2006-375: 15 YEARS OF ENGINEERING EDUCATION REFORM: LESSONS LEARNED AND FUTURE CHALLENGES

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15 Years of Engineering Education Reform: Lessons Learned and Future Challenges

Introduction

Since the founding of the ECSEL and Synthesis coalitions in the early 1990's, the National Science Foundation, ARPA, and other government agencies as well as private foundations have made substantial investments to improve engineering curricula, teaching and learning practices, and the 'pipeline' from K-12 into engineering. In 2001, Bjorklund and Colbeck[1] reported the results of their interviews with 27 leaders of engineering colleges and professional organizations in which they discussed change that had taken place over ten years since the founding of the first coalitions. The participants were asked what they believed were the two most significant changes over that decade. Greater exposure to design and emphasis on effective teaching were mentioned by ten of the 27 participants, followed closely by implementation of computer technology in research and teaching, which was mentioned by nine participants. Next in line were accreditation/assessment and funding, mentioned by seven of 27.

Experience at Penn State in reforming our engineering undergraduate programs has largely mirrored these responses. Indeed the ECSEL coalition, made possible by NSF support, was built around the theme of "integration of design across the curriculum." ECSEL had a very significant impact on our College-wide efforts to enhance teaching and learning, steering us in a direction and path of work that continue today. We have introduced a variety of new, more effective teaching and learning strategies on our campuses including active and collaborative learning along with technology-based teaching and learning. Clearly, implementing new processes of assessment of outcomes for ABET is having a significant effect on our programs. We have been fortunate to have other influences, as well, including good counsel from external advisory boards and the resources from an endowed center for engineering education, both of which have been effective in fostering change.

Over the last 15 years, these diverse drivers for change have nurtured nearly 50 major projects for which substantial funding was available. These 50 initiatives, however, do not begin to represent the totality of the effort because many individual faculty and small groups of faculty carried out projects to improve what they are doing in their own classes without the benefit of additional funding. Over this time, a number of different approaches to leading the change process have been applied. In reflecting on our experiences, it is apparent that we employed different approaches to facilitate change depending on the circumstances, in a sense applying situational leadership, and also that our change model has evolved much along the lines described by Clark *et al.,*[2] shifting to a model that always has the question of how we will sustain an innovation built in from the outset.

To write this paper, we have selected projects from which we drew significant lessons about the process of implementing and sustaining change. For each, we briefly summarize the approach

taken to implement the change, typically curricular or pedagogical innovation, the current status of the change, and the lessons that we learned in the process. At the close of the article, we discuss the major challenge facing all of engineering education at this time, which is how to better prepare our students to succeed in a marketplace being transformed by globalization.

The Beginning: ECSEL

A 15 year period of sustained effort to renew and enhance undergraduate engineering education at Penn State began with the creation of the team that eventually became the ECSEL Coalition. The team was formed by the Deans of the seven coalition partners, many of whom had worked together over the course of their careers, including John Brighton of Penn State and Lucius Walker of Howard University. In this case, the early leadership was 'top-down' in that the Deans led the formation of the coalition of schools. The Deans each identified key leaders on their own campuses who worked with them to define the coalition theme of 'integration of design across the curriculum' and also the initial focus areas for the coalition – design across the curriculum, teaching and learning modules, student and faculty development, and K-14 outreach. Implementation within each coalition institution was led by the local principal investigator and the Dean.

Over the ten year life of the coalition, the NSF funding and matching funds from Penn State provided resources for a number of significant initiatives including design and implementation of a first-year design course; integration of design in Aerospace, Architectural, Electrical and Civil Engineering; the design and construction of a new networked, heterogeneous platform computer lab dedicated to undergraduate design courses; an undergraduate teaching intern program; and a workshop to help faculty better understand student experiences in engineering classrooms.
The design and implementation of a first-year design course for all Penn State engineering students was the largest single project undertaken as part of the ECSEL efforts at Penn State. It represented a tremendous challenge not only because of the number of first year students, nearly 2000, but also because they are taught on 19 different campuses. The initial development efforts occurred at the University Park Campus that enrolls the largest number of first-year engineering students, or approximately 1000 annually. The development process began with a small team of Engineering Design and Graphics faculty who conceived and implemented pilot sections of the class.[3, 4] Eventually the project was scaled up to the level of 1000 students per year with a class size of 32, which means that over 30 sections are offered each year.

Facilitating the implementation of the course at the other Penn State campuses presented a substantial challenge. One major challenge was getting buy-in from all faculty members who would teach the course, and another was that the available computing and lab resources were not uniform across the different campuses. Leadership provided by the coordinators of the effort was critical to the acceptance of the new course format. Workshops were organized that brought together key faculty members from all of the campus locations to decide on the major competencies to be achieved by students, and a critical decision was made to focus on achieving these learning outcomes rather than implementing exactly the same course at all locations. The latter decision allowed instructors to be creative and apply their best ideas for using the facilities and resources available to them, while maintaining common outcomes from the courses.[5, 6] For

instance, each campus could partner with local companies and develop corresponding industry-driven design projects. The process required time and patience, but was eventually successful. More than 2000 students each year take the first-year design course and achieve the key outcomes established for the course on 19 campuses.

At the department level, the major curricular related initiatives typically involved introducing and threading active learning experiences into the programs and occurred in Aerospace, Electrical, Chemical, Civil, and Architectural Engineering. The Aerospace initiative revolved around active learning implemented through an extra-curricular project in which teams of students from the first-through senior years designed and built full-scale sail planes. Over the course of ECSEL program, the sailplane project eventually became integrated into the curriculum in such a way that students receive up to 11 credits toward their degree requirements if they complete four years in the program, which involves 20 credits of effort.[7] In Electrical Engineering the changes included creation of a laboratory course on micro-controllers that eventually became a required course and redesign of laboratories to be fully integrated with lectures in two other courses, Circuits & Devices[8] and Electronic Circuit Design I. The Civil Engineering project integrated industrial design cases into the entry level structural design class.[9] The Chemical Engineering project entailed the creation of two detailed case studies for use in the capstone course,[10, 11] and the Architectural Engineering project involved the development of a computer-based tutor to assist students in designing steel structures.[12] The latter two initiatives did not have a lasting impact because they were each led by a single investigator who eventually left Penn State before being able to convince other colleagues to buy into the pedagogical innovation. In Aerospace and Electrical Engineering the involvement of multiple investigators and the integration of the projects into formal curricular changes led to their continuation, and in Civil Engineering, the project was led by a single investigator who persisted in his efforts, eventually leading to a follow-on project involving more faculty members.

Experience with curricular and pedagogical innovations during ECSEL highlighted the critical role of the faculty champion. However it also showed the vulnerability that arises when the champion remains the only person behind the innovations. Reforms based on the efforts of a single individual are at significant risk of extinction; this lesson was integrated into the approaches used to support and sustain change in other initiatives, especially those within our endowed education center, The Leonhard Center for the Enhancement of Engineering Education.

Continuing the Integration of Design: MEEP

Penn State was very fortunate to have an opportunity to amplify the impact of our ECSEL efforts through our involvement in the Manufacturing Engineering Education Partnership (MEEP). This Partnership, funded by NSF through the Technology Reinvestment Program, consisted of Penn State, University of Washington, University of Puerto Rico at Mayaguez, and Sandia National Lab. The MEEP was built around the concept of a "Learning Factory"[13] and led to the creation of a like-named facility on the University Park Campus of Penn State. In The Learning Factory, cross-disciplinary student teams work on industry problems as part of their capstone courses that meet degree requirements in a variety of engineering majors. It is also used for K-12 outreach programs and in lower division design courses that are being added through curricular renewal processes. The Learning Factory is the hands-on laboratory for the Product Realization Minor,

which was started through the MEEP and for nearly 20 courses in six engineering departments. Since 1995, more than 400 sponsored projects have been completed for over 100 companies.

