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Preface

Each year, U.S. colleges and universities prepare tens of thousands of talented individuals who wish to pursue careers in engineering. In 2006 alone, more than 68,000 students earned a bachelor's degree in engineering; another 33,000, a master's degree; and 7,100, a doctorate.[1] As in other technical professions, great care is taken by the engineering community to assure that degree recipients receive their training at programs accredited by peers.[2] Nonetheless, educators have come to recognize that improvements are needed in engineering education to prepare future graduates for the opportunities and challenges facing the profession in the 21st Century – most notably the emergence of the global marketplace and the attendant demand for well-trained high-technology workers who will assure a continuing, strong U.S. presence.[3]

The cadre of scientists who conduct research in engineering education have responded to this concern over the future of engineering education by turning their attention to needed improvements in the curriculum as well as instructional issues involving such topics as cooperative learning and teamwork, the timing of student exposure to new technologies, and characteristics of student learning strategies and styles – especially given the greater diversity of students now pursuing careers in engineering.[4]

The National Science Foundation (NSF) represents a significant source of support for research in engineering education,[5] and recently renewed its commitment to this area following the release of a report by the National Science Board outlining steps that might be taken to improve engineering education.[6] To assure the efficient investment of public funds in the coming years, the NSF Engineering Education and Centers Division (EEC) of the Directorate for Engineering asked the IDA Science and Technology Policy Institute (STPI) to examine a sample of NSF grants programs in engineering education, while also developing a master plan for longer term support for research in engineering education. STPI

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[1] National Science Foundation, Science and Engineering Degrees: 1966 – 2006 Detailed Statistical Tables, NSF 08-321, Arlington, VA.
[2] ABET, Inc. is the recognized national accreditation body for colleges and universities providing training in applied science, computing, engineering, and technology. ABET currently accredits 2,800 programs at more than 600 US colleges and universities. See: www.abet.org.
[3] See, for example, the National Academy of Engineering, Educating the Engineer of 2020, Washington DC: National Academies Press, 2005.
[4] J. Heywood, Engineering Education: Research and Development in Curriculum and Instruction, Hoboken, NJ: John Wiley & Sons, Inc., 2005, provides a useful overview of research in engineering education.
[5] See, for example, program announcement NSF 08-610 "Innovations in Engineering Education, Curriculum and Infrastructure" available at www.nsf.gov/2008/pubs.
[6] National Science Board, Moving Forward to Improve Engineering Education NSB 07-122, Arlington, VA, 2007.

launched a six-month study in April 2008 to provide the NSF's Engineering Education program with a systematic review of the outcomes and impacts of active grants in three engineering education program areas:

Subtask 1: How People Learn Engineering (HPLE)

Subtask 2: Department-Level Reform of Undergraduate Engineering Education (DLR)

Subtask 3: International Research and Education in Engineering (IREE)

This report presents the results of the STPI's evaluation of the Department-Level Reform program (subtask 2).

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Executive Summary

In November 2007, the National Science Foundation's National Science Board (NSF/NSB) issued a report outlining recommendations to improve U.S. engineering education. The report emphasized the vital role of engineering in the nation's technological innovation and economic strength, and cited the need for improvements in engineering education given the current U.S. dependence on international students and workers, the declining interest in engineering studies and careers among U.S. students, and demographic trends that are "unfavorable to increasing citizen participation rates in these fields."

Program Description

In 2002, the NSF established the Department-Level Reform (DLR) of Undergraduate Engineering Education to provide funding to engineering schools and departments for three specific developmental functions: 1) to reformulate, streamline, and update their degree programs, 2) to develop new curricula for emerging engineering disciplines, and 3) to meet the emerging workforce and educational needs of U.S. industry. NSF funded Principal Investigators to undertake reform of their department, a group of departments, or a specific program within their engineering school. From 2003 to 2005, NSF awarded 20 Implementation Grants ranging from $424,184 to $1.5 million each, typically over the course of three years.

NSF expects two outcomes from these grants. First, NSF expects the grants to increase the relevance of the undergraduate engineering curricula to modern engineering practice, making the instruction more effective and more applicable to the range of on-the-job experiences. Second, NSF expects the grants to increase the number of engineering degrees by encouraging more engineering students to complete degree programs. Under the NSF program model, engineering schools are expected to achieve these outcomes by introducing modern learning strategies, expanding both the disciplinary breadth and range of problem-solving techniques, and effectively integrating the powerful software tools used in engineering practice.

Evaluation Goals

In April 2008, NSF asked STPI to conduct a systematic review of the outcomes and impacts of the Department Level Reform program. The objectives of this evaluation are to assess the extent to which DLR has accomplished its goals, to determine whether the DLR program is an effective and efficient way to encourage engineering departments to update their programs by incorporating new teaching methods, and finally, to establish metrics of success for both individual projects and the portfolio of DLR projects.

STPI began by developing a logic model to highlight the effect of the events and processes at different points in the life cycle of the projects and portfolio of projects. This model provided a systematic framework to track the progress of funded projects, estimate the benefits and costs of these projects, identify more difficult-to-measure effects, and relate the findings back to the program's mission.

The study sought to answer three fundamental questions:

- Is the DLR program accomplishing its goals?
- Is the DLR program a good way to encourage engineering departments to update their programs to incorporate new teaching methods?
- What are the indicators of success for individual projects as well as the portfolio of DLR projects?

Methods

NSF provided STPI with data on the processes, events, and status of the funded projects. In addition, STPI reviewed DLR proposals and progress reports, and followed up with telephone or in-person discussions with each DLR team. Telephone discussions were conducted with each team's Principal Investigator and one or two members of the institution's project team. In-person discussions were conducted during site visits to the institution and typically involved the institution's entire project team, including students and faculty from engineering and other departments.

Summary of Main Findings

Is the DLR program accomplishing its goals?

Analysis of the data show that each DLR team accomplished significant curriculum reforms to make the engineering program more relevant, hands-on, and team-based using an approach customized to the specific needs of their institution. At this stage in the DLR programs, projects tend to show accomplishments such as increased engineering enrollment and an increased interest among engineering students in a graduate engineering education. However, since most institutions are only completing the implementation stage of their reformation with the first cohort of students, it is too soon to tell if the reforms are contributing to diversification of the student population or leading to an increase in the recruitment and retention of students[7] on a permanent basis.

[7] Retention refers to keeping students in engineering with the goal to increase the number of students graduating with a degree in engineering.

Table ES-1 presents a summary of the curriculum changes made by the DLR teams at each university. Each team took a unique approach in accomplishing significant curriculum changes. Underlying their different approaches were common themes. For example, many of the curriculum reforms focused on providing an integrated systems or multidisciplinary approach (for example, *systems thinking, block scheduling, spiral learning, Interlinked Curriculum Components*). Others focused on introducing students to new areas of technology, such as MEMS, advanced materials, nanotechnology, nontraditional energy, bioengineering, and microelectronics. And a third type of reform focused on incorporating projects throughout the curriculum, such as service learning projects for several semesters, design projects every semester, or a combination of the two in programs such as Urban Studios.

All DLR projects introduced facets of these approaches but combined them in unique ways, and emphasized primary approaches to their reform efforts tailored to the needs of the school and program. In general, the goal was to introduce design and hands-on learning earlier in the engineering program, usually in the freshman year. Another goal was to introduce new areas outside of engineering such as business and entrepreneurship.

Curriculum reforms also involved significant changes in teaching methods, with less emphasis on lectures and more emphasis on teaming and hands-on experiences. The use of technology was also important for providing modules on specific topics, to test knowledge, to allow remote access for students, and to encourage interactive participation in class through the use of Tablet laptop computers. To raise awareness of learning styles and methods of both faculty and students, the University of North Texas requires students and faculty to take a Learning-to-Learn (L2L) class. The L2L class includes topics on consciousness and self-awareness, learning styles, memory, language, reading, writing, problem solving, creativity, and biological aspects of learning. Finally, to develop communication skills, many institutions require students to regularly present their methods and findings as well as provide written summaries. The University of Utah, for example, requires that their students take communication classes to improve their oral and written skills. These classes are tailored for engineering students. Other institutions integrate this content into their classes.

Service learning is an important facet of the curriculum reform for about half of the institutions. These projects benefit both the community and engineering students. Students work on teams and apply their engineering knowledge and design skills to solve a problem. These projects provide hands-on problem solving and design experiences and require presentation and communication skills. Some of the institutions required service learning projects every semester while others required at least one to two projects during the life of the engineering program.

Table ES-1: Summary of DLR Curriculum Changes by University

Institution	Curriculum Changes	New Technology Areas	Changes in Teaching Methods	Service Learning	Advisory Board
California Polytechnic	Adopted systems approach that combined economics, engineering, and society with focus on sustainability.	Nano-Bio course; Sustainability	Build mastery of foundational skills: teamwork, communication, and self-directed learning	Yes	Yes
Central Florida	Integrated cognitive learning theory with emphasis on human information processing	Engineering Leadership and Management minor	Encourage technology use to create experiential learning opportunities.	No	Yes
City College of New York	Incorporated emerging technologies into curriculum.	MEMs Advanced Materials Computer Aided Engineering, Intelligent Systems, Biotechnology, Nanotechnology, Nontraditional Energy	Provide opportunities to stimulate critical thinking, foster development of teamwork skills, for written, graphic, and oral communication.	No	Yes
Columbia	Adopted Urban Studios-an intensive environment for collaborative, goal-oriented problem solving that promotes the synthesis of materials and concepts with focus on solving urban problems	Sustainability	Use variety of cognitive learning methods, including activity and team based strategies, simulations, and case studies, complemented by mentored practical experiences.	Yes	Yes
Duke	Implemented Integrated Sensing and Information Processing.	Biotechnology and biomedical applications	Focus on early design, synthesis, and real-world experiences, with emphasis on hands-on experiences	No	Yes
Johns Hopkins University	Minimize critical path lengths. Integrate across technical topics. Integrate across technical and nontechnical topics. Introduce more focus on applications. Emphasize the (positive) impact of engineering on society	Novel applications related to fluids, solids, and design.	Added teamwork experiences. Fostered an atmosphere of inclusivity.	No	No
Lehigh	Created a Bioengineering program that bridges the Science and Engineering Schools with focus on integrated experiential learning curriculum.	Biotechnology; Biostructural Mechanics Integrated Photonics	Incorporation of mentoring, teaming and hands on experiences into the curriculum. Also use of computer-based experiments and distance learning in the curriculum.	No	Yes
Massachusetts Lowell	Incorporated real world service-based projects for learning engineering content.	--	Service Learning used to enhancing critical thinking and tolerance for diversity. It leads to better knowledge of course subject matter, cooperative learning, and problem-based	Yes	No

Institution	Curriculum Changes	New Technology Areas	Changes in Teaching Methods	Service Learning	Advisory Board
			learning.		
North Texas	Introduced "Project every semester" model to teach design and to encourage strong communication skills. Introduced business and entrepreneurship into curriculum.	--	"Learning to learn" – (L2L) active learning: develops understanding of how engineering is learned and how faculty facilitates learning. Topics include: consciousness and self awareness, meta-cognition, learning styles, memory, language, reading, writing, problem solving, creativity, and biological aspects of learning.	No	Yes
Oklahoma State	Transitioned from knowledge based to development based curriculum (focus on developing engineers who can solve real-world problems)	Engineering education	Developed 10 new courses to focus on experiential development of students. The intent is that a student would take one course per semester over 5 years. These 10 courses result in a cognitive apprenticeship where students learn to document, analyze data, and report on work. These are design courses that broaden skills based on common things that engineers should do (to be factual, meta-cognitive, procedural, and conceptual).	No	Yes
Old Dominion	Introduced interactive modules using simulation and visualization to enhance learning.	Virtual technology using simulation and visualization	The simulation and visualization modules employ the pedagogy of "learning-by-doing in virtual environments." This is also known as technology enabled self learning, or student-centric learning.	No	Yes
Pittsburgh	Adopted Block Scheduling, which allows for courses with considerably longer contact hours to focus on topics comprehensively.	Molecular and multi-scale chemical engineering	Block scheduling allows for extensive team-based learning for both faculty and students. Labs are now vertically integrated into each pillar (comprehensive, topically-centered courses that range from 5-7 credits). Previously lab courses were only taken in senior year.	No	No
Purdue	Implemented a Multidisciplinary Engineering program to integrate science and engineering classes with focus on specific topics.	Biology and Nanotechnology	Faculty teaming and collaboration to teach classes, e.g., Integrated Science class. Student teaming for projects.	Yes	Yes
Rochester Institute of	Developed a Microelectronics and Nanofabrication minor for	Nanotechnology	Teach nanotechnology using a bottom up approach based on	Yes	Yes

Institution	Curriculum Changes	New Technology Areas	Changes in Teaching Methods	Service Learning	Advisory Board
Technology	non-Microelectronic majors and a program in nanotechnology and MEMS.		hands on lab experiments. Formed multidisciplinary teams that included both faculty and industry in mechanical and imagining sciences. Industry funded the nanofabrication lab.		
South Florida	Implemented a Multidimensional Spiral Curriculum that focuses on integrating core concepts in a specific discipline for the synthesis, analysis, and design of a product or process of societal value.	Emerging technologies in chemical engineering.	Active learning. Use of technology for more efficient delivery of the core concepts. Use of virtual modules and team-oriented, hands-on exercises to reinforce the concepts being covered in class.	No	Yes
Sweet Briar College	Established a Physics and Engineering Science program at a women's college	--	Small class sizes. Hands-on approach to learning. Focus on projects that directly benefit society.	Yes	Yes
Texas A&M	Developed Interlinked Curriculum Components (ICC) which are web-based learning sites for students. Developed comprehensive program assessment plan that includes integrated learning outcomes for all engineering courses and new assessment techniques Incorporated a new course on Engineering Biology	Materials; System synthesis and integration; Microchemical systems; Molecular modeling; and Environment and sustainability	Experiential learning, problem based learning, inquiry guided learning, internship and co-op programs and service learning. Concept mapping and inventories are developed and used to assess conceptual understanding of a specific subject.	Yes	Yes
Utah	Incorporated system-level design through lab projects, project management, entrepreneurship, and communication skills.	--	Team learning and learning by teaching Understanding learning styles and how to teach for everyone Mentoring. Enhancing hands-on laboratory experiences at all levels. Require communications classes.	Yes	Yes
Vermont	Applied integrated Systems Thinking to problem definition and problem solution. New courses use ecological systems and engineered environmental and transportation systems as major examples.	Systems analysis tools introduced; new geotechnical analysis tools and equipment	Systems thinking and analysis integrated into multiple courses; service-learning, as pedagogy to practice systems approach, implemented into multiple required courses, Open-ended research exercises, used in core junior courses. Hands on real world learning experiences	Yes	No

Institution	Curriculum Changes	New Technology Areas	Changes in Teaching Methods	Service Learning	Advisory Board
			throughout curricula.		
Vermont	Applied integrated Systems Thinking to problem definition and problem solution. New courses use ecological systems and engineered environmental and transportation systems as major examples.	Systems analysis tools introduced; new geotechnical analysis tools and equipment.	Systems thinking and analysis integrated into multiple courses; service-learning, as pedagogy to practice systems approach, implemented into multiple required courses, Open-ended research exercises, used in core junior courses. Hands-on, real-world learning experiences throughout curricula.	Yes	No
Virginia Tech	Incorporated Spiral Learning approach to strengthen students' understanding of basic concepts by revisiting the concepts periodically with different contexts and with increasing sophistication throughout the curriculum.	Biological Systems Engineering and Freshman Engineering	Curriculum reformulation using spiral theory in bioprocess engineering using supporting principles of design, ethics and systems approach. Hands-on learning in freshman engineering. Emphasis on teamwork, communication, life- long learning skills. Incorporation of feedback based learning models using Tablet PC and DyKnow technologies, particularly in freshman engineering. Assessment based learning modules.	No	No

For DLR teams with Advisory Boards, the Advisory Boards provided guidance for the DLR projects. Almost three-fourths of the DLR projects either had an Advisory Board specifically for the DLR project or their department or sometimes both. The Advisory Boards, which include company representatives, professors from other universities, and university staff, provided insights and advice on curriculum reform, funding for some of the reform activities, and internships for students.

In addition to the opportunity for curriculum changes, the DLR bestows a prestigious external recognition on the department receiving it and thereby increases support and buy-in from faculty and administrators. The additional support received (money, labs, new hires) allows the DLR teams to accomplish more and ensures the permanence of the reform efforts.

There are some indications that the DLR reforms are leading to increased student interest in entering and completing engineering programs. Many of the DLR teams reported an increase in student enrollment in their engineering programs. Most, however, reported that diversifying the student body is still a challenge. Some DLR teams report that the focus on engineering education has sparked interest among some students to now consider graduate school. Since most programs are only now completing the implementation of their new curriculum with the first cohort of students, it is too soon to tell if the reforms are leading to an increase in the recruitment and retention of students on a permanent basis.

Is the DLR program a good way to encourage engineering departments to update their programs to incorporate new teaching methods?

One indication of how well the DLR program encourages engineering departments to reform their curricula lies in the recommendations project teams make for DLR improvements. As part of this evaluation, evaluators asked the DLR teams to suggest ways to improve the DLR program. They recommend that NSF:

- Continue the DLR program and extend the time frame for the grants from 3 to 5 years (or longer);
- Provide supplementary grants to allow dissemination of the findings resulting from the DLR grants and complete assessment of the program;
- Focus NSF conferences on specific topics and provide trained facilitators to guide discussion;
- Provide more opportunities for NSF program managers to interact with the DLR teams; and
- Link undergraduate reform to graduate level reform.

In addition to the feedback from the DLR teams, STPI conducted an *ex ante* and *ex post* mapping of the criteria and accomplishments against the National Academy of Engineering's (NAE) report and the Accreditation Board for Engineering and Technology (ABET) Criteria to provide two indications that the DLR program meets the NAE recommendation and address the ABET criteria.

The *ex ante* mapping compared the DLR criteria to the NAE recommendations and found that the two mesh well. The NAE report provides recommendations for training future engineers to be prepared to practice in a global world. In harmony with the desired outcomes of the DLR program, the NAE recommendations encourage programs to introduce engineering concepts and designs early in students' undergraduate education in an effort to motivate them to obtain graduate degrees.

The *ex post* mapping of the DLR outputs and outcomes addressed the ABET criteria. These criteria focus on what engineering students should learn, including techniques, skills, and engineering tools that are used by practicing engineers. Each DLR project successfully implemented curriculum changes that teach students to apply their science and engineering knowledge to design, and to conduct experiments, interpret and analyze data, and design systems that are in line with the ABET criteria.

What are the indicators of success for individual projects as well as the portfolio of DLR projects?

The following are recommended as short-term indicators of success:

- Faculty buy-in to adopt new teaching methods and to undertake engineering education research;
- A revised curriculum that reflects emerging areas and use of technology in courses/laboratories and the use of modern learning methods;
- Student enthusiasm and perceptions of the role of engineers in society;
- Increased quality and extent of students' design projects, computational skills, and communication skills; and
- Incorporating formative and summative assessments into the engineering curriculum.

For long-term indicators of success, the following are recommended:

- Ongoing interest in curriculum refinement;
- Retention of students in engineering programs;[8]
- Increased diversity of engineering students; and
- Employer recognition that interns/graduates who receive their engineering degrees in these revised programs are valued.

Given the time-frame, the study focused on the short-term indicators of success that describe the inputs, outputs, and near-term outcomes. The DLR program will need to be evaluated several years out to assess the permanency of the program changes and the impacts of the changes on diversity, retention, and career paths of students.

The National Science Foundation's Department-Level Reform (DLR) of Undergraduate Engineering Education program appears to be successful in encouraging engineering departments to undertake and implement curriculum reform that introduced emerging areas of technology and teaching methods. In addition, the DLR grants demonstrated that curriculum reform requires:

- An infusion of funding (such as the NSF grants) as well recognition and support by Engineering School and University administration;

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[8] Retention refers to keeping students in engineering with the goal to increase the number of students graduating with a degree in engineering.

- Dedication and leadership of faculty leading in and participating on the DLR project and embracing engineering education research; and
- Dissemination of curriculum reform modules, lessons learned, and best practices through workshops, websites, conference presentations, and journal publications.

I. Introduction

In its report, “Educating the Engineer of 2020,” the National Academy of Engineering (NAE) concluded that to meet the needs of the 21st century, engineering graduates must possess a broad set of skills beyond technical knowledge. The NAE advocated for educational programs that develop skills in communication, teaming, ethical reasoning, and contextual analysis, as well as in technologies.

One of the efforts of the National Science Foundation to address these goals was to create a new program in 2002 the program called the *Grants for the Department-Level Reform (DLR) of Undergraduate Engineering Education.* In 2002, NSF offered planning grants, and between 2003 and 2005, they also offered implementation grants to implement curriculum reforms in engineering schools and departments.

This evaluation study presents findings from the 20 DLR implementation grants funded from 2003–2005, most of which are just ending or will end in 2009. This study measures outputs and near-term outcomes that resulted from the DLR implementation program. Appendix D presents mini case studies for each of the DLR projects included in this study. Appendix E presents list of publications, presentations, and workshops that resulted from each project.

The purpose of the evaluation is to address three questions:

- Is the DLR program accomplishing its goals?
- Is the DLR program a good way to encourage engineering departments to update their programs to incorporate new teaching methods?
- What are the metrics of success for individual projects as well as the portfolio of DLR projects?

Appendix Table A lists the universities that received a DLR grant, the titles of their projects, the Principal Investigators, and the amounts of the grants.

A. Background

The goal of the program *Grants for the Departmental-Level Reform (DLR) of Undergraduate Engineering Education*, offered by the NSF from 2002–2005, was to provide planning and implementation funds to engineering schools or departments to reformulate, streamline, and update engineering and engineering technology degree programs, develop new curricula for emerging engineering disciplines, and meet the emerging workforce and educational needs of U.S. industry. The expected outcomes of the grants were to increase the relevance of undergraduate engineering curricula to modern engineering practice and to induce an increased proportion of students who enroll to complete engineering degree programs. The expectation was that the DLR goal and outcomes could be accomplished by:

- More fully use multiple learning strategies[9];
- Expanding both the disciplinary breadth and the range of problems and problem-solving techniques to which engineering students are exposed; and
- Incorporating new laboratories and research experiences, and effectively integrating the powerful software tools used in engineering practice.

The goals of the DLR are in accord with NSF's Division of Engineering Education and Centers (EEC) mission and objectives to "support the development of diverse, creative, innovative, and globally competitive engineers." To reach those goals through education reform and curriculum development requires a clear understanding of how learning occurs in the engineering education environment: how students learn engineering, how faculty teach engineering, and how learning can be assessed. To move from curriculum design to successful curriculum implementation, however, involves a change in the culture of the engineering education environment. That cultural change requires active faculty participation and clear leadership from the department head.

The 2007–2012 plan for the NSF's Division of Engineering Education and Centers (EEC) points out that less than 7 percent of all students entering four-year colleges are choosing to study engineering, compared to 10 percent of students two decades ago. In absolute numbers, engineering enrollment has remained steady due to the increasing number of high school graduates. However, these numbers are expected to decline in 2010, when the number of high school graduates is expected to decline.

The DLR program directly addresses the EEC objective to "promote the success of the undergraduate learning experience" with the goal that three out of four students who begin the study of engineering will complete at least a B.S. degree in engineering.

Under the predecessor program, Engineering Education Coalitions (1990–2004), NSF funded eight coalitions involving over 40 universities with the mission to "catalyze systematic changes across the engineering education community by

[9] The instructional design literature suggests that the methods used to teach new knowledge and skills vary significantly with regard to how much is retained. For example, only 5% is retained from lectures while 90% of material is retained when teaching others. Retention rates for other activities are: reading (10%), audiovisuals (20%), demonstration (30%); discussion (50%); and practice by doing (75%) (Silberman 2006).

developing and demonstrating the efficacy of new curricular models." (Borrego, 2007)

The Engineering Education Coalitions focused on encouraging 1) the development of innovative models for systematically reforming undergraduate engineering education, and 2) the retention of women and underrepresented minorities in engineering fields. During the program's existence, the Engineering Education Coalitions found a number of effective methodologies, including: 1) active, experiential learning environments, 2) student teams, and 3) integration across disciplinary boundaries (Froyd, 2005). Another outcome of the coalitions was the use of assessments to illustrate the success of the teaching innovations that were implemented. Coalition participants made the assumption that "quality assessment results will compel other faculty to adopt educational innovations" (Borrego, 2007).

B. Description of the Department Level Reform (DLR) Grant Program

The National Science Foundation offered DLR grants from 2002–2005. The 2002 solicitation (NSF 02-091) offered universities $100,000 to plan a program to reform their undergraduate engineering programs. In September 2002, NSF awarded 37 DLR planning grants. This program focused on improving the curriculum in engineering departments and schools in response to new fields emerging in information technology and engineering innovations (Evensen and Lattuca, 2005). The DLR Planning Grants were expected to result in plans to implement curricula changes that "capitalized on theory-driven pedagogical innovations such as team- and problem-based learning, computer simulations, and mentoring." (Evensen and Lattuca, 2005)

The 2003, 2004, and 2005 solicitations (NSF solicitations 03-562, 04-523, 05-531) provided funding for both planning and implementation grants. The focus of this evaluation is on the implementation grants.

The implementation grants provided funding to reform a curriculum for a specific department, a group of departments, or a program within an Engineering School, such as the freshman curriculum. From 2003 to 2005, NSF awarded 20 Implementation Grants. These grants ranged from $424,184 to $1.5 million each. In 2004, the top funding amount decreased to $1 million.

The DLR solicitations were a collaborative effort between NSF's Directorate for Engineering and the Directorate for Education and Human Resources.

The criteria for the 2003 grants focused on:

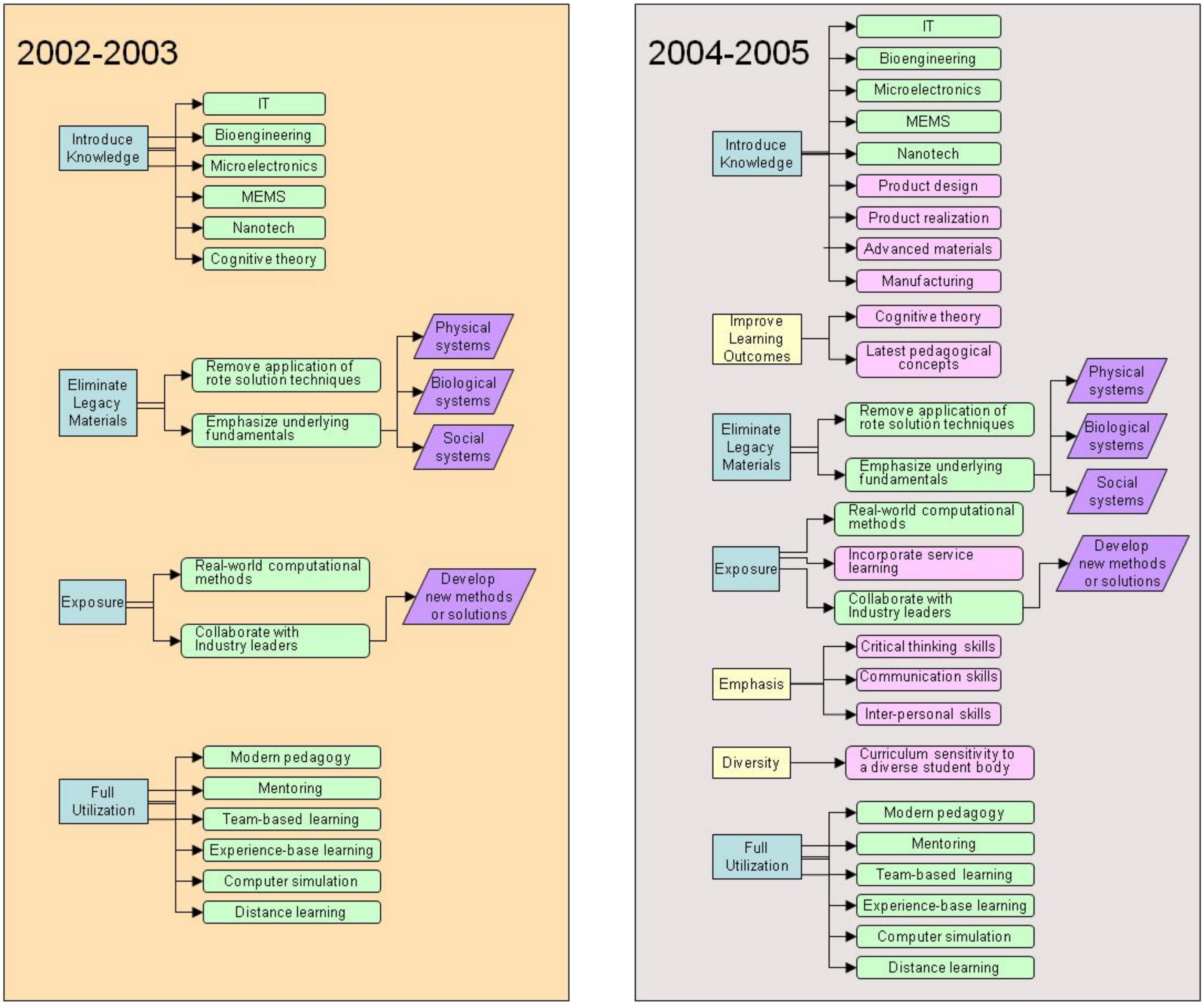
- Introducing emerging knowledge related to information technology, bioengineering, microelectronics, microelectromechanical systems (MEMS), nanotechnology, cognitive theory, etc.;
- Making full use of modern teaching methods, including mentoring, team-based and experience-based learning, computer simulation, and distance learning;
- Eliminating legacy materials emphasizing the application of rote solution techniques and replacing them with content emphasizing the fundamental, underlying behavior of physical and biological systems and the social systems in which they are employed; and
- Exposing students to the computational methods employed by practicing engineers to solve engineering problems, preferably in collaboration with industry leaders in developing tools implementing such methods.

In 2004–2005, NSF expanded each of the 2003 criteria to:

- Include new areas of knowledge, such as product design and realization, advanced materials, and manufacturing;
- Utilize new ways to improve learning outcomes based on cognitive theory and the latest pedagogical concepts;
- Incorporate service learning;
- Emphasize critical thinking skills, communication skills, and interpersonal skills; and
- Develop a curriculum of interest to a diverse student body.

Figure 1 compares the criteria for 2002-2003 to 2004-2005

Figure 1: Comparison of 2002-2003 DLR Grant Program with 2004-05 DLR Grant Program



SOURCE: IDA Science and Technology Policy Institute

II. Methodology and Findings

A 2008 National Research Council (NRC) report proposes that evaluation of federal programs distinguish between "investment efficiency" and "process efficiency" and recommends that these aspects be evaluated in different ways. Both these criteria are addressed in this evaluation.

A. Investment Efficiency Method and Findings

Evaluating investment efficiency focuses on whether the DLR is 1) investing in research that is relevant to NSF's mission and long-term plans, and 2) is performed at a high level of quality. To assess investment efficiency, the DLR criteria were compared to ten recommendations made by the National Academy of Engineering (NAE) in its report, *Educating the Engineer of 2020, Adapting Engineering Education to the New Century*. In this report, the NAE asks, "What will or should engineering look like today or in the near future, to prepare the next generation of students for effective engagement in the engineering profession in 2020?" The report offered recommendations to address the issues facing undergraduate engineering education.

An *ex ante* comparison of the DLR criteria indicates that the DLR program meets NAE's criteria. NAE recommends that the B.S. degree in engineering should be an engineering-in-training degree and that the M.S. degree should be recognized as a professional degree. They also recommended that universities introduce engineering concepts and designs early in students' undergraduate education, that they encourage life-long learning, and motivate them to obtain graduate degrees. On the faculty side, NAE recommends that research in engineering education be rewarded and that case studies of engineering successes and failures be used as a learning tool. Finally, they recommend that the NSF assist in collection of data on new

National Academy of Engineering Recommendations

- ✓ The B.S. degree should be considered a pre-engineering or "engineer in training" degree.
- ✓ Engineering programs should be accredited at both the B.S. and M.S. degree levels so that the M.S. degree can be recognized as the engineering "professional degree."
- ✓ Institutions should take advantage of the flexibility inherent in the EC2000 accreditation criteria of ABET, Incorporated in developing curricula and students should be introduced to the essence of engineering early in their undergraduate careers.
- ✓ Colleges and universities should endorse research in engineering education as a valued and rewarded activity for engineering faculty and should develop new standards for faculty qualifications.
- ✓ In addition to producing engineers who have been taught core knowledge and are capable of defining and solving problems in the short term, institutions must teach students how to be lifelong learners.
- ✓ Engineering educators should introduce interdisciplinary learning in the undergraduate curriculum and explore the use of case studies of engineering successes and failures as a learning tool.
- ✓ 4-year schools should accept the responsibility of working with local community colleges to achieve workable articulation with their 2-year programs.
- ✓ Institutions should encourage domestic students to obtain M.S. and Ph.D. degrees.
- ✓ The engineering education establishment should participate in efforts to improve public understanding of engineering and the technology literacy of the public as well as efforts to improve math, science, and engineering education at the K–12 level.
- ✓ NSF should assist in the collection of data on program approach and student outcomes for engineering departments/schools so that prospective freshmen can better understand the engineering baccalaureate programs available.

SOURCE: National Academy of Engineering, *Educating the Engineer of 2020, Adapting Engineering Education to the New Century.*

approaches to teaching engineering and the resulting student outcomes.

The DLR criteria did not directly address two NAE criteria, the first stating that engineering programs should be accredited at the M.S. degree level so that this degree can be recognized as the engineering professional degree. (However, *ex post*, one Principal Investigator, or PI, did suggest linking undergraduate reform to graduate reform.)

The second criterion not directly addressed is that four-year schools should work with community colleges to ensure successful transitions to four-year programs. However, several of the DLR teams did interact with community colleges to recruit students to four-year programs.

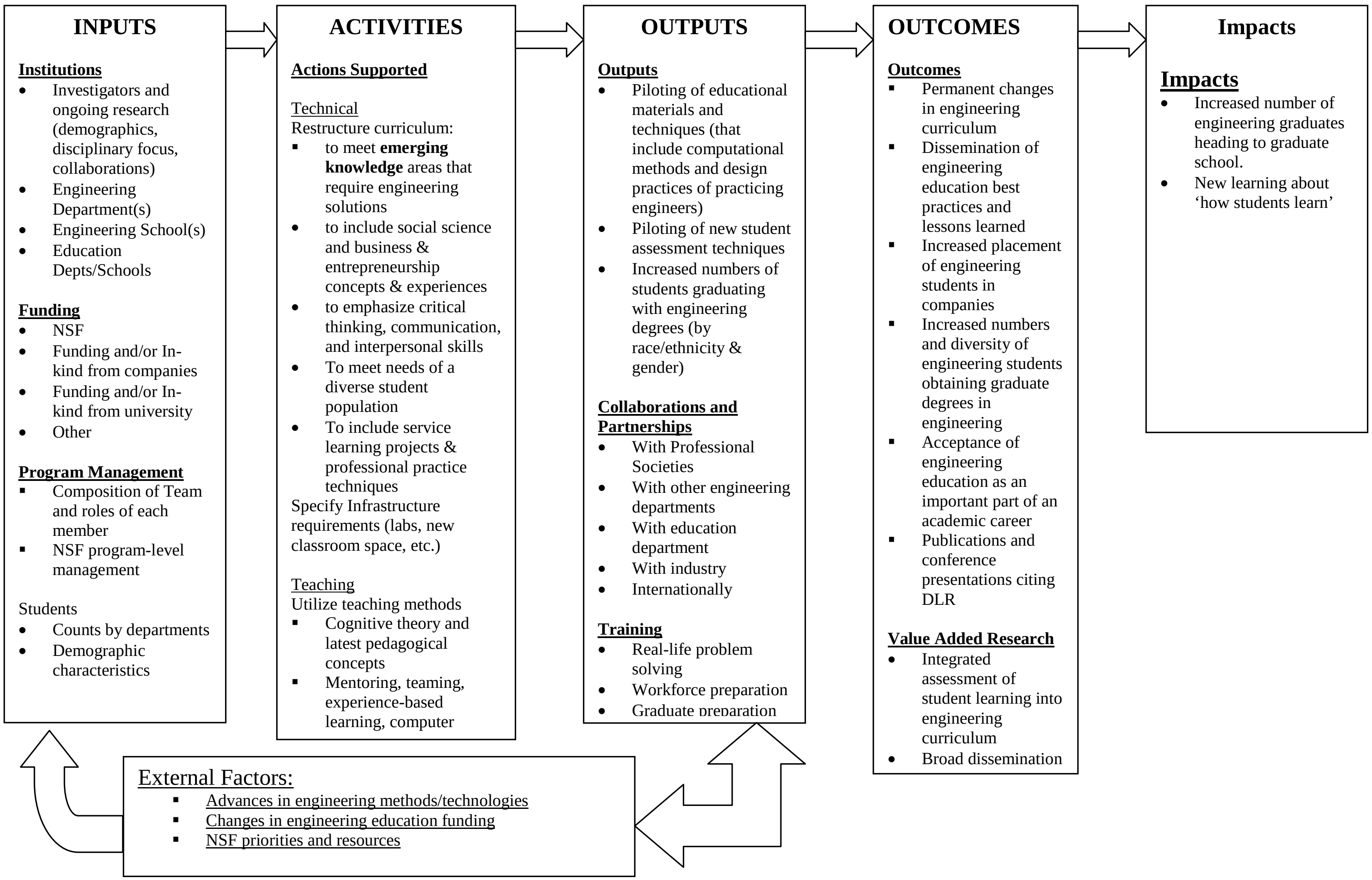
In addition, the NAE report notes other factors at play, including "the influence of the global marketplace for engineering services, the integration of technology in our public infrastructure which will require more involvement of engineers in public policy, and the need for increased interaction of engineers in industry and the academic establishment." The DLR criteria address all of these factors.

B. Process Efficiency Methods and Findings

The 2008 National Research Council (NRC) report defines process efficiency as an evaluation that asks how well the grants are managed. It monitors activities such as inputs, outputs, and short-term outcomes. The logic model for the evaluation of the DLR grants provides a picture of the factors that can be evaluated at different points in the life cycle of each project and portfolio of projects (Figure 2). The model also identifies five categories of measurement:

- Inputs to the projects (players, funding, project management, students);
- Activities to be described (changes to the curriculum, use of teaching methods);
- Outputs (new curriculum tested, collaborations, training);
- Outcomes (permanency of curriculum changes, dissemination of best practices, acceptance of engineering education as an important part of an academic career, higher-quality graduates); and
- Impacts (increased numbers and diversity of engineering students obtaining graduate degrees in engineering, new information about "how students learn").

Figure 2. Department-Level Reform Logic Model



Evaluation objectives include tracking progress of funded projects; estimating the benefits and costs of projects and or the overall program; identifying more difficult-to-measure effects, such as acceptance of engineering education as an important part of an academic career or producing higher-quality graduates; and relating findings back to the program's mission. Additional objectives include disseminating evaluation results and feeding them back to program administrators (to improve the program) and to policy makers (to inform them and meet reporting requirements).

Using the logic model as a guide, the evaluation aims to address the following questions:

- Is the DLR program accomplishing its goals?
- Is the DLR program a good way to encourage engineering departments to update their programs to incorporate new teaching methods?
- What are the metrics of success for individual projects as well as the portfolio of DLR projects?

The approach to gathering data involved review of DLR proposals and progress reports, followed up with discussions by phone or in person with each team. By phone, these discussions were often with the Principal Investigator and one or two other team members. Site visits often involved the entire team, including students and faculty from other departments. Regarding these visits, one Principal Investigator[10] commented: "The visit has actually helped participants to get a bigger picture of the project and become more involved. ... [M]any of the students commented on the fact they learned a lot from simply observing the interactions. I would actually recommend to NSF that if they have future DLR programs that annual site visits by an external team (perhaps professional evaluators as well as previous DLR recipients) be a mandatory part of the project. If we had had such a visit annually I think it would have helped provide more focus for the project and helped energize participants."

Data collection efforts focused on the following:

- Basic characteristics of the project;
- Technical and teaching strategies;
- Funding (distribution of funding, additional sources of funding);
- Service learning projects;
- Integration of DLR research and teaching;
- Project assessments;
- Project accomplishments;
- Dissemination of DLR plans;
- Expectations about the permanence of DLR changes; and

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[10] Alan Cheville, Oklahoma State University.

- Opportunity to provide feedback to NSF.

1. Inputs

NSF awarded implementation grants to 20 colleges and universities ranging from approximately $424,184 to $1.5 million. They awarded five grants in 2003, seven grants in 2004, and eight grants in 2005. The total amount awarded in each year was about $6 million in 2003, $7 million in 2004, and $8 million in 2005 (see Appendix A).

Institution size. A variety of colleges and universities competed for and received DLR grants, ranging from a small women's college to large state universities with student bodies of 15,000 to 40,000 students. Five of these universities have more than 30,000 students (chart 1).

The distribution changes somewhat when school size is shown by the number of undergraduates, as some schools have large graduate populations (chart 2A).

Forty percent of the DLR universities (8) have engineering schools with 1,501 to 2,500 undergraduates, another 40 percent have 2501 or more undergraduates, and the remainder (5) have fewer than 1,500 students (chart 2B).

Half (10) of the lead (or primary) engineering departments that received a DLR grant have 100 to 199 students. The distribution of the remaining engineering departments is almost evenly spread from 200 students to more than 1,000 students (chart 2C).

Chart 1. Distribution of universities by number of students

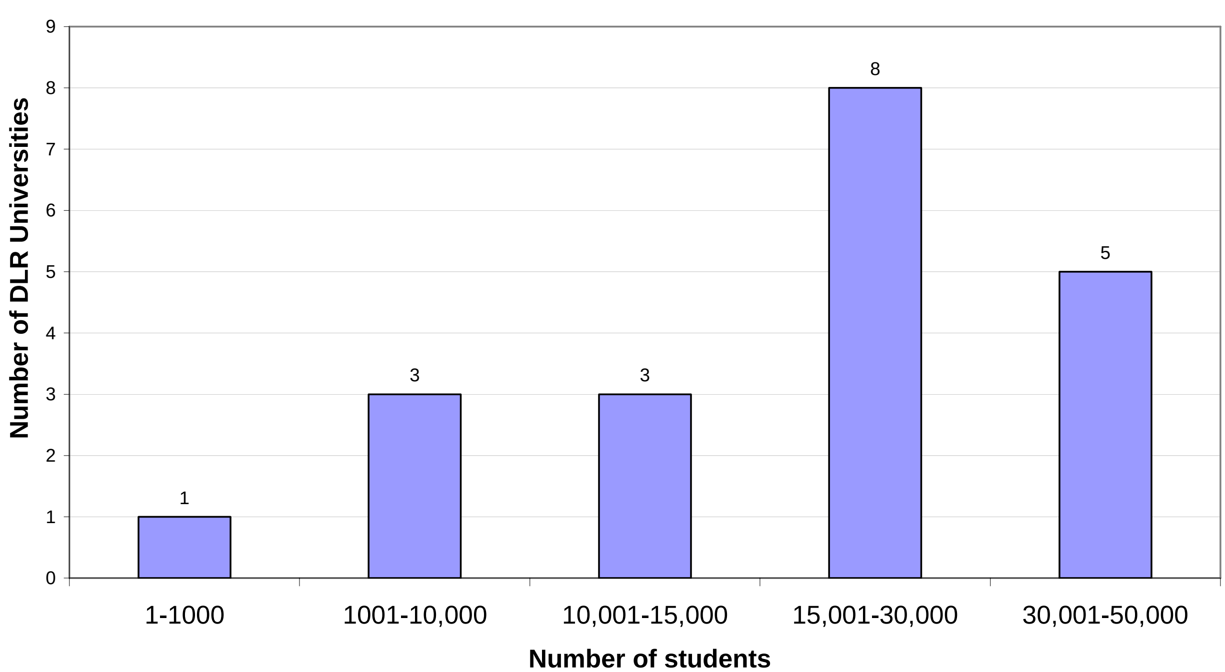


Chart 2A. Distribution of universities by number of undergraduates

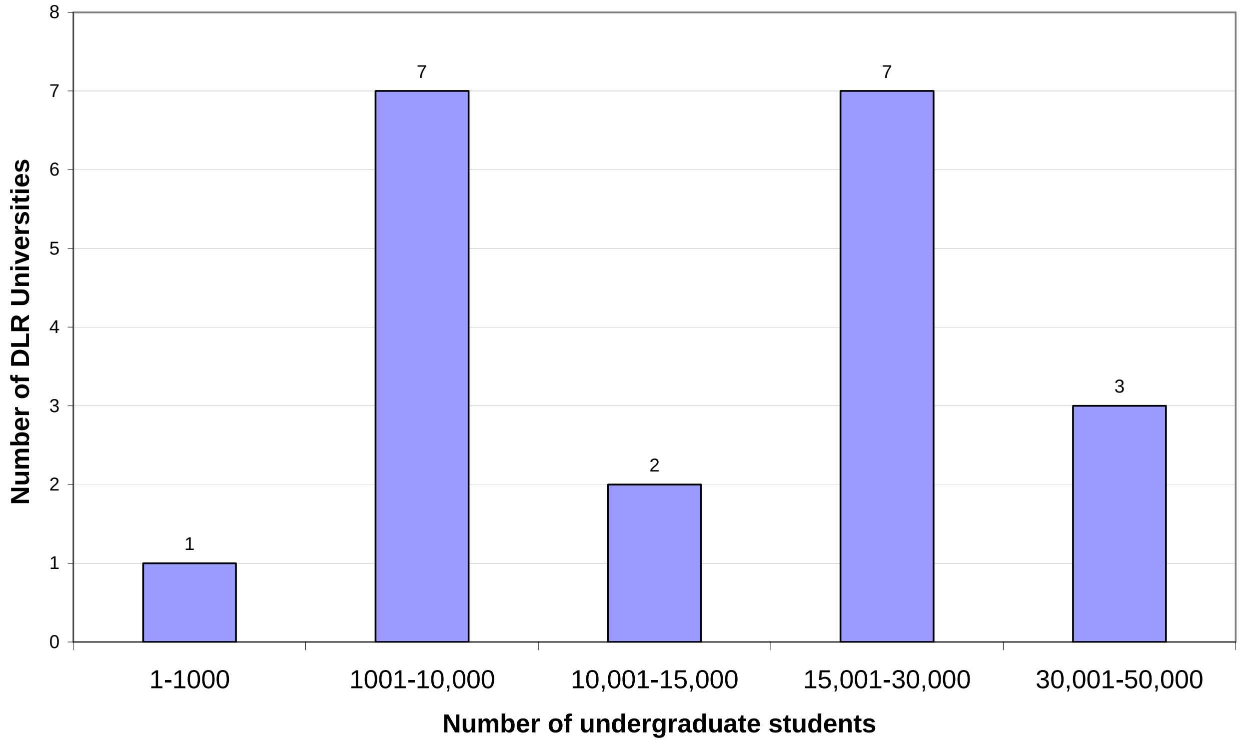


Chart 2B. Distribution of universities by number of undergraduates in Engineering School

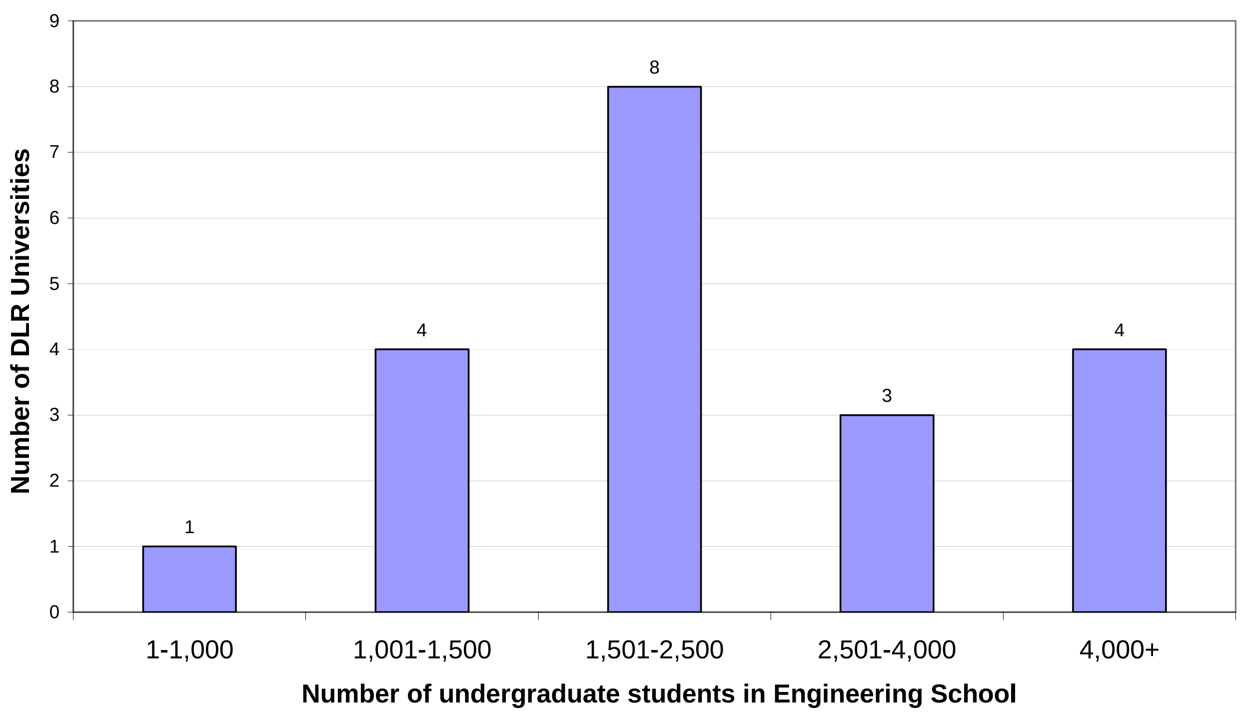
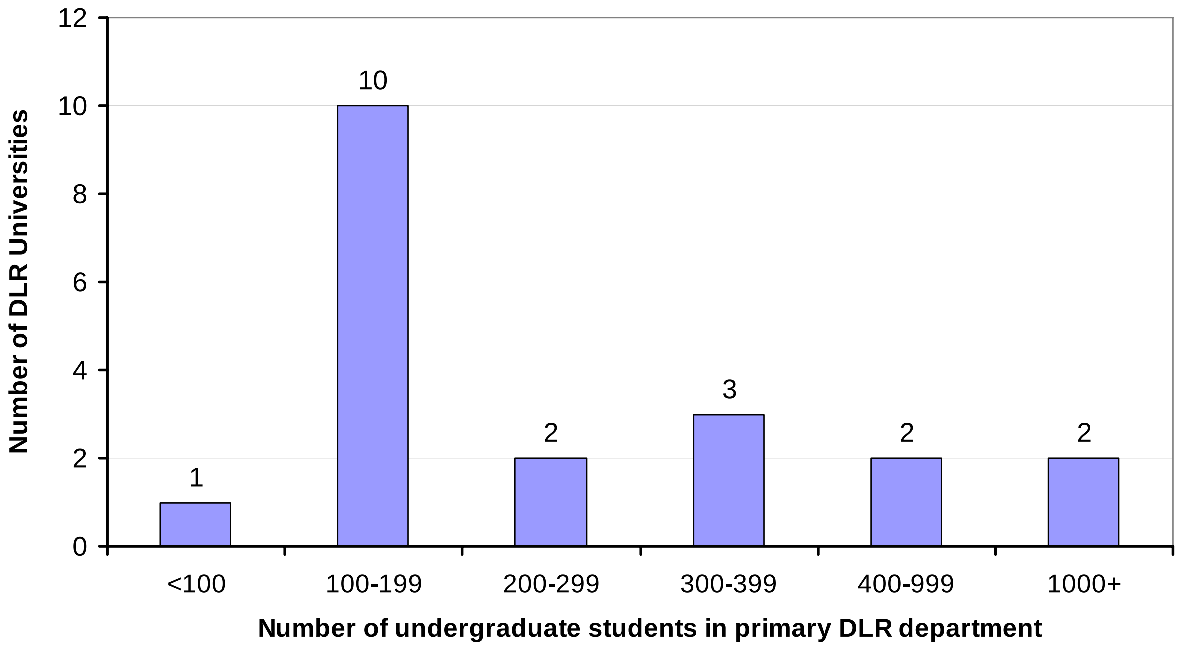


Chart 2C: Distribution of universities by number of undergraduates in primary DLR department



Engineering Departments. DLR grants were awarded to a variety of engineering disciplines (see Table 1). Electrical Engineering departments received four grants, followed by Chemical Engineering departments with three grants, and Mechanical Engineering, Civil Engineering departments, and Engineering Education Departments, each with two grants. Other departments were also involved in the DLR projects.

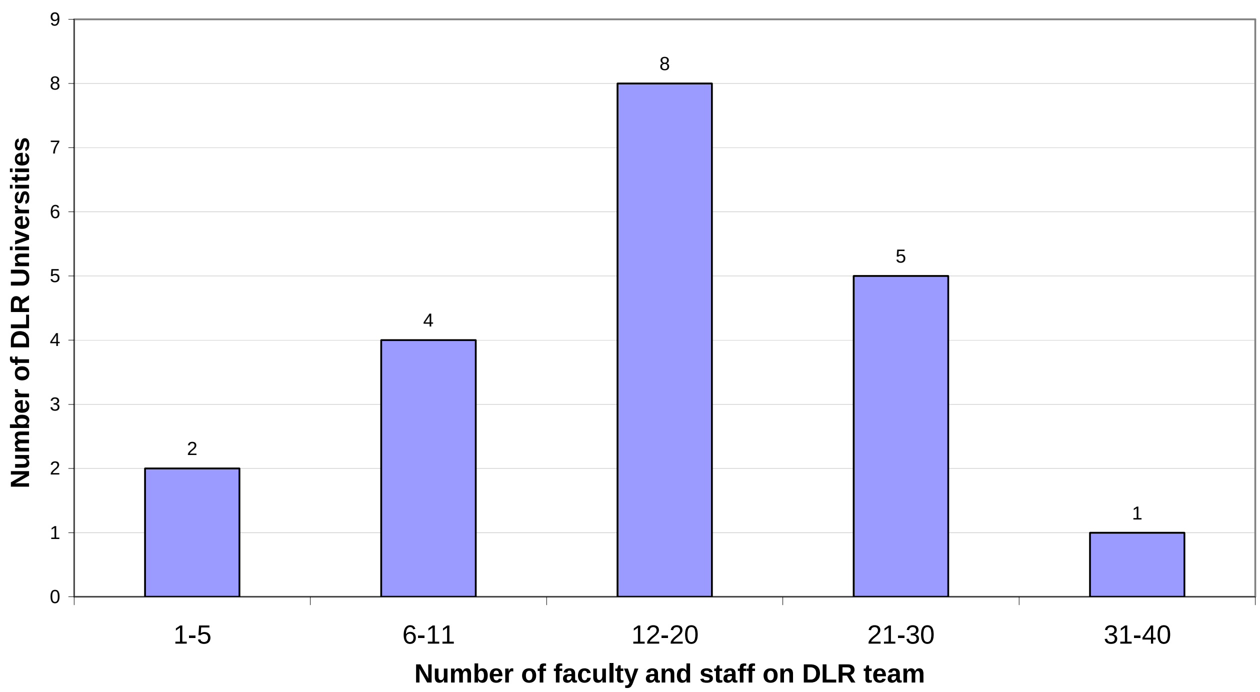
Table 1. List of Universities and Engineering Departments that Received DLR Grants (sorted by type of department)

University	Engineering Department (1)	Engineering Department (2)
Lehigh	Bioengineering	
Pittsburgh	Chemical Engineering	
South Florida	Chemical Engineering	
Texas A&M	Chemical Engineering	
Old Dominion	Civil and Environmental Engineering	Electrical Engineering
Vermont	Civil Engineering	Environmental Engineering
Massachusetts Lowell	College of Engineering	
Columbia	Earth and Environmental Engineering	Civil Engineering and Engineering Mechanics
Duke	Electrical and Computer Engineering	
Utah	Electrical and Computer Engineering	
North Texas	Electrical Engineering	
Oklahoma State University	Electrical Engineering	Chemical Engineering

Virginia Tech	Engineering Education (EngE)	Biological Systems Engineering (BSE)
Purdue	Engineering Education (DEED)	
Central Florida	Industrial Engineering	
Cal Poly	Materials Science and Engineering	
CCNY	Mechanical Engineering	
Johns Hopkins	Mechanical Engineering	
RIT	Microelectronic Engineering	
Sweet Briar	Physics and Engineering Science	

DLR team size. The size of the DLR teams varied from quite small (one to five faculty and staff) to quite large (20 to 40 faculty and staff). Seven teams had 12 to 20 members and five teams had 21 to 30 members (chart 3).

Chart 3. Distribution of universities by number of faculty and staff on DLR team

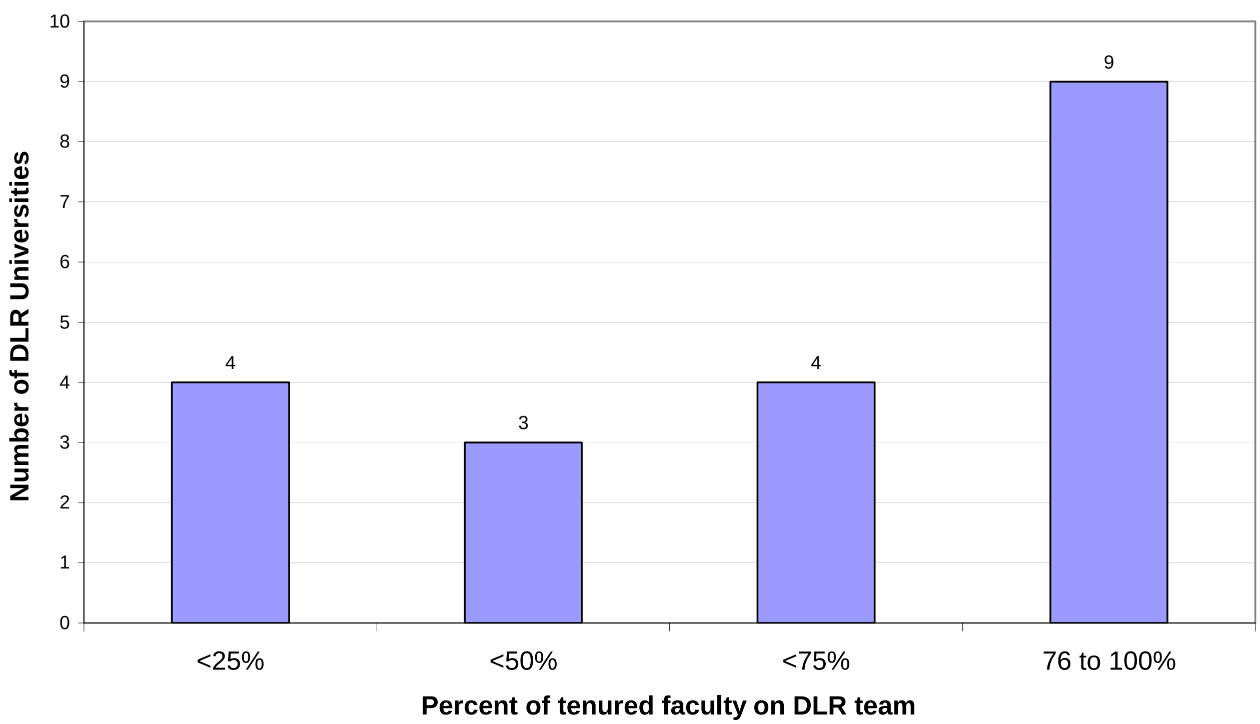


An early assumption[11] was that untenured faculty would not participate on the DLR team because it would not help them get tenure. At some institutions, untenured faculty on the DLR team obtained tenure and the Principal Investigators (PI) believed that participation on the DLR team contributed to their success, although they noted that it was only a small facet of their tenure package. The distribution does show that 13 of the 20 teams were

[11] Based on discussion at the May 15, 2008 DLR conference at NSF.

composed mostly of tenured faculty (chart 4). The PI for the DLR grants in all cases was tenured.

Chart 4. Distribution of universities by percent of tenured faculty on DLR team



The PIs on most of the DLR projects hired graduate and undergraduate students to develop course modules, lab experiments, and other activities including outreach and service learning. Four-fifths (17/20 teams) hired graduate students. Ten of these teams hired 1 to 5 graduate students and 6 teams hired 6 or more graduate students to work on DLR projects (chart 5). Two-thirds of the institutions hired undergraduate students to work on the DLR project (chart 6). Students indicated that this was a positive experience for them. Based on interviews, many graduate students indicated a new desire to teach when they graduate and many undergraduate students indicated that they were now thinking about going to graduate school as a result of their DLR experience.

Involvement of faculty and staff on the DLR team. Teams varied in the level and breadth of involvement in the DLR project. For seven of the teams, almost all members were very involved, for another eight, about half of the members were very involved. For five of the teams, about one-fourth of the team was very involved (chart 7). As expected, the larger the DLR team, the smaller the number of members that were very involved. There seemed to be a core team that ranged in size from two to twelve members. At some institutions, the PIs were less concerned with having all faculty very involved in all aspects, and instead used DLR funds to gain buy-in from faculty by having them participate in some facet of the project.

Chart 5. Distribution of universities by number of graduate students who worked on DLR project

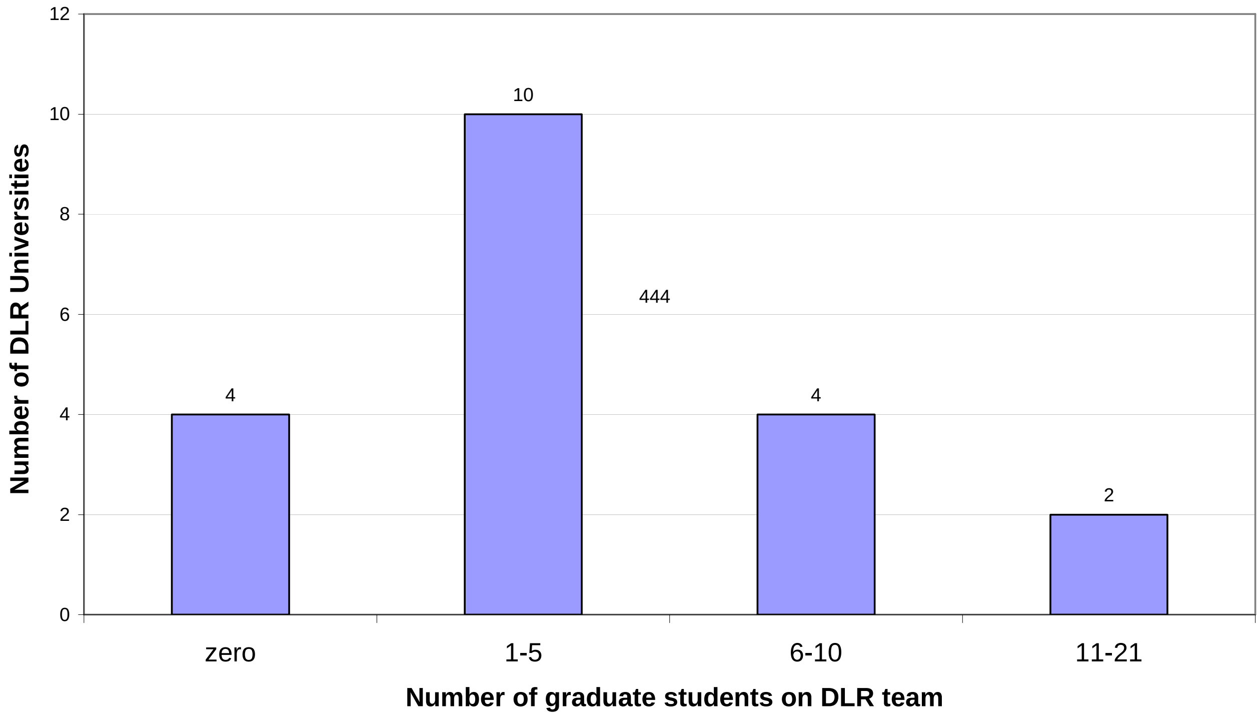


Chart 6. Distribution of universities by number of undergraduate students who worked on DLR project

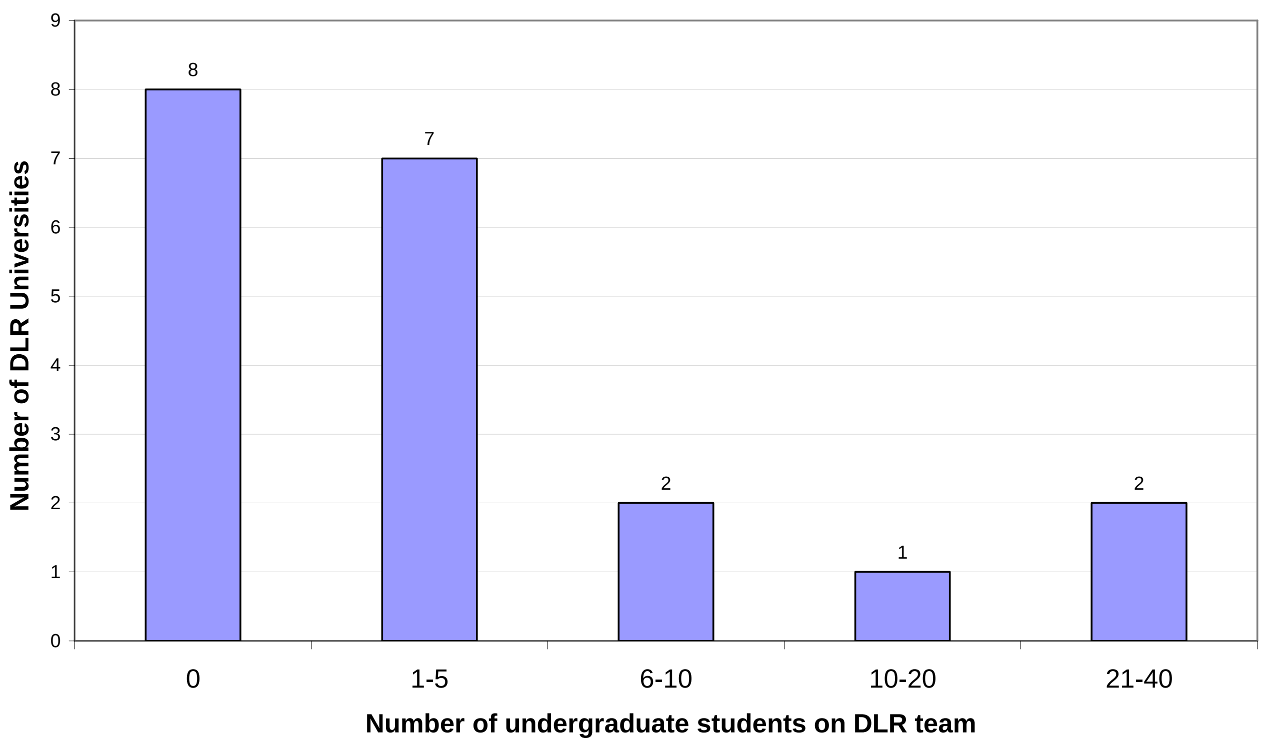
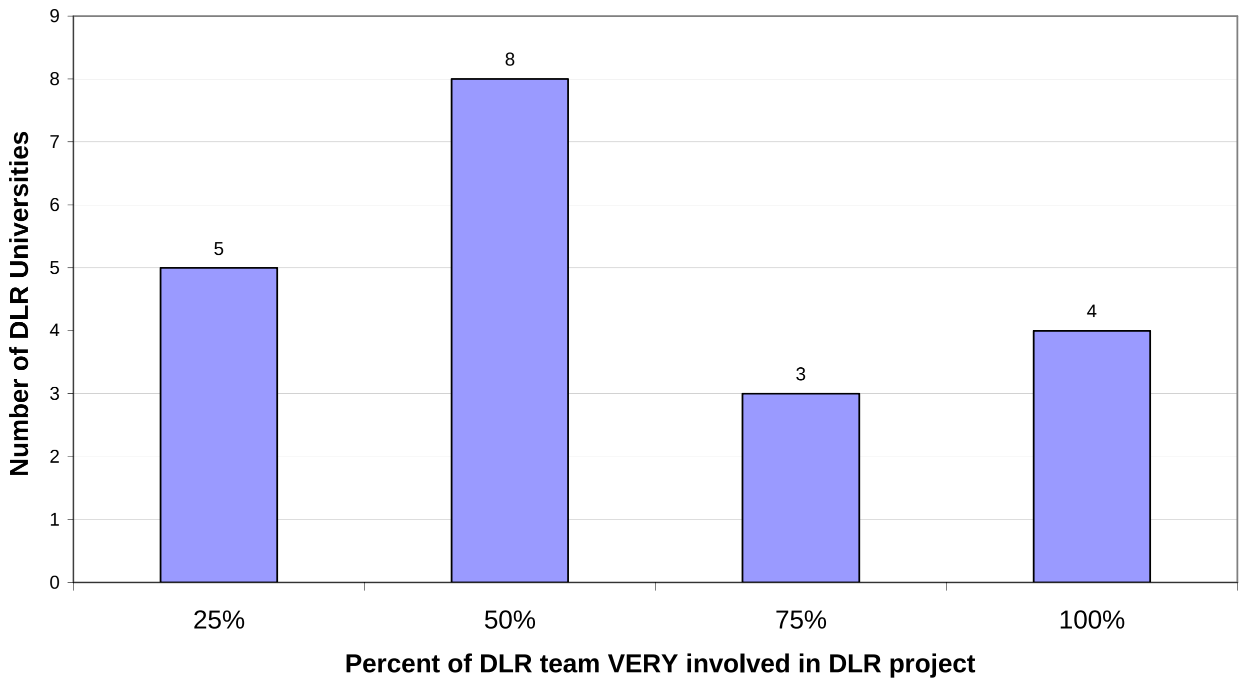


Chart 7. Distribution of universities by percent of DLR team VERY involved in DLR project

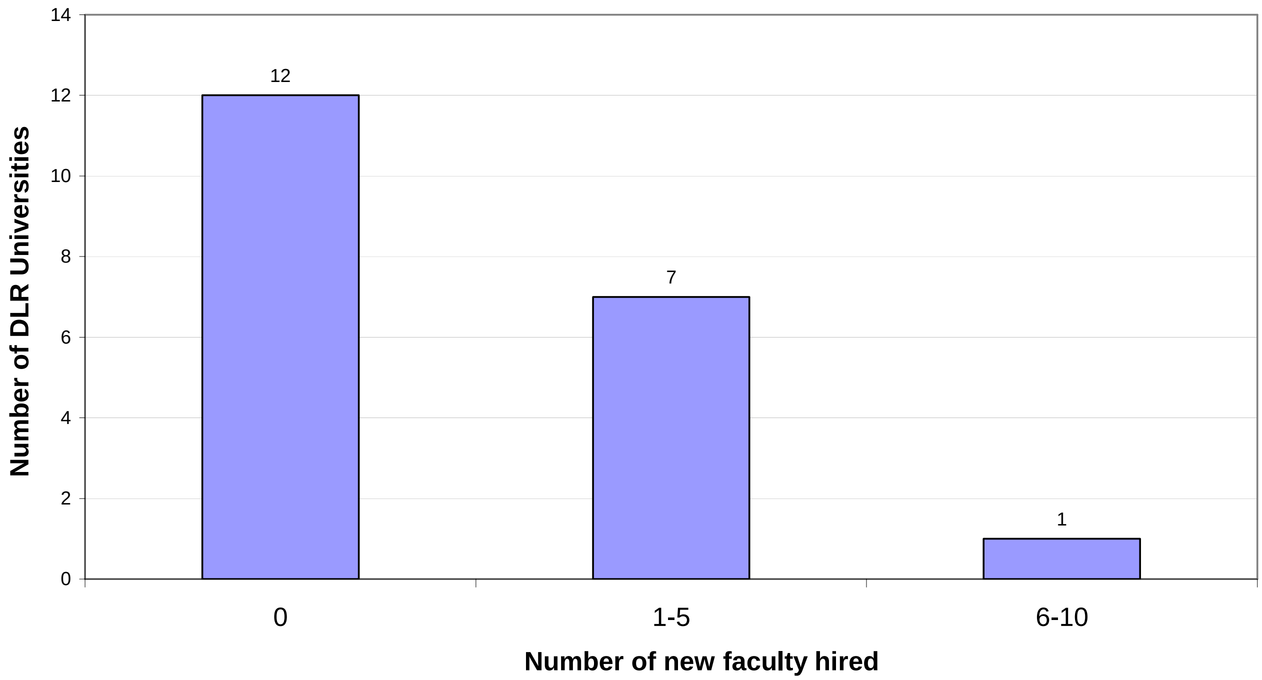


New faculty and staff hired for the DLR project. Eight of the institutions hired new faculty and staff to work on the DLR project (chart 8). These new hires made significant contributions to the success of the DLR implementation. For example, one school hired a lab manager who coordinated and helped to develop the projects to incorporate team learning, hands-on approaches, and lab projects. This same department hired an outreach specialist who coordinated activities with the local high school and community colleges. In a few cases, departments were planning to hire new staff but had not yet received approval. These departments seemed very concerned about simultaneously managing continuation of the service learning projects at the same level, completely documenting the new modules and completing the assessment work. Other departments that did not hire staff used undergraduate and graduate students on the DLR project in creative ways.

Additional sources of funding. The DLR grant encouraged the departments to seek additional funding to support the DLR project. Four-fifths of the DLR teams received additional funding from their department, the engineering school, or the university. These internal sources of funding recognized the importance of the department-level reform and provided additional resources. Funds were generally given for specific purposes, including:

- Giving faculty release time, especially in summer, to work on the reform efforts;
- Disseminating the methods throughout the engineering school;
- Paying for salaries for new faculty to implement and maintain the reform efforts;
- Hiring additional staff to help manage the labs or undertake outreach;

Chart 8. Distribution of universities by number of new faculty hired as a result of DLR project



- Creating an education center for sustainable engineering; and
- Creating partnerships across the university.

Two-thirds of Engineering Departments or universities also contributed funds to build or upgrade labs and provide equipment. In three cases, major contributions were given to build new lab space, and to acquire new space or buildings. Five schools received equipment, usually computers, for use in the classroom or lab.

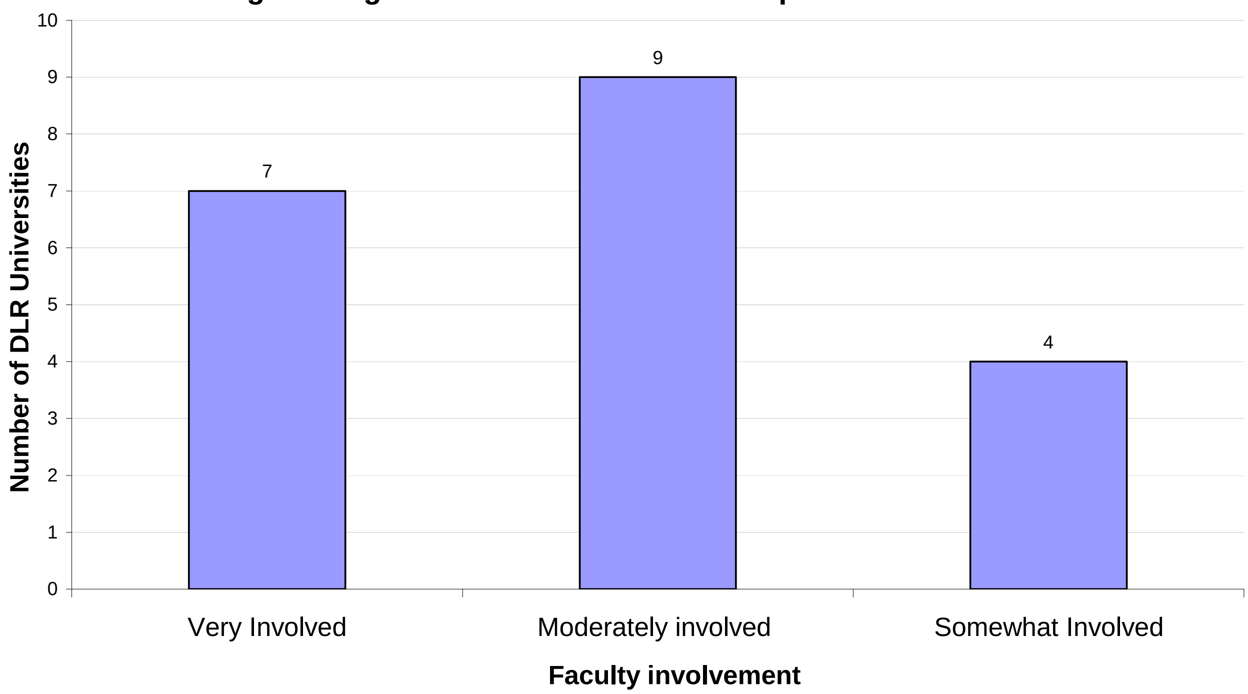
Three-fourths of the DLR teams received external funding from multiple sources, including additional grants that the Principal Investigators (PIs) felt were a result of the work they had done under the DLR grant. Some of the external funding was for directed purposes such as fellowships and equipment while other funding was for use at the PI's discretion.

The amount of additional funding procured as a result of the DLR funding is estimated at about $13 million: $3 million from internal funding and $10 million from external sources. This is a conservative estimate, because often a PI would report a contribution but could not estimate its value.

2. Activities

Education school involvement. Two-thirds of the schools (12/20) involved the Education School in the DLR project. At about one-third of the DLR institutions, faculty are very involved in Engineering Education on a department-wide basis, and at about one-half of the institutions they are moderately involved (chart 9). Education Schools provided significant input into the introduction of new teaching methods and the assessment work of each project.

Chart 9. Distribution of universities by faculty involvement in engineering education research on a department-wide basis



DLR criteria. Most projects actively used the DLR criteria to introduce new areas of engineering (17/20) and to replace legacy materials with improved content, or the projects created new areas of study (18/20). All projects included computational methods and practices employed by practicing engineers, and incorporated modern teaching strategies and methods.

Level of reform. For the majority of projects, the DLR grant encouraged the DLR team to undertake reforms of their engineering programs. However, four institutions were already implementing reform. The funding from the DLR grant allowed these institutions to accelerate their reform efforts.

A majority of teams would have undertaken department-level reform without the DLR grant but would have done so on a much smaller scale. Based on discussions with the DLR teams, they estimated that the reform efforts would have been, on average, less than 40 percent compared to the level of reform that the funding from the DLR grants allowed.

Recruitment and retainment of students. Two-thirds of the DLR projects (13/20) included plans to recruit and retain students in their engineering departments. Some used their DLR funds to explicitly recruit students at the high school and community college level, and others used existing recruiting mechanisms at the university through which they highlighted changes made to curriculum as a recruiting tool.

About one-third of the DLR projects reached out to community colleges to recruit students. One school holds a design competition for students at community colleges; another works with community college faculty to ensure that the community college classes meet the requirements for students to transition into the four-year engineering program; and another offers scholarships to a local women's college.

About 25 percent of DLR projects reached out to high school students through a variety of methods, including summer programs and camps for high school students, often at low-income high schools.

One school holds an Electrical Engineering Design Day every spring to showcase student work. Hundreds of visitors attend, including high school students, and company representatives also attend the event. The event led to a cultural change at the school that resulted in additional funds for the department.

Another school hired an outreach specialist and a high school physics teacher on a part-time basis to hold workshops for middle and high school teachers, giving them optics and electronic kits to demonstrate how to bring engineering into their classrooms. This school has conducted many field trips for students; they found that focusing on the teachers is more successful.

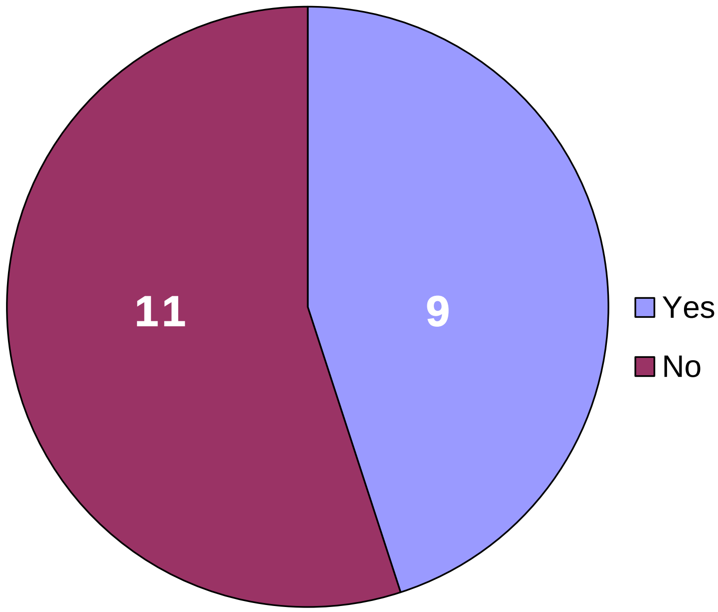
Most schools noted that it is too soon to tell whether department-level reforms have led to an increase in recruitment and retention of students in their engineering departments. For about a third of the schools, there was an increase in the quality and quantity of students entering and staying in their programs. Two schools said that the number of women who enrolled increased. Some schools noted that while they already were quite diverse, they were taking steps to increase the number of women in the program.

Almost one-third of the departments (6/20) showed an increase in students going to graduate school or taking engineering jobs in industry (8/20). Student involvement in developing materials for the new or revised classes, together with service learning projects, appears to have positively affected students' attitudes about continuing their education. Most schools, however, said that it was too early to tell whether department-level reform was having an impact on recruiting and retaining students in engineering.

3. Outputs

Service learning projects. Almost half (nine) of the DLR projects involved service learning (chart 10). Three DLR projects focused on service learning as the focal point of their reform. With four of the projects, service learning was an important facet of the reform, and two of the projects used existing service learning mechanisms at their universities, but they were not a major part of their department-level reform.

Chart 10. DLR Projects that included Service Learning Projects



Service learning includes four stages: formulation of the project, project promotion, designing and project completion, and project reflection. The PIs firmly believed that the service learning projects should be real projects, and that students should see them through to completion. One PI noted that such commitment was critical to becoming a real community partner, and that the projects should have a focus broader than simply the needs of the students.

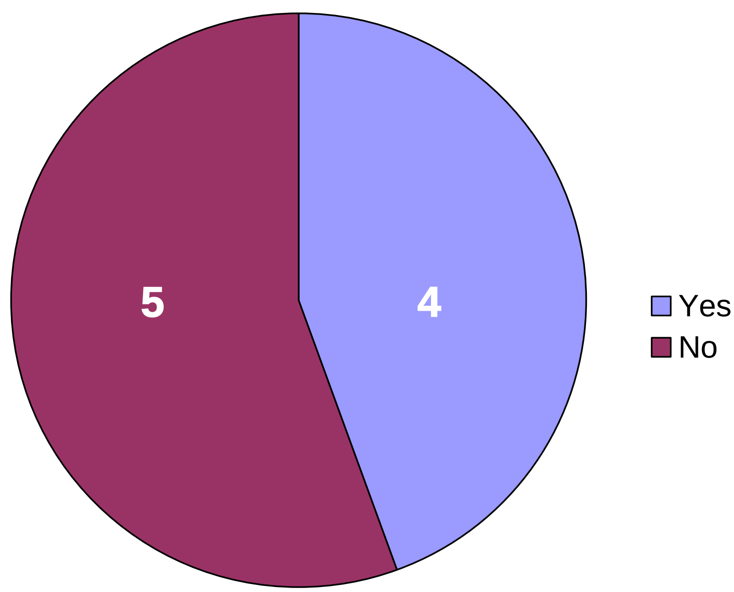
Service learning as pedagogy teaches students to think critically and to accept other viewpoints and ways of life. One PI pointed out that "in service learning students are faced with working with people who are very different from themselves, and they had to reflect on this and use moral reasoning. This helped the students grow morally, which fits in with the program's mission of creating engineers that are socially conscious and that practice engineering to help advance humanity." The PIs added that the effects of service learning enhanced the university's standing as a community partner, and, more importantly, encouraged students to think about lifelong learning and service to the community.

Another university based its program on the hypothesis that service learning can be effectively integrated into required engineering courses. The premise of this DLR grant was that exposing students to service learning each semester throughout each of the four college years would be more beneficial to both the students and the community rather than just one service learning course, even if it is an intensive course such as capstone design. The DLR team tested the hypothesis that a mixture of required and elective service learning is more effective than either one or the other, and that service learning results in less coursework time than traditional programs. This school lists dozens of service learning projects on their website.[12]

A variety of approaches to service learning were used. Some schools introduced service learning during freshman year, some required service learning every semester or every year, and some required service learning as part of specific classes. The goal was for students to learn skills that will benefit them in the workplace. For example, a community has a water drainage problem and needs technical support with a limited budget. In working to solve such problems, students gain more skills as they learn about politics (perhaps part of the community does not want to fix the water problem), social behavior (understanding who benefits and who does not), regulations (obtaining permits), and historical preservation.

Of the nine DLR projects that included service learning, four had an international component (chart 11). For example, at one school, students designed a water supply system for a village in Guatemala and the following spring, they went to Guatemala to build the system.

Chart 11. Service learning projects that included an international component



Service learning was, by definition, multidisciplinary. Classes counted for course credit in almost all cases and were a required part of the curriculum. In virtually all cases, service

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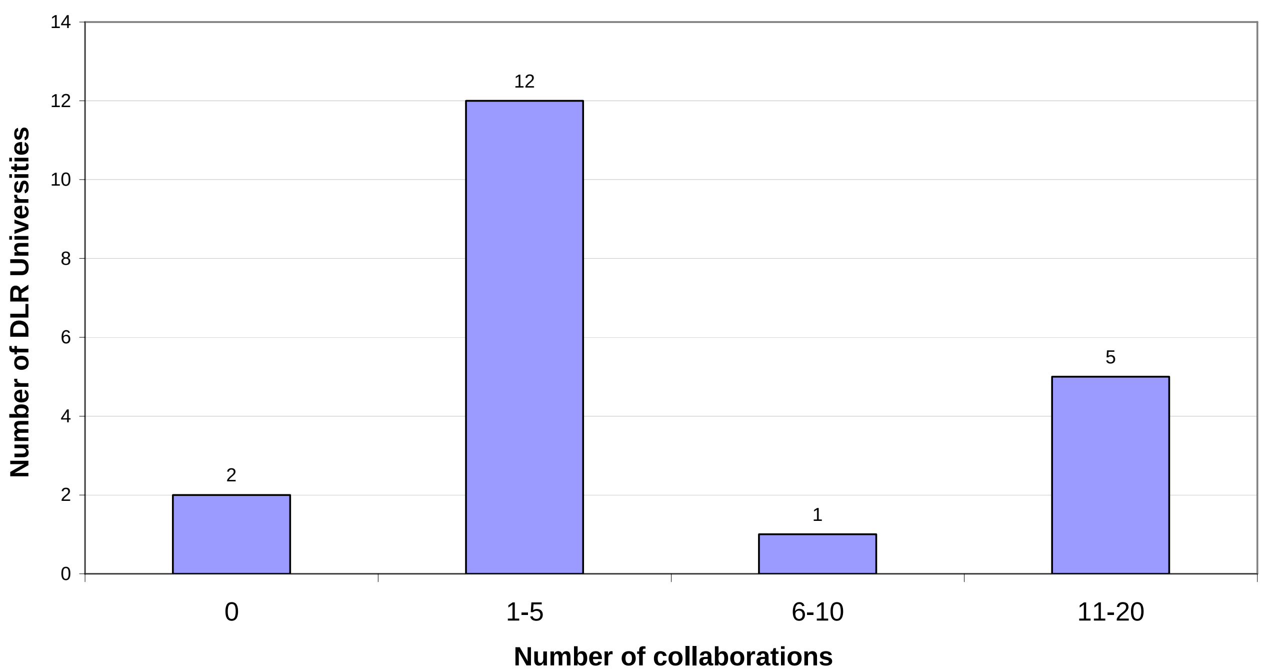
[12] See http://slice.uml.edu/project_examples/

learning addressed the ABET Accreditation criteria (see Appendix B), especially those for teamwork, communication skills, and project-based experiences.

Collaborations. Collaborations within engineering departments undertaking department-level reform were one of the overwhelming successes of the grants. Every team mentioned that one of the major benefits of the DLR grant was that it broke down the stovepipes in the departments and encouraged faculty to talk, share ideas, collaborate, and work on reforming the curriculum as a team. This collaborative behavior would not have occurred without the DLR. PIs would distribute the DLR funding among as many faculty as possible to get them involved in the reform efforts, which was usually a successful tactic. Even in those cases where faculty did not buy in, there seemed to be a new willingness to listen and appreciate their differences.

Two-thirds of the teams were involved in at least one to five collaborations, not including the collaborations within the DLR team (chart 12). Six of the teams collaborated with six or more partners; and five had at least 11 or more partners.

Chart 12. DLR: Distribution of universities by the number of collaborations (as a result of DLR)



One of the hallmarks of the DLR teams is the number of collaborations formed within the university. These collaborations crossed engineering departments and schools, involving many disciplines, such as business, entrepreneurship, architecture, and liberal arts. These collaborations added context and breadth to the engineering students' design projects and helped them to see the project as a whole.

Three types of external collaborations resulted from DLR projects. The first was with other universities, which generally involved proposing and working on grants that directly resulted from their department-level reform work. However, one school (Johns Hopkins) formally collaborated with seven other universities as an integral part of their DLR project.

The second type of external collaboration was generally with non-profit organizations for service learning projects. These collaborations were important for students to understand the needs of each organization as well as to be responsible for completing projects in a way that met their satisfaction. (This collaboration is more fully discussed under service learning.)

The third type was with industry in the form of the personnel who served on boards, either for the department, the DLR project, or both. Half of the DLR projects (10/20) had advisory boards that were formed specifically for the project. Half (10/20) of the DLR primary departments had advisory boards who also provided advice on the DLR project. [Seven of the ten schools had two advisory boards-one that advised the DLR project specifically and one that advised the department.] These advisory boards were composed of company representatives that provided important input into the design of the program. These companies also contributed funding for the program, and some hired students for internships, summer jobs, and post-graduation employment. The advisory boards also include faculty from other universities as well as university faculty and staff.

4. Outcomes

Curriculum changes. Table 2 presents a summary of the curriculum changes made by the DLR teams at each university. Each of the teams succeeded in accomplishing significant curriculum changes. While there are similarities across schools, what is notable is the uniqueness of each approach. Curriculum reforms had three main themes:

1. The curriculum reforms focused on providing an integrated systems or multidisciplinary approach. These included systems thinking, block scheduling, spiral learning, Interlinked Curriculum Components, and other approaches that emphasized a holistic approach to the curriculum.

2. The curriculum reforms introduced new areas of technology, such as MEMS, advanced materials, nanotechnology, nontraditional energy, bioengineering, and microelectronics. Some schools also introduced entrepreneurship, business, and leadership as an integral part of the curriculum.

3. The curriculum reforms incorporated design projects throughout the curriculum, such as service learning projects, design projects every semester, or a combination of the two in programs such as Urban Studios. A pervasive theme throughout all the projects was to introduce design projects in freshman year.

All DLR projects introduced facets of these approaches, but each had a primary approach that dominated their reform efforts.

Table 2. Department Level Reform: A Summary of Curriculum Changes Made

University	Title of DLR Project	Curriculum Changes Made	Service Learning Project
California Polytechnic	Triple Bottom Line Awareness in Design (TriAD): Diversifying the Engineering Profession of the 21st Century	Adopted systems approach with focus on sustainability.	Yes
Central Florida	Reengineering the Undergraduate Industrial Engineering Program	Integrated cognitive learning theory with emphasis on human information processing	No
City College of New York	Redefining Mechanical Engineering: Systemic Reform of the Mechanical Engineering Program	Incorporated emerging technologies such as, MEMS, Advanced Materials, Intelligent Systems/ Electronics, Nanotechnology and Nontraditional Energy	No
Columbia	Reforming Undergraduate Education in Environmental Engineering: Urban Studios as Knowledge Delivery Systems and Vehicles for Service Learning	Adopted Urban Studios-an intensive environment for collaborative, goal-oriented problem solving that promotes the synthesis of materials and concepts	Yes
Duke	Theme-Based Redesign of the ECE Undergraduate Curriculum	Implemented Integrated Sensing and Information Processing.	No
Johns Hopkins University	Enhancing Diversity in the Undergraduate Mechanical Engineering Population Through Curricular Change	Increased linkages between fundamentals and applications and between technical and nontechnical topics.	No
Lehigh	Establishing a Cross-Disciplinary Bioengineering Program with a Technical Entrepreneurship Focus	Created a Bioengineering program that bridges the Science and Engineering Schools with focus on integrated experiential learning curriculum.	No
Mass. Lowell	Service-Learning Integrated throughout a College of Engineering (SLICE)	Incorporated real world service-based projects for learning engineering content.	Yes
North Texas	A Project- and Design-Oriented Innovative Electrical Engineering Program	Introduced "Project every semester" model to teach design and to encourage strong communication skills.	No
Oklahoma State	Collaborative Research: Engineering Students for the 21st Century	Transitioned from knowledge based to development based curriculum (focus on developing engineers who can solve real-world problems)	No
Old Dominion	Simulation and Visualization Enhanced Engineering Education	Introduced interactive modules using simulation and visualization to enhance learning.	No
Pittsburgh	Pillars of Chemical Engineering: A Block Scheduled Curriculum	Adopted Block Scheduling, which allows for courses with considerably longer contact hours to focus on topics comprehensively.	No
Purdue	Reforming Engineering Education: Multidisciplinary Engineering (MDE)	Implemented a Multidisciplinary Engineering program to integrate science and engineering classes with focus on specific topics.	Yes
Rochester Institute of Technology	Leading Microelectronic Engineering Education to New Horizons	Developed a semiconductor processing minor for non-Microelectronic majors and a program in nanotechnology and MEMS.	Yes
South Florida	Transforming the Educational Experience of Transfer Students in Chemical Engineering using a Multi-Dimensional Spiral Curriculum	Implemented a Multidimensional Spiral Curriculum that focuses on integrating core concepts in a specific discipline for the synthesis, analysis, and design of a product or process of societal value.	No
Sweet Briar	Reform of the Engineering Program at	Established a Physics and Engineering	Yes

University	Title of DLR Project	Curriculum Changes Made	Service Learning Project
College	Sweet Briar College	Science program at a women's college	
Texas A&M	Chemical Engineering Undergraduate Curriculum Reform	Developed 6 interlinked Curriculum Components (ICC) which are web-based learning sites for students. Developed comprehensive program assessment plan that includes integrated learning outcomes for all engineering courses and new assessment techniques Incorporated a new course on Engineering Biology.	Yes
Utah	Integrated System-Level Design in Electrical Engineering	Incorporated system-level design through lab projects, project management, entrepreneurship, and communication skills.	Yes
Vermont	A Systems Approach to Civil and Environmental Engineering Education: Integrating Systems Thinking, Inquiry-Based Learning and Catamount Community Service-Learning Projects	Applied integrated Systems Thinking to problem definition and problem solution. The new courses use ecological systems and engineered environmental and transportation systems as major examples.	Yes
Virginia Tech	Reformulating General Engineering and Biological Systems Engineering Programs	Incorporated Spiral Learning approach to strengthen students' understanding of basic concepts by revisiting the concepts periodically with different contexts and with increasing sophistication throughout the curriculum. Curriculum reformulation using spiral theory in bioprocess engineering using supporting principles of design, ethics and systems approach Hands-on learning in freshman engineering Emphasis on teamwork, communication, and life- long learning skills Incorporation of feedback based learning models using Tablet PC and DyKnow technologies, particularly in freshman engineering Assessment based learning modules	No

Permanence of DLR reforms. The majority of the curriculum changes made as a result of the DLR grants are permanent. Seventeen teams reported that the probability that the reforms will continue for at least three years is between 90 and 100 percent. The remaining three teams reported that the probability of permanence is at least 75 percent. However, some teams expressed concern that the permanence of the reform rests on either faculty remaining at their schools or departments obtaining approval and funding to hire or retain faculty needed to maintain all components of the reform. One PI commented that, "If key faculty left, the reforms would end instantaneously. [Permanence of the reforms] depends, to a large extent, on our ability to develop a rubric for evaluating faculty performance on effective practices. The team has begun this process. However, the faculty who have actively participated have been permanently changed by this experience."

A second PI stated that the students like the reformed curriculum and it schedules faculty in an efficient way also noting that it would be prohibitively expensive to go back to the traditional approach to educating engineers. Another PI indicated that the systems courses are permanent but that the service learning projects are so time intensive that they could force service learning projects into just the freshman and senior years.

Assessment. Each DLR team is undertaking three evaluation stages. The first is the immediate assessment of each component of the reform—revised classes, labs, and service learning projects—and their impact on student learning. The second is the assessment that occurs near the end of the project to evaluate the overall success of implementing reform and the impact on students and faculty. This stage includes evaluating retention and recruitment of students, demographics, impact on learning, post-graduate placement, and sustainability of the reform. The third stage will occur several years later to examine whether the impact of the reformed curriculum really had an effect on students in terms of their success in graduate school and the workplace. This may require interviewing students, employers, and graduate schools.

Each DLR team took assessment of their work quite seriously and understood the importance of feedback to continuously improve their curriculum, labs, service learning projects, and outreach. Students are then told at the beginning of each semester what the changes are and why they were made (based on student feedback from the previous semester). The text box below highlights one example of assessment results from one of the DLR projects.

From Spencer, David, and Dawes, Sharon. 2008. Report of the Advisory Committee for the GPRA Performance Assessment. National Science Foundation, highlighting findings of a DLR project.

A number of highlights described alternative pedagogical approaches to undergraduate science education. For example, a project summarized in **From Sausages to Skateboards** (*Highlight ID 15221*, *Award 0431756*), measured the impact of teaching real-life applications in undergraduate mechanical engineering courses. The research demonstrated that the use of applications had a positive impact on final course grades only when the whole course was applications based. Students in the application-based course had significantly higher final course grades than comparison students matched by instructor and course who did not receive application-based teaching or when only two or three applications were used during a course.

The assessment to measure whether students learn better using the new curriculum and pedagogy is still underway. The PIs indicated that they have a lot of data to evaluate but expressed concern about the need for resources to conduct a full assessment. Some teams have already built this long-run assessment into their DLR project. For example, an evaluator from one of the teams plans to use her sabbatical to analyze the data collected throughout the reform.

The DLR teams use a variety of methods for their assessments. These include surveys of attitudes, individual and team-based performance tests, constructs to measure motivation to learn, and self-directed learning. In addition, they are conducting focus group sessions and exit interviews of graduating students. Feedback from ABET evaluators and industrial advisory boards is also an important source of information. At one school, at the end of the year, students complete a battery of assessment instruments geared toward measuring the readiness for self-directed learning, motivation profiles, levels of self-efficacy, learning styles, and moral and ethical reasoning. Another school is proposing an assessment similar to the ABET process, described in Appendix B, which includes content analysis of courses and labs, faculty and student surveys and interviews, and retention data. An important facet of the assessment is training faculty on how to use these assessment instruments.

Sample findings from the assessments[13] undertaken throughout the grant show:

- Students reported significant improvements in problem solving, design, and team building.
- Students reported that the use of technology in the classroom has enhanced their learning.
- Students reported and exhibited higher levels of motivation to learn by seeing the societal connections of the course material.
- Students reported gaining greater communication abilities through working with a real client.[14]
- Tighter coupling of lecture and laboratory has led to an increase in just-in-time and inquiry based learning.

Broad dissemination of DLR practices The DLR teams showcased their findings and experiences in various ways. Three-fourth of the teams published at least one journal article (including conference proceedings). Nearly one-third conducted workshops to share what they learned from implementing a revised curriculum (see Part 2, Section B of this study). Froyd (2005), however, notes that journal articles, conference proceedings, etc. are "insufficient to catalyze systemic reform" because only a small percentage of articles are published and few engineering faculty read engineering education publications. Thus, innovations in curriculum reform were not well known. Froyd notes that the Engineering Education Coalitions program used websites, workshops, and condensed summaries. (See Dissemination under DLR Team Recommendations to NSF for description of these condensed summaries.)

Lessons learned from implementing DLR. The DLR teams are interested in sharing their experiences with other engineering departments and schools. They provided many insights that could benefit others undertaking such a reform. Some of these lessons also overlap with their insights about student learning and other characteristics of DLR projects.

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13 These are findings from two schools that represented the findings across most schools.

14 The PI notes that not all service learning experiences were positive. Faculty learned that the service learning clients and activities need to be carefully screened.

At least half the PIs felt that reform efforts should begin with freshman-year classes so that the new methods and approaches could be taught from the beginning of each student's engineering experience. For example, implementing design projects, service learning projects, and hands-on learning during freshman year can engage student interest in engineering early on. The goal is for students to appreciate that engineering projects benefit society and address goals that extend beyond their own learning. PIs also emphasized the importance of teaching students about their role in society.

Many of the lessons learned concerned getting active participation in the program. For many departments, the prestige of receiving a large NSF grant set the stage for administrative support and approval from the dean, provost, and president of the college or university. In other cases, this was not sufficient. The PIs noted that spending time upfront to explain the reforms to students and faculty helped considerably.

To involve students and obtain their buy-in, one team set up meetings and created a brochure to explain the reform. Another team examined why students don't stay in engineering and found that taking calculus freshman year was a stumbling block that impacted a student's decision to change. Engineering students at this school are now tested at the beginning of their freshman year to determine who should postpone calculus to junior year. This deferral allows students time to gain engineering experience, which provides a foundation for when they do take calculus. A third team developed a new course that focuses on translating math into engineering concepts and examples. Part of the preparation for this course involves training teaching assistants and faculty how to teach math in this new way.

The PIs used a variety of methods to involve faculty in developing and using teaching methods and instilling in them a caring approach to teaching. One method was to offer teacher training to all faculty in the department. Another was to spread the DLR funds among more faculty for smaller projects. One team brought in a facilitator to help the faculty work together.

Working with the School of Education was beneficial on two fronts: first, in learning about and understanding the benefits of using pedagogical techniques, and second, in learning about and implementing assessment tools to inform teaching and provide feedback. Faculty confidence increased as they tried these new methods.

The administrative aspects of the project and the documentation of the reform have taken more time than anticipated. Many PIs indicated that they would build more time into future grants for these activities. Many were surprised at how long it took to get a new class approved by the university administration. In short, active learning and hands-on learning takes more time, but the outcomes are worth it.

5. Impacts – Learning about Student Learning

The DLR teams focused on similar themes when asked about what they learned about student learning as a result of the DLR grant. These themes include:

- Creating a learning community;
- Teaming;
- Active learning;
- Taking an integrated approach;
- Starting design projects in freshman year;
- Students taking responsibility for their own learning; and
- Service learning.

However, what cannot be conveyed in this list is that most PIs and team members were surprised and delighted that integrating teaching methods into their classroom was well received and improved student learning. They almost uniformly expressed that using these methods takes extra time. One approach that some teams took to alleviate the time pressure was to involve students in developing new labs and course materials. This collaboration also contributed to creating a learning community.

Many of the findings about Learning About Student Learning overlap. For example, taking an integrated approach involves teamwork and active learning. One facet of teaming means that students must be responsible for their own learning. Separating the key findings out, however, highlights what was important about student learning.

Creation of a learning community requires that students and faculty work together, grow in shared experience, and learn from each other. One PI noted that this "boosts students' resilience and gives them a sense of belonging, creating a social identity and meeting a hierarchy of needs (basic, relationships, and desire to grow)." The premise is that students learn better if they explain concepts and new learning to each other and not just receive the information from the instructor.

One school requires that all students and faculty in the department take a "Learning to Learn" (L2L) class so that they understand their roles in learning and teaching. In this course, students develop an understanding of how engineering is learned and how the faculty facilitates and encourages the lifelong learning process. Topics covered include: consciousness and self-awareness, meta-cognition, learning styles, memory, language, reading, writing, problem-solving, creativity, and the biological aspects of learning. These concepts are reinforced in every course being taught by the department.[15]

Teamwork was cited as an important facet of student learning. Several PIs noted that students really liked team-based activities, with one saying that he underestimated the impact of this approach. Another PI said, "Students love teams, especially small project teams. They learn by example." Another stated, "The teamwork among the faculty involved a true pedagogical change in how we teach classes." Almost universally, PIs

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15 www.ee.unt.edu/L2L

discussed how the DLR grant engaged faculty and brought them together to work as a team.

Active learning involves hands-on learning. Students are more engaged and, as a result, learn better.[16] One PI noted that the DLR team observed a significant increase in the quality and complexity of design projects as a result of early and repeated exposure to extensive hands-on learning early in the curriculum. Part of the active learning involved learning about active learning. The DLR teams were open to the fact that new methods and approaches to teaching were being used. In a few schools, students (and some faculty) were initially resistant, but this changed as they experienced active learning.

An integrated approach teaches students to focus on all aspects of the project. Each school took a different approach to this integration, using systems, spiral curricula, pillars, and multidimensional approaches. Across schools, this meant that projects involved teams from several departments, not just engineering departments. Students learn how to interpret engineering and scientific concepts from multiple perspectives. At some schools, industry is now specifically requesting students who have participated in integrated approaches to learning.

Starting design projects freshman year was an important factor in the success of the DLR projects. Traditional engineering programs are based on the premise that students must take all the required science, math, and engineering fundamentals before they can begin to undertake design. As a result, many students switch majors after freshman year. Involving students in design projects early on helps make classroom learning real and helps students care about what they are learning.

An important theme of many of the DLR projects is the expectation ***that students would be responsible for their learning and follow-through***. While only explicitly mentioned by two PIs as "learning about student learning," it was a theme underlying teaming, active learning, taking an integrated approach, and service learning.

Service learning is an important teaching tool to create a "new generation of engineers who understand the community perspective and that projects must have tangible results." Students learn about how to create trust, to understand community needs, and to implement solutions that benefit the community. Service learning also gives students a reason to care about what they are learning.[17] As is true of introducing design projects in

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[16] The instructional design literature suggests that the methods used to teach new knowledge and skills vary significantly with regard to how much is retained. For example, only 5% is retained from lectures while 90% of material is retained when teaching others. Retention rates for other activities are: reading (10%), audiovisuals (20%), demonstration (30%); discussion (50%); and practice by doing (75%) (Silberman 2006).

[17] Heath and Heath (2007) describe how to make ideas stick. For an idea to stick, it has to be useful and lasting as well as make the audience pay attention, understand and remember it, believe it, care about it, and be able to act on it. Service learning allows students to apply what they learn in engineering to real-world situations.

freshman year, students learn better when the curriculum involves more than just lectures.[18]

III. DLR Team Recommendations to NSF

The DLR teams overall conveyed their appreciation to NSF for the DLR grants. In addition, they wanted to provide suggestions about areas for improvement and requests for follow-on support. These included the following suggestions:

- Continue the DLR program;
- Extend the time frame for the grants;
- Provide supplementary grants for dissemination and assessment;
- Suggestions for NSF conferences'
- Provide more interactions with NSF Program Managers; and
- Recommendations for how to improve the progress reports.

Each recommendation is described in more detail below.

Continue DLR program. The DLR teams stated that DLR solicitations should be continued. They noted that a holistic reform is needed to make curriculum and teaching changes across a department or school, but that a comprehensive reform is not possible without an infusion of funds. One PI noted that the DLR provides funding to schools that cannot compete for Engineering Research Center grants, either because they are too small or they do not have sufficient stature. The PIs uniformly noted that there are multiple spillover benefits that occurred as a result of the DLR grants, the most important being to recruit and retain students in engineering. To quote one PI, "Programs such as the DLR drive change and encourage an interdisciplinary approach to learning that is focused on meeting societal goals. It allows students to be more involved and to study subjects that they care about." One PI proposed that the DLR grants be expanded to link undergraduate levels of reform in engineering programs to the graduate level, believing that similar reforms are also needed at the graduate level.

Many PIs also said that the prestige of receiving such a large NSF grant to implement department-level reform encouraged support from deans, provosts, and presidents. In many (but not all) cases, this support spilled over to the faculty. Department-level reform has the significant advantage of generating widespread enthusiasm and buy-in among faculty and administrators. They noted that the DLR grant made it easier to undertake the more extensive reforms to obtain additional internal and external support.

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[18] See footnote 16.

Extend time frame for DLR grants. The suggestion made by most schools was to extend the time frame for the grant from three to five years, to allow a longer time to implement the reform, as well as to allow one cohort of students to graduate. Most schools requested a one-year (and very often a two-year) extension, which NSF granted, so in fact most DLR grants were implemented over four to five years. One PI suggested that DLR grants could be funded in phases (implementation, dissemination, assessment) and the team would have to compete for funds at each phase. Another PI felt strongly that the DLR grant be only for three years, otherwise she felt that the project would start too slowly if the time period were extended. She did, however, favor a phased approach to funding.

Provide supplementary grants. The suggestions for supplementary grants focused on two themes: dissemination and assessment.

Dissemination. Teams were passionate about wanting to share modules that they developed as well as the best practices and lessons learned from their department-level reform. One PI noted that "it is especially critical that the results of the program be widely disseminated and that the knowledge gained be transferable and applicable (at least partially) to other programs." Several suggestions were made for providing supplementary grants to encourage dissemination. For example, the PIs from the four Electrical Engineering Departments suggested they team up to prepare a presentation or workshop to disseminate their reform across the country. The grant would provide funds for them to meet one or two times to prepare the workshop and then to travel to other schools to present their findings. The PIs could present individually or as a team. Some DLR teams are already doing this on a limited basis, but they expressed frustration about the lack of time and funds to fully accomplish their dissemination goals. Travel grants would facilitate the dissemination of department-level reform results.

Another suggestion is to provide funds to build a website to share the outputs of the department-level reform. Such a website (or Wiki) would provide a forum to create a virtual community of professors interested in department-level reform. This method worked well for the Engineering Education Coalition projects. Froyd (2005) describes how compact summaries synthesizing the results of educational innovations were posted on the Foundation Coalition website. These one-page introductions could be read in 10 to 20 minutes. Over 20,000 of these compact summaries have been downloaded.

Assessment. Most teams had implemented a course-by-course assessment that provided feedback for improvements to make the following semester. They noted, however, that a systematic review of the entire department-level reform would require additional funds, in part because it is a large task, and in part because many of the outcomes from the department-level reform could not measured until after the DLR grant funding ended. These outcomes include assessing the quality and number of students who obtained jobs in engineering firms (either through surveys or interviews with alumni or employers), the quality and number of students who continued on to graduate school, and the long-term effect on the engineering department and school.

Suggestions for NSF conferences. Overall, the PIs like the annual conferences and the sharing of ideas. There were suggestions that the conferences focus on a theme and that trained facilitators guide the discussion. There were also requests that the date of the conference be moved to June, since graduations are held in early May. In addition, one PI suggested that NSF offer faculty training on how students learn. He felt that if NSF sponsored such a workshop, faculty would participate.

NSF interactions with awardees. A few PIs mentioned that they would like to receive feedback from NSF staff each year, after they submit their progress report. This would allow them to explore opportunities to change the budget and plans.[19]

Progress reports. The majority of PIs were indifferent about the annual progress reports, viewing them as a requirement of receiving the grant. About one-third of the PIs offered suggestions for improvement. One suggestion was for NSF to ask a small team of PIs to meet to design a progress report that is specific to the grant, so that lessons learned and other important information could be more easily shared among PIs.

IV. Conclusions

Is the DLR program accomplishing its goals?

The DLR was designed to provide funding for departments to reformulate, streamline, and update engineering curriculum to make it relevant to modern engineering practices and to increase student interest in engineering. The expectation was that the DLR funding would allow engineering programs to incorporate learning strategies (such as mentoring, teaming, experienced-based learning, and computer simulation), to emphasize critical thinking, communication, and interpersonal skills, and to include new areas of technology and research experiences, including service learning projects.

Based on the findings in this evaluation study, the DLR teams accomplished significant curriculum reforms to make engineering more relevant, hands-on, and team-based. Each of the DLR projects took very different approaches that met the needs of their department, school, and student body. Yet, underlying their different approaches were common themes. All DLR projects introduced facets of these approaches, but each had a primary approach that dominated their reform efforts.

- Many of the curriculum reforms focused on providing an integrated systems or multidisciplinary approaches (systems thinking, block scheduling, spiral learning, Interlinked Curriculum Components).

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[19] See Appendix C for a similar recommendation from one of the Principal Investigators.

- Others focused on introducing new areas of technology, such as MEMS, advanced materials, nanotechnology, nontraditional energy, bioengineering, and microelectronics. Technology (using online tools) was also used to encourage students to engage in lectures, to allow students to prepare for class, or to review concepts.[20] Other new areas outside of engineering were also introduced, such as business, entrepreneurship, and social science classes.
- Still others focused on incorporating projects throughout the curriculum, such as service learning projects for several semesters, design projects every semester, or a combination of the two in programs such as Urban Studios.

In addition to the opportunity for curriculum changes, the DLR bestows a prestigious external recognition on the department receiving it and thereby increases support and buy-in from faculty and administrators. The additional support received (money, labs, new hires) allowed the DLR teams to accomplish more and ensured the permanence of the reform efforts.

There are some indications that the DLR reforms are leading to increased student interest in starting and staying in engineering programs. Many of the DLR teams reported an increase in student enrollment in their engineering programs (the STPI evaluators could not establish that these enrollments could necessarily be traced to DLR-funded reforms, there may be multiple other reasons for the increase). Most, however, reported that diversifying the student body is still a challenge. The focus on engineering education has sparked interest among some students to now consider graduate school. Since most programs are only completing the implementation of their new curriculum with the first cohort of students, it is too soon to tell if the reforms are leading to an increase in the recruitment and retention of students on a permanent basis.

Is the DLR program a good way to encourage engineering departments to update their programs to incorporate new teaching methods?

The *ex ante* and *ex post* mapping of the DLR criteria and accomplishments against the National Academy of Engineering's (NAE) report and the ABET Criteria provide two indications that the DLR program meets the NAE recommendation and address the ABET criteria.

The *ex ante* mapping of the DLR criteria against the NAE recommendations found that the two mesh. The NAE report provides recommendations for training future engineers to be prepared to practice in a global world. The NAE recommendations focus on the undergraduate experience being an engineering-in-training degree and the master's degree being recognized as a professional degree. They also recommended that universities introduce engineering concepts and designs early in students' undergraduate

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[20] Learning can be enhanced through the use of the computer to learn through online exercises, the internet (through Google, Wikipedia, etc.) as well as through social networks (personal webpages, Facebook, MySpace, etc.) (Preskill, 2008)

education, that they encourage life-long learning, and motivate students to obtain graduate degrees. On the faculty side, the NAE recommends that research in engineering education be rewarded.

The *ex post* mapping of the DLR outputs and outcomes addressed the ABET criteria. The ABET criteria focuses on what students learn. The DLR projects successfully implemented curriculum changes that teach students to apply their science and engineering knowledge to design projects and to conduct experiments as well as to analyze and interpret data, to design systems that meet many criteria (ethical, social, political, etc.), and to use techniques, skills, and engineering tools used by practicing engineers. In addition, the DLR projects and the ABET criteria focus on students' ability to work on teams and communicate effectively, a recognition of the importance of life-long learning, and a knowledge of contemporary issues.

What are the indicators of success for individual projects as well as the portfolio of DLR projects?

The short-term indicators of success are:

- Faculty buy-in to adopt new teaching methods and to undertake engineering education research.
- A revised curriculum that reflects emerging areas and use of technology in courses/laboratories and the use of modern learning methods,
- Student enthusiasm and improved perceptions of the role of engineers in society, and
- Increased quality of students' design projects, computational skills, and communication skills.
- Incorporating formative and summative assessments into the engineering curriculum.

The enthusiasm and dedication of the DLR teams is noteworthy. Even though the DLR grants provided significant funding, the projects required a huge amount of time and perseverance. The DLR teams have a strong desire to continue the efforts and to share accomplishments, best practices, and lessons learned with other schools.

Ultimately, the long-term indicators of success are:

- Ongoing interest in curriculum refinement;
- Attracting new students and their retention in engineering programs;[21]
- Increased diversity of engineering students, and

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[21] Retention refers to keeping students in engineering education with the goal to increase the number of students graduating with a degree in engineering.

- Employer recognition that interns/graduates who receive their engineering degrees in these revised programs are valued.

The ABET criteria also provide mid- to long-term indicators of success (see Appendix B). These criteria emphasize that students must develop the ability to apply mathematical, engineering, and design principles to their work. The criteria also stress that students learn to participate on multidisciplinary teams and to communicate effectively. Finally, the criteria underscore the importance of students learning about and understanding the ethical responsibilities of their work in global setting that demonstrates an awareness of societal issues. These criteria are summarized in one overarching theme that students engage in life-long learning.

This study evaluates inputs, activities, outputs and outcomes in the short run. An intermediate evaluation might be undertaken to conduct a meta-analysis of the assessments from each school, once they are completed. An evaluation of the DLR programs 5 to 10 years out is needed to evaluate whether the DLR program has addressed the long-term indicators of success.

The National Science Foundation's Department-Level Reform (DLR) of Undergraduate Engineering Education program was successful in encouraging engineering departments to undertake and implement curriculum reform that introduced emerging areas of technology and teaching methods. In summary, the DLR grants demonstrated that curriculum reform requires:

- An infusion of funding (such as the NSF grants) as well recognition and support by Engineering School and University administration;
- Dedication and leadership of faculty leading in and participating on the DLR project and embracing engineering education research; and
- Dissemination of curriculum reform modules, lessons learned, and best practices through workshops, websites, conference presentations, and journal publications.

In addition, the Department-Level Reform teams provided several suggestions for improving the execution and follow-up for DLR awardees. These include recommending that the NSF:

- Continue the DLR program;
- Extend the time frame for the grants from three years to five years (or longer;
- Provide supplementary grants for dissemination and assessment of existing DLR programs;
- Use trained facilitators to guide focused discussion at the PI conferences at NSF;
- Provide more interactions with NSF program managers, including follow-up on progress reports; and
- Form a team of awardees to design improved progress reports.

Teams were especially passionate about wanting to disseminate the curriculum changes to other engineering schools and departments, but noted that this will require supplementary grants to make this happen.

References

Borrego, Maura. 2007. Development of Engineering Education as a Rigorous Discipline: A Study of the Publication Patterns of Four Coalitions." *Journal of Engineering Education.* January.

Evensen, Dorothy, and Lattuca, Lisa. 2005. Educational Innovation through Interdisciplinary Collaboration: A Study of NSF Planning Grants, 2002-2003. Center for the Study of Higher Education, University of Pennsylvania. June.

Froyd, J.E. 2005. "The Engineering Education Coalitions Program." *Educating the Engineer of 2020, Adapting Engineering Education to the New Century*, National Academies Press, Washington DC.

Heath, C. and Heath, D. 2007. *Made to Stick: Why Some Ideas Survive and Some Die*. New York. Random House.

National Academy of Engineering (NAE). 2005. *Educating the Engineer of 2020, Adapting Engineering Education to the New Century*, National Academies Press, Washington DC. Available at www.nae.edu.

National Research Council (NRC). 2008*. Evaluating Research Efficiency in the U.S. Environmental Protection Agency*. National Academies Press, Washington DC.

National Science Board. 2007. *Moving Forward to Improve Engineering Education*, NSB 07-122

National Science Foundation (NSF), The Division of Engineering Education and Centers (EEC), Directorate for Engineering, Division Plan, 2007-2011

Preskill, Hallie. 2008. Evaluation's Second Act: A Spotlight on Learning. *American Journal of Evaluation*. Volume 29. No. 2. Sage Publishers.

Silberman, M. 2006. Active Training: A Handbook of Techniques, Design, Case Examples, and Tips. San Francisco. Pfeiffer.

Spencer, David, and Dawes, Sharon. 2008. Report of the Advisory Committee for the GPRA Performance Assessment. National Science Foundation. July 31.

Appendix A: NSF Department Level Reform Grants

NSF Project Number	University	Title of DLR Project	Principal Investigator	Grant Amount
342713	University of Pittsburgh	Pillars of Chemical Engineering: A Block Scheduled Curriculum	McCarthy, Joseph	$1,317,557
343071	Sweet Briar	Reform of the Engineering Program	Yochum, Hank	$424,184
343154	CUNY City College	Redefining Mechanical Engineering : Systemic Reform of the Mechanical Engineering Program at City College	Delale, Feridun	$1,505,000
343268	University of Central Florida	Reengineering The Undergraduate Industrial Engineering Program	Rabelo, Luis	$1,058,807
343283	Lehigh	Establishing a Cross-Disciplinary Bioengineering Program with a Technical Entrepreneurship Focus	El-Aasser, Mohamed	$1,403,902
431756	Johns Hopkins University	Enhancing Diversity in the Undergraduate Mechanical Engineering Population Through Curricular Change	Busch-Vishniac, Ilene	$999,962
431779	Virginia Polytechnic Institute and State University	Reformulating General Engineering and Biological Systems Engineering Programs	Lohani, Vinod	$1,082,944
431812	Duke University	Theme-Based Redesign of the ECE Undergraduate Curriculum	Collins, Leslie	$1,002,805
431818	University of North Texas	A Project- and Design-Oriented Innovative Electrical Engineering Program	Garcia, Oscar	$1,003,688
431906	Purdue University	Reforming Engineering Education: Multidisciplinary Engineering	Haghighi, Kamyar	$1,047,532
431946	Columbia University	Reforming Undergraduate Education in Environmental Engineering: Urban Studios as Knowledge Delivery Systems and Vehicles for Service Learning	McGourty, Jack	$999,494
431958	University of Utah	Integrated System-Level Design in Electrical Engineering	Furse, Cynthia	$1,004,654
530365	Old Dominion University Research Foundation	Simulation and Visualization Enhanced Engineering Education	Chaturvedi, Sushil	$1,004,741
530444	University of South Florida	Transforming the Educational Experience of Transfer Students in Chemical Engineering using a Multi-Dimensional Spiral Curriculum	Gupta, Vinay	$1,005,000
530469	University of Vermont & State Agricultural College	A Systems Approach to Civil and Environmental Engineering Education: Integrating Systems Thinking, Inquiry-Based Learning and Catamount Community Service-Learning Projects	Hayden, Nancy	$801,657
530575	Rochester Institute of Tech	Leading Microelectronic Engineering Education to New Horizons	Kurinec, Santosh	$1,063,194
530588	Oklahoma State University	Collaborative Research: Engineering Students for the 21st Century	Cheville, Alan	$1,057,672
530632	University of Massachusetts Lowell	Service-Learning Integrated throughout a College of Engineering (SLICE):	Duffy, John	$1,036,177
530638	Texas Engineering Experiment Station	Chemical Engineering Undergraduate Curriculum Reform	Glover, Charles	$1,152,391
530760	California Polytechnic State University Foundation	Triple Bottom Line Awareness in Design (TriAD): Diversifying the Engineering Profession of the 21st Century	Vanasupa, Linda	$1,004,982

Note: The first number of the grant number shows the year of the solicitation for the awarded grants; for example, NSF grant 342723 was submitted in 2003.

Appendix B: ABET Accreditation Criteria

The ABET accreditation criteria provide a summary of the long-term indicators of success. The focus of the accreditation process is on what is learned rather than what is taught.[22]

To be accredited, each engineering department (or school) must conduct an internal evaluation and complete a self study that documents whether students, curriculum, faculty, administration, facilities, and institutional support meet the established criteria. In addition to the self study, an ABET committee conducts an onsite evaluation to review course materials, student projects and assignments, interviews students, faculty, and administrators. They prepare a written report synthesizing their findings from the visit and the self study to address whether the ABET criteria are met. ABET encourages systematic experimentation that responds to emerging fields and new pedagogy. There are nine general criteria for undergraduate engineering programs and specific criteria for 24 engineering fields. Accreditation is voluntary and an engineering department or school must request an evaluation of its program. If a new program is implemented, such as the department-level reforms, at least one student must have graduated from the program before an accreditation process can begin.

The ABET criteria state that each engineering program must demonstrate that its students attain the following skills:

a. Apply mathematics science and engineering principles

b. Ability to design and conduct experiments and interpret data

c. Ability to design a system, component, or process to meet desired needs

d. Ability function on multidisciplinary teams

e. Ability to identify, formulate, and solve engineering problems

f. Ability to understand professional and ethical responsibility

g. Ability to communicate effectively

h. Ability to understand the impact of engineering solutions in a global context

i. Ability to recognize the need for and to engage in life-long learning

j. Ability to Know of contemporary issues

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22 Criteria for Accrediting Engineering Programs: Effective for Evaluations During the 2007-2008 Accreditation Cycle Incorporates all changes approved by the ABET Board of Directors as of March 17, 2007, http://www.abet.org/Linked%20Documents-UPDATE/Criteria%20and%20PP/E001%2007-08%20EAC%20Criteria%2011-15-06.pdf.

k. Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

For the purposes of the DLR grant, an *ex ante* evaluation of the ABET criteria against DLR criteria is presented. The conclusion is that the DLR projects met all the ABET criteria.

ABET Criteria: Program Outcomes and Assessment

ABET Criteria **Engineering students must demonstrate attainment of:**	**Did DLR criteria and implementation meet ABET criteria?**
(a) an ability to apply knowledge of mathematics, science, and engineering	YES
(b) an ability to design and conduct experiments, as well as to analyze and interpret data	YES
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	YES
(d) an ability to function on multi-disciplinary teams	YES
(e) an ability to identify, formulate, and solve engineering problems	YES
(f) an understanding of professional and ethical responsibility	YES
(g) an ability to communicate effectively	YES
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	YES
(i) a recognition of the need for, and an ability to engage in lifelong learning	YES
(j) a knowledge of contemporary issues	YES
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	YES

Appendix C: A Detailed Comparison of the DLR Criteria: 2002/03 to 2004/05

2002 Planning Grant/2003 Implementation Grants[23]	2004-2005 Implementation Grants[24]
The proposed efforts should define the interfaces between the new elements and existing programs and streamline and update course offerings to make the curriculum both more attractive and effective by:	The proposed efforts should define the interfaces between the new elements and existing programs, and streamline and update course offerings to make the curriculum both more attractive and effective by:
▪ Introducing emerging knowledge related to information technology, bioengineering, microelectronics, microelectromechanical systems (MEMS), nanotechnology, product design and realization, advanced materials, manufacturing, etc.	▪ Introducing emerging knowledge related to information technology, bioengineering, microelectronics, microelectromechanical systems (MEMS), nanotechnology, product design and realization, advanced materials, manufacturing, etc.
▪ Eliminating legacy materials emphasizing the application of rote solution techniques and replacing them with content emphasizing the fundamental, underlying behavior of physical and biological systems and the social systems in which they are employed	▪ Replacing legacy materials with improved content emphasizing the fundamental, underlying behavior of physical and biological systems and the social systems in which they are employed
▪ Exposing students to the computational methods employed by practicing engineers to solve engineering problems, preferably in collaboration with industry leaders in developing tools implementing such methods	▪ Exposing students to the computational methods and design practices employed by practicing engineers to solve engineering problems, preferably in collaboration with industry leaders in developing tools implementing such methods
▪ Making full use of modern teaching methods, including mentoring, team-based and experience-based learning, computer simulation, and distance learning.	▪ Making full use of modern teaching methods, including mentoring, team-based and experience-based learning, computer simulation, and distance learning
	▪ Using cognitive theory and latest pedagogical concepts to improve learning outcomes
	▪ Emphasizing critical thinking skills as well as communication and interpersonal skills
	▪ Ensuring that the course content as well as pedagogy are sensitive to the needs of a diverse student body
	▪ Incorporating service learning as a means to broaden students' professional skills and enhance their learning outcomes and academic performance, while providing sustained support for community service organizations

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23 NSF Program Solicitation 03-563. http://www.nsf.gov/pubs/2003/nsf03562/nsf03562.htm

24 NSF Program Solicitation 05-531, http://www.nsf.gov/pubs/2005/nsf05531/nsf05531.htm

2002 Planning Grant/2003 Implementation Grants[23]	2004-2005 Implementation Grants[24]
	Proposals should reflect: ▪ An understanding of the research on how students learn engineering and how the practice of teaching must build on this understanding ▪ An understanding of the research and practice of the assessment of learning outcomes ▪ The benefits of integrating teaching and research ▪ The appreciation that faculty participation, faculty development, and faculty appreciation for the scholarship of learning are critical to the success of departmental reform ▪ The appreciation that faculty participation, faculty development and faculty appreciation for the scholarship of learning are critical to the success of departmental reform ▪ The realization that collaboration with experts in the field of learning, pedagogy and assessment is critical to departmental reform ▪ The importance of stimulating students, particularly underrepresented minorities, to pursue graduate studies.
	Proposals which incorporate service learning projects must ensure that these projects: ▪ Count for engineering course credit (for example, not be in addition to requirements but replacements for them) ▪ Align with ABET requirements, especially those for teamwork, communication skills, and project based experiences ▪ Be multidisciplinary ▪ Include a strong assessment and evaluation plans, and research on the impact of service learning on teaching and learning ▪ An international dimension to the service learning projects is also encouraged.

Appendix D: Case Studies

California Polytechnic State University: Materials Engineering Department

"Triple Bottom Line Awareness in Design (TriAD): Diversifying the Engineering Profession of the 21st Century"

September 2004 to September 2008

The DLR project

The goal of the Departmental Level Reform (DLR) reform at Cal Poly is to equip engineers to solve the technical challenges in the context of a complex, global society. Their strategy is to apply the rich body of results and best practices from education research to the re-design of a curriculum that emphasizes Triple Bottom Line Awareness in Design (TriAD). The work comes out of the urgency to not only create a more diverse population of engineers, representative of society, but to instill new thinking, new ideas, new ways of balancing **economics, the environment, and society's** needs (i.e., an awareness of the triple bottom line) in engineering design. The basic premise is that young people are motivated to study and apply their creative energies to benefit society if they are aware of these needs and know they can make a difference.

The materials engineering department, whose faculty and student constitute roughly 4% of the approximately 180 faculty and 5000 students in Cal Poly's College of Engineering, was able to strongly influence the larger Cal Poly College of Engineering through their DLR grant work. As an example, Cal Poly's College of Engineering redefined its previous vision and mission to align with the goals of the DLR grant. The college's vision was to prepare students for industry; its new vision is to "lead engineering education and innovation to serve society."

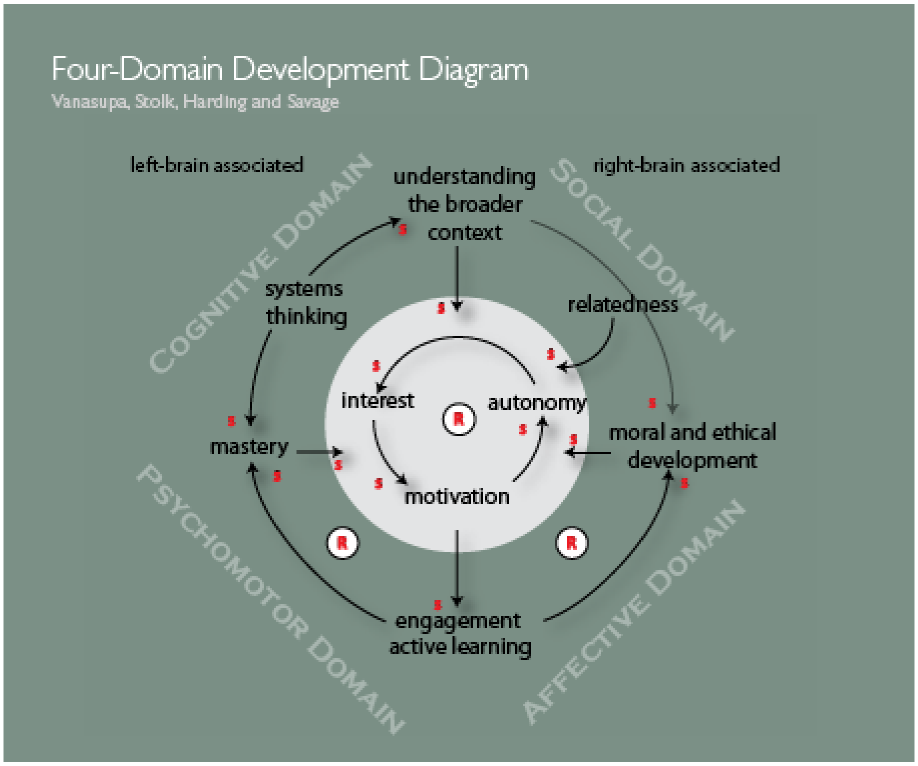
Curriculum Reform

The curricular revision constitutes a change in approximately 80% of the materials engineering courses at Cal Poly. Many of the ideas had been piloted over the last few years; the proposed curriculum derives from over 180 hours of planning by the faculty, 60 of which were in consultation with their industrial advisory board.

The ultimate goals are to create: 1) a greater awareness of engineers' professional responsibility to apply their knowledge to benefit society; 2) a greater level of awareness of global challenges and design constraints that include ethical, social, political, health and safety, environmental, sustainability and manufacturing issues; 3) a shift in thinking towards that of holistic, systems approaches; 4) learning communities that strengthen students' resilience in difficult academic times;

In addition, the goals are to a) increase the retention rates of underrepresented individuals; b) increase the retention rate of engineering freshman; c) effectively reach students of all learning styles; d) increase engineering students' valuation of related subject domains (science, math, communication); and e) effect deeper learning in lower-level science, math and communication courses.

Figure. CalPoly's approach to curriculum reform: Development of and learning by an engineer should involve both left-brain and right-brain activities. (Four-Domain Development Diagram. 'S' at arrowheads indicate that changes in one construct cause the same type of changes in the other. 'R' indicates a reinforcing set of changes.)



New engineering programs

The curriculum changed from materials science based on analysis of materials, to a design oriented, practice of designing materials with a holistic , systems and processes approach. The systems approach allows students to see how everything is connected, which makes it easier to understand the whole picture.

Functional goals for each year

- Within the Materials Engineering units, which comprise 40% of the entire degree curriculum, years 1 and 2 emphasize systems thinking and engineering basics, year 3 emphasizes process design and control through integrated, project-based learning and in year 4, the course emphasis is on professional depth and breadth. The fourth year also contains a senior design project that emphasizes communication, synthesizing and applying knowledge.
- Core competencies: systems thinking, socially conscience application of concepts and methods. Each semester, students work on 1 to 3 design projects for up to 12 hours a week in large blocks of time. This is supplemented with textbooks and

other more traditional activities, but is self-directed, i.e., students must pick up textbook on their own to read chapter about tomorrow's lab, it is not assigned.

New technical areas

- Updated courses dealing with new technologies applied to real-world scenarios. For example, the DLR team created a nanotechnology-biology course in which covered materials selection that takes into account life cycle. The students loved the course because it was relevant to today's problems.

Integrated approach focusing on Sustainability, a social imperative. There is no one class on this. Sustainability is integrated to all classes throughout new curriculum. However, there is a new course on "materials selection for the life cycle."

Teaching methods used

The threads that run though the curriculum are (a) to build mastery of foundational skills (teamwork, communication, and self-directed learning) as well as (b) systems thinking (design and analysis of