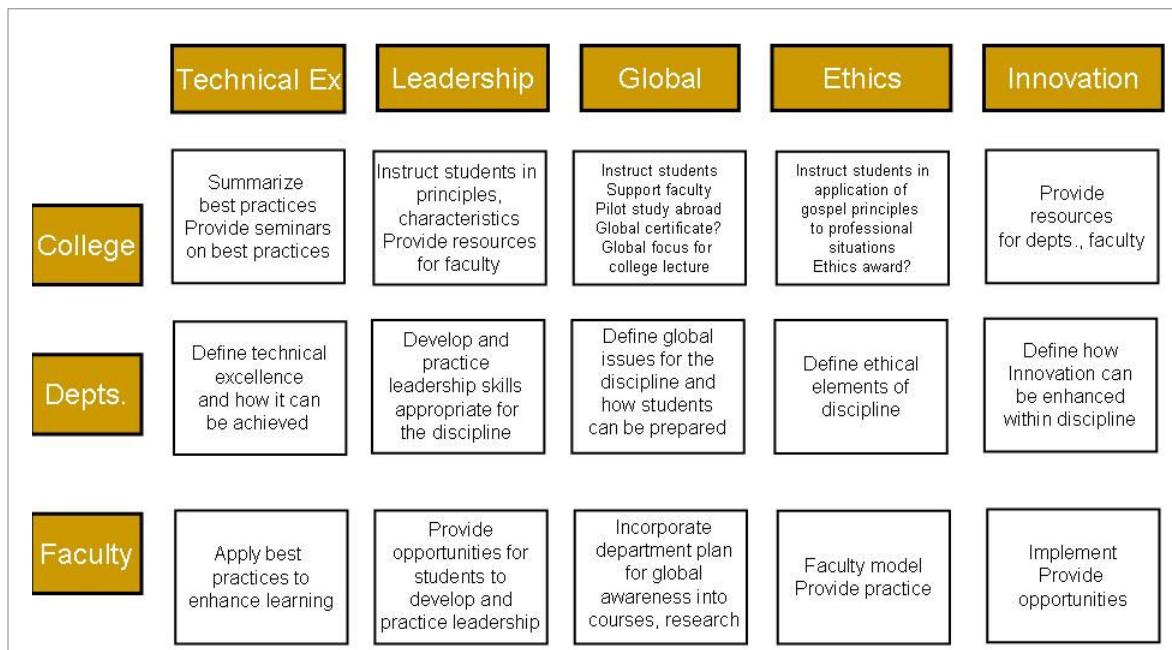


Figure 4. Activities defined for each of the focus areas at each level.

Faculty Member Role

Faculty members are the key implementers for change. The expectation for the faculty is that each faculty member be involved in at least one of the five focus areas, in accordance with their department strategy. In addition, all are expected to learn and apply best teaching practices. Faculty members are accountable to the department for their involvement in the strategic initiatives.

Results

There have been a number of tangible changes in the curriculum, mentoring, scholarship and operational approaches in the college as a result of emphasis on the strategic objectives. In addition to the actual changes, there is evidence of changes in the thinking of faculty and a willingness to consider new approaches. Of course, effective change in an academic setting cannot be dictated, as mentioned previously. With this in mind the results outlined below are moderate in their current state, but show a change in direction and the hope of significant, long-lasting change that will effectively address the additional needs of the 21st century.

College Level

Many of the changes at the college level have come about as a result of a focus on faculty development in the strategic areas, and an effort to promote and fund prototype activities that would lead to further development and implementation at the department level.

Listed below are key educational faculty development activities and/or firm plans directed towards preparing and motivating faculty to move ahead in new strategic areas:

- Two new college-level professorships in Global Engineering and Leadership were created, joining an existing professorship in Ethics. A professorship in Innovation is planned. The faculty members awarded these competitive professorships are expected to provide leadership in the college in the focus area aligned with the award. For example, successful leadership seminars for faculty have already resulted from the Leadership Professorship, and a curriculum for teaching leadership is being prototyped.
- Eight Global Fellowships for faculty have been awarded, four last year and an additional four this year. These fellowships provide the recipients with summer support and travel funds to explore and establish relationships and programs that promote global awareness for students. Examples of accomplishments include initiation of a new study program in Mexico, development of internship opportunities in Asia and organization of a BYU chapter of Engineers without Borders.
- A yearly faculty development trip of about 2 weeks has been initiated to areas of the world that are influencing engineering and technology. A group is already set to travel to China in 2007 with plans for Eastern Europe in 2008 and India in 2009.
- The college SPIAC committee has begun planning for seminars and symposia on best practices in teaching, and has already conducted a successful conclave on Problem Based Learning that was attended by three quarters of the college faculty. The College has also reached out to other units on campus and co-sponsored symposia on ethics and innovation.
- A prototype teaching laboratory that will promote real-time international interaction with students and faculty around the world is nearing completion.
- The college has approved development of an Innovation Founders Group to foster innovation within the college and develop a major innovation conference on campus during Fall semester.