The leadership that led to the founding of the MEEP was to a large extent from the "bottom-up" since the team leaders were primarily faculty members rather than administrators. On Penn State's campus, the leadership fell to a small team of faculty members, for which John Lamancusa served as the leader. The creation of The Learning Factory required an addition to a building and purchasing of the equipment to support rapid prototyping, fabrication and assembly of student designs. A major leadership challenge arose when the external funding was no longer available so finding ways to sustain The Learning Factory – particularly to support the personnel to maintain and supervise activity in the facility -- was our first major lesson on the need to consider institutionalization of a reform. This problem was solved through cooperation between the College and the Departments who were the major users of the facility. The Learning Factory continues to grow and to thrive. The national impact of MEEP and The Learning Factory concept was recently recognized through the awarding of 2006 Gordon Prize from the National Academy of Engineering.

Sustaining the Change Process: The Leonhard Center

At about the time the ECSEL coalition was beginning, Penn State's College of Engineering was presented with a unique opportunity to respond to the interest of one of our alumni, William Leonhard, in sponsoring a major initiative to support undergraduate education. Mr. Leonhard was concerned about the global competitiveness of the US and also about our nation's ability to recruit "the best and brightest" into engineering. Penn State's response was a proposal to establish a center focused on innovation in engineering education. Mr. Leonhard found our proposal to be attractive and endowed the Leonhard Center for the Enhancement of Engineering Education at an initial level of $4,000,000. Several years after the founding of the Center, Mr. Leonhard informed Penn State that he was willing to make another major gift. Dean John Brighton prepared a second proposal with additional ideas to enhance activities in the Center. Ultimately, Mr. Leonhard accepted this second proposal and agreed to provide a total of $10,000,000 to endow the Center. The Center's endowment principal was then built up over a period of approximately ten years to yield an annual income that supports the Center today. Available earnings from the endowment are used primarily to fund educational initiatives in the Departments and the College.

The Center has two advisory boards that play distinct and critical roles in the mission of the Center: an external advisory board, simply referred to as the Advisory Board, and the Faculty Advisory Board. The Advisory Board, formed at the founding of the Center in 1991, is composed of Penn State Alumni and Alumnae who have been strongly connected to their departments and the college through their service and philanthropic activities; they represent nearly all of the majors offered by the College. All have held or are holding positions of substantial leadership responsibility in the public and private sectors so they provide a deep and diverse set of perspectives on engineering education. The Advisory Board meets twice per year with the Dean, the Associate Deans, and Department Heads along with the Director of the Center to learn about progress on various projects, and most importantly to offer guidance on key issues related to undergraduate education. In 1994, the Advisory Board created the vision of a World-

class Engineer, which has become the guiding framework for educational reform in the College, anticipating by nearly ten years the current national attention on the issue of globalization. The Faculty Advisory Board was formed in the mid-1990's to assist the Director in setting and updating the strategic goals for Center and to provide internal feedback on project proposals that come to the Center. It plays a second important role in the College as the coordinating group for ABET-related assessment processes, a role that will be discussed more fully later in this article.

The Leonhard Center has had a central role in sustaining the change process in the College. It has been involved in numerous projects to support curricular renewal, course re-design, and new course initiatives. From the early years of the Center, the most significant effort was the design and implementation of the Engineering Leadership Development Minor.[14] The Advisory Board was crucial in developing the overall design of the Minor and in supporting its implementation through its early years. One member of the Advisory Board even taught courses within the Minor. The Minor requires completion of 18-credits including an internship and is available to students from across the University. Currently operating a full capacity the Minor serves approximately 200 students per year, or about 10% of our junior and senior students. It provides students with critical leadership principles and skills required of those who will take leadership roles in the highly competitive, global marketplace.

Establishing the Minor required that it find an academic home because the Leonhard Center has no explicit authority to offer courses. The Minor was made possible through the willingness of the then Department Head of Electrical Engineering, Larry Burton, to offer it a home within his Department. The decision was not without its controversy, given the professional as opposed to strictly technical nature of the course content in the Minor, but Larry remained a steadfast supporter of the Center. About five years after its creation when the Minor was well established, the Dean formed a committee to review the Minor and its placement within the College. The committee recommended that the Minor be moved to the Engineering Design and Graphics group because of its existing College-wide teaching responsibility. The committee also recommended that the course designations within the Minor be changed to ENGR from EE, since the EE designation was confusing to potential applicants for the Minor and made students not majoring in Electrical Engineering apprehensive about their preparedness for the course content. The transition went smoothly and the Minor continues to thrive within the newly restructured School of Engineering Design, Technology, and Professional Programs. Funding for the creation of the Minor was provided by the College of Engineering and the Leonhard Center, and both continue to be the primary sponsors of the Minor along with a growing number of related endowment gifts.

In summary, the concept for the Engineering Leadership Development Minor grew out of input from the Advisory Board, which was then taken up by a team of faculty and students who developed the structure of the Minor. Implementation of the Minor was contingent upon finding an academic home, which required that a department head take the risk in making a leadership decision. It then fell to the first director of the Minor, Jeff Soper, to make the concept a reality. The change process in this case was driven by the recognition of the need for better leadership education for engineering students and the courage and energy of several champions who stepped up to the challenge The Minor is now firmly in place, facing its next, though not so disagreeable hurdle, of meeting excess demand for its courses.

As was the case for the Leadership Development Minor, recognition of the need for a minor in entrepreneurship grew out of the advice of the Advisory Board. Discussions of how to start this new initiative were underway for about one year when the opportunity arose to propose the creation of an entrepreneurship minor to the GE Fund for Learning Excellence. The successful proposal to the GE Fund was composed by the Associate Dean for Undergraduate Studies, the Head of the School of Engineering Design and Professional Programs, and the Director of the Leonhard Center. They jointly supervised the ramp up of the Minor although the major leadership responsibility fell to the Head of the School of Engineering Design, Technology, and Professional Programs, where the Minor is housed. The eventual Director, Liz Kisenwether, an electrical engineer and an entrepreneur, has assumed responsibility for and built the program to a very strong position over its first five years forging close connections with colleagues in the Smeal College of Business. The development of this new minor with cross-college appeal and applicability was facilitated by the experience gained in creating and institutionalizing the Leadership Development Minor.[15]

The Entrepreneurship Minor began as largely a "top down" approach to change, with those in leadership positions conceiving the vision and plan and then implementing them. In crafting a successful NSF Action Agenda effort, the opposite approach was used in which a vision and strategy were built from the "bottom up." Shortly after the formation of the Faculty Advisory Board of the Leonhard Center, the Director began a strategic planning process with the Faculty Advisory Board around the following question: "If you could make any changes you wished, what would you do to increase the success of your students in the workplace?" From this discussion grew two major themes: (1) have more major design experiences and (2) increase interactions with industry. These two themes became the foundation for proposals from five departments that were then integrated into a proposal to NSF under the Action Agenda initiative. In addition, the need for a new facility in which students could carry out their projects was also identified by the Faculty Advisory Board; creation of the facility was integrated into the proposal to NSF as part of the required matching funds.

The five proposals were for (i) a new two-course sequence in Industrial and Manufacturing Engineering in which students took products from concept to manufacturing called "IME, Inc.;"[16] (ii) Integrated Design, Experimentation, Analysis, and Life Skills (IDEALS) courses in Mechanical Engineering;[17] (i) Case Studies in Civil Engineering;[18] (iv) a cognitive apprenticeship in Chemical Engineering;[19] and (v) increasing the design content in upper level mechanics courses.[20] Based upon our on prior experience that showed the importance of broad support in sustaining change, all department proposals were required to have the approval of the department head and also to be vetted with the full faculty prior to submission of the NSF proposal. The size of faculty teams working on each initiative varied significantly, however. IME, ME, and CE projects involved groups of four or five faculty members, whereas the Engineering Mechanics project was led by two faculty members, and the ChemE project by one. Of the five projects, four have resulted in lasting changes. The ChemE project was not sustained, for two reasons. First, although it was very effective, the ChemE project proved to be so facility and people intensive that it became clear that it could not be institutionalized in its original form. Secondly, the faculty champion departed Penn State before lower cost ways to adapt the approach could be investigated.

The fate of the IME and ME projects gave us some new insights into the change process. The IME, Inc. project was a definite success and met expectations for student outcomes. Its success allowed the IME faculty to see that such changes could be undertaken successfully and set the faculty on a path of exploration that ultimately led to a major restructuring of the curriculum around active learning and case studies. The ME IDEALS courses were implemented and became an integral part of the curriculum, but only as elective classes. The experience with them, however, contributed important ideas to the re-design of the ME curriculum, so subsequently all of the learning outcomes for the IDEALS classes have been integrated into a new junior level design course that is required of all students. Thus, although neither of these projects themselves constituted courses required of all students, they ultimately supported substantial reforms that are affecting all students. The lesson here is that even a partial success can have significant consequences and impact later in time.

ABET and the Change Process

At the time that the Faculty Advisory Board of the Leonhard Center was being formed the need to implement new processes related to EC2000 was also becoming apparent. The Associate Dean for Undergraduate studies saw value in using the same set of faculty members to serve as the coordinating body for ABET as well as serving in an advisory capacity for the Director of the Leonhard Center. The motivation for this linkage was the need to "close the loop" as a principal aspect of ABET processes. Since the Leonhard Center was the primary internal vehicle to support changes in courses, curricula, and pedagogy, it made perfect sense to create an explicit alignment of these activities with the ABET assessment processes.

To form the Faculty Advisory Board, the Associate Dean and the Leonhard Center Director met with each Department Head to discuss the charge to the Board and possible candidates from the department to serve on it. Meetings of the Board were scheduled bi-weekly to introduce members to the processes required to meet ABET's EC2000 expectations. Leading the group required managing a delicate balance of coordinating and guiding the departments through the necessary processes without absolving departments from the responsibility for ABET preparation. It was also necessary that each program have the latitude to implement assessment processes in ways that accommodated their particular departmental culture, would meet the requirements for ABET, and would not impose unreasonable levels of additional work on the faculty. Ultimately, this approach led to a successful outcome for all programs in their first evaluation under EC2000.

ABET-related assessment process were instrumental in identifying needed changes in many of the individual programs and also one major issue that cut across departments, which was the need for more ethics related experience in the curriculum. This need was addressed through a collaborative effort between the Leonhard Center and the Doug & Julie Rock Ethics Institute in the College of the Liberal Arts. The initial work of this partnership was stimulated by philanthropic gifts from an Engineering alumnus whose daughter graduated from the College of the Liberal Arts. The conditions for the gift were that the two colleges should work together to enhance ethics education at Penn State, so tackling the identified curricular shortcoming in student exposure to professional ethics in Engineering was a natural place to start. The

collaboration resulted in a jointly sponsored workshop for Engineering faculty on methods to integrate ethics into engineering classes,[21] fashioned after the successful model at the Illinois Institute of Technology.[22] During this weeklong workshop, participants receive introductions to ethics and instructional design through active learning methods; they then apply their new knowledge and skills to create ethics activities for their classes. All participants receive a week of summer supplemental salary. The workshop has been offered for four consecutive summers and has reached more than 30 faculty members, or roughly 10% of the College faculty. While the workshop has been very successful, it has not yet reached all departments. The lesson here is that even having resources available to compensate faculty members for their time to attend such a workshop does not insure that every department will assign the same value or urgency to the initiative and that competing activities in faculty careers can still outweigh the benefits of participating in the workshop. We are currently beginning a more aggressive marketing campaign to try to get representatives from remaining departments to attend the next offering of the workshop.

Current Challenges: Addressing Globalization

The issue of most concern to our undergraduate programs at this time is how to better prepare our students to succeed in a marketplace being transformed by globalization. Once again the Advisory Board of the Leonhard Center has played a key role in bringing this question into sharp focus and in helping us think through how we can address it. From strategic discussions among Advisory Board members and the leadership of the College, we have begun to develop plans to approach this question via two avenues – a new course that emphasizes key organizational and leadership skills for the global workplace and a more aggressive plan to bring the World-class Engineer vision to our students early in their studies.

The key elements of the new course, described in more detail in Reference 23, were first outlined in strategic discussions with the Advisory Board; they include dealing with cultural differences in the workplace, project management skills, conflict resolution skills, and working in dispersed teams. The course, designed to be problem-based and interactive, is being taught in small sections during the development phase. We are now facing the challenge of scaling up the class so that all juniors in engineering can take it if they wish. This goal will almost certainly involve re-designing the course for blended, or perhaps, fully on-line delivery.

The other element of our current approach is to develop and implement a marketing plan to take better advantage of the World-class Engineer vision during the first two years of our programs. We hope that by getting this vision into the minds of our students early in their academic careers, we can help them make better decisions to maximize their preparation to enter the increasingly global marketplace. We are developing marketing and advising materials to make students aware of the many opportunities that are available to them to make progress toward being a World-class Engineer. In addition we have instituted a World-class Engineer Alumni Award that brings successful, young graduates back to campus to speak with current students about the exciting opportunities and challenges of the global workplace.

Conclusions

From our 15 years of leading educational change at Penn State, we have drawn a number of lessons that inform our current efforts. These lessons are that:

- Flexible approaches to leadership, matching the approach to the opportunity and the circumstances, enhance the chances of success.
- Having more than one or two faculty champions increases the probability of successful change and for sustaining that change.
- Even partial success can help to lead to cultural changes and an increased willingness of a faculty to consider making changes to their undergraduate program.
- All renewal and enhancement projects must have plans for sustaining and institutionalizing them built in from the beginning.
- Additional resources increase the chances of a successful outcome, but certainly do not guarantee it.

References

[1] Stefani Bjorklund and Carol Colbeck, "A View from the Top: Leaders' Perspectives on a Decade of Change in Engineering Education," *The Journal of Engineering Education*, Vol. , pp. 13-19. (2001)

[2] M. Carolyn Clark, Jeffrey Froyd, Prudence Merton, and Jim Richardson, "The Evolution of Curricular Change Models within the Foundation Coalition," *Journal of Engineering Education*, Vol. , pp. 37-47. (2004)

[3] Sathianathan, D., R. S. Engel, and R. J. Foster, "A Freshman Engineering Design Course," in "Shaping Our World, Century II," Proceedings of 1993 ASEE Conference, pp. 883-888, Urbana-Champaign, IL, June, 1993.

[4] Sathianathan, D., R. Devon, N. Kallas, and R. Engel, "First-Year Design Curriculum at Penn State" International Conference on Engineering Education, Proceedings Volume II, p. 597-610, 1997.

[5] Sathianathan, D., "Faculty Collaboration and Course Coordination in Geographically Dispersed Campuses," Frontiers in Education, CD-publication, Session TID, 1997.

[6] Sathianathan, D., "Curriculum Coordination and Faculty Collaboration among Multiple Campuses," ASEE – Conference for Industry and Education Collaboration Proceedings. pp. 53-56, 1997.

[7] Maughmer, M.D., and D. W. Jensen, "Enhancing the Aerospace Education Experience with a Multi-Year Sailplane Design Project," Proceedings of the 1992 ASEE Annual Conference, pp. 714-717, Toledo, OH, July, 1992.

[8] Mayer, T. S., J. R. Medunick, C. Zhang, and T. N. Jackson, "A New Design-Oriented Laboratory for the Introductory Circuits Core Course at Penn State University," Proceedings of the 1997 FIE Conference, Pittsburgh, PA, 1997.

[9] Scanlon, A., M. E. Kendall, "Active Learning in the Structural Engineering curriculum," Proceedings of the 1994 ASEE Annual Conference, pp. 2269-2272, Edmonton, Alberta, Canada, June, 1994.

[10] Ronald J. Gatehouse, M.S. Thesis, "Vertical Integration of Design in Chemical Engineering," The Pennsylvania State University, 1998.

[11] George J. Selembo, Jr., M.S. Thesis, "The Vertical Integration of Design in Chemical Engineering," The Pennsylvania State University, 1998

[12] Aminmansour, A., "SteelDEM: An Interactive Multimedia Intelligent Tutor and Teaching Aid for Structural Steel Design," First Congress on Computing in Civil Engineering, American Society of Civil Engineers, Washington, DC, June, 1994.

[13] John s. Lamancusa, Jens e. Jorgensen, and Jose l. Zayas-castro, "The Learning Factory – A New Approach to Integrating Design and Manufacturing into the Engineering Curriculum," *The Journal of Engineering Education*, Vol. 86, No. 2, pp. 103-112. (1997).

[14] Larry C. Burton, Jeffrey G. Soper, Jack V. Matson**,** Penn State's Engineering Leadership Development Minor, Proceedings of the 1996 Frontiers in Education Conference, Salt Lake City, UT.

[15] Liz Kisenwether and Jack Matson, Launching An Undergraduate Engineering Entrepreneurship Program, Proceedings of the ASEE Annual Conference and Exposition, Montreal, Quebec. (2002)
[16] T.W.Simpson, D.J.Medeiros, S.Joshi, A.Lehtihet, R.A.Wysk, G.R.Pierce and T.A.Litzinger, IME Inc.- A New Course for Integrating Design, Manufacturing and Production into the Engineering Curriculum, International Journal of Engineering Education, Vol. 20, No. 5, 2004, pp.
[17] Thomas Litzinger, Martin Trethewey, John Gardner, Integrated Design, Experimentation, Analysis and Life Skills (IDEALS) Courses, Proceedings of the ASEE Annual Conference and Exposition, Albuquerque, NM, 2001
[18] Andrew Scanlon and Andrea Schokker, Integration of Analysis and Design in the Structural Engineering Curriculum, Proceedings of the ASEE Annual Conference and Exposition, Albuquerque, NM, 2001
[19] Alfred Carlson, Making Memories - The Penn State Bio-processing Cluster Program 2000-2002, ASEE Annual Conference and Exposition, Salt Lake City, UT, 2004
[20] C.J. Lissenden, G.S. Wagle, and N.J. Salamon, Design Project for Advanced Mechanics of Materials, ASEE Annual Conference and Exposition, Montreal, Quebec, 2002.
[21] Thomas Litzinger, John Christman, Andy Lau, Nancy Tuana, and John Wise, Learning and Teaching Ethics In Engineering: Preparing Engineering Faculty To Teach Ethics, Proceedings of the ASEE Annual Conference and Exposition, Nashville, TN, 2003.
[22] Davis, M. "Ethics across the curriculum," in Ethics and the University, Routledge Press, 1999.
[23] John Wise, Natalia Kapli, Wes Donahue, and Thomas Litzinger, Preparing Students to Compete in the Global Marketplace, submitted for presentation at the 2006 ASEE Conference and Exposition.