- Curriculum development grants, international travel subsidies and student international travel fellowships round out the remaining development programs that are now in place.

Listed below are key activities that the college has helped to prototype and/or initiate.

- An initial college-sponsored study abroad program in China will be offered in Summer 2007 for students from our college. This program will heavily leverage prior BYU experience and connections in China⁸, and will incorporate instructional materials and experiences that target engineering and technology students.
- An additional study abroad experience in France will be available Summer 2007 for students from our college who will participate as part of the Georgia Tech France summer study abroad program.
- A water resources class will coordinate with a group of students in Mexico to study dams that are in the planning stage. The BYU students will then travel to Mexico to make presentations and to train the Mexican students and others on the use of simulation software needed for the project.
- College-wide seminars have been aligned with the strategic directions of the college. Outstanding speakers from industry have helped to build momentum among students and faculty in the focus areas.
- A course entitled “Moral Leadership in a Technological World” has been developed and taught. This course will serve the entire college and provide training for our students in leadership, ethics and global awareness.
- An external advisory group, the Advancement Committee for Engineering and Technology (ACET) consisting of successful friends from industry has been formed at the college level. The purpose of this group, formed in August 2006, is to provide guidance, mentoring, resources and connections in order to help move the college forward in the defined strategic directions. ACET has been actively contributing in a number of ways and will begin “hands-on” mentoring of students in leadership and other areas next month.

Department Level

At the department level, most of the change to date has come about from reexamining program objectives and learning outcomes in the context of our strategic objectives and the needs of the specific discipline. Definition of appropriate strategic outcomes will lead to modification and refinement of curriculum⁹, promotion of more international student experiences, and collaboration with international groups through travel or advanced communications.

Experimentation with global design projects completed by student groups around the globe has been very successful in mechanical engineering and will have an influence on other departments. Many units are expanding internship possibilities and seeking global sponsors for senior projects. One unit has already proposed a significant change in their curriculum to focus on global manufacturing. Another department has initiated a global projects course, available to students of all majors in the college, that is affiliated with Engineers without Borders. They will be designing and fabricating a biodiesel facility that will be installed in Tonga this summer.

As prototype college-level initiatives mature, we will work to utilize them at the department level. Department-level initiatives that show promise will be shared with other departments.

Individual Faculty Level

The faculty level is where the real and lasting change in a college must occur. The results outlined above are the product of faculty working together at the college and department levels. For most individual faculty the changes associated with these strategic goals are manifest in their classrooms. There has been an increased interest on the part of faculty in how to bring these topics and associated skills into the classroom without diluting the technical content of the courses. We have noted more interest in new pedagogies and classroom management techniques. Last semester all faculty members were asked to try something new related to the strategic direction of the college, and we are in the process of assessing what was done and the extent to which it was successful. As faculty gain experience with the integration of strategic topics into the classroom, we will work to create forums for sharing of results and best practices.

Summary

This paper describes a college-wide initiative to prepare students for the 21st Century. Efforts on this initiative began Summer 2005, soon after a new college administration took office. During this time, ownership of the initiative by the faculty as a whole has been achieved, specific outcomes and recommendations have been defined, a multi-level strategy for implementation has been developed, and a variety of changes have been effected. Faculty will soon report their specific efforts as part of our annual review process that has been modified to include reporting of activities in the five focus areas. Curricular modifications are underway, and strategic outcomes are being incorporated into our ABET outcomes for the units in the college. Successful friends of the college from industry are also teaming with us to enhance the education of students in these critical areas. We look forward to continuing growth and improvement as we prepare our students to succeed in a changing global environment.

Acknowledgment

The generous support of Ira and Mary Lou Fulton and members of ACET is gratefully acknowledged.

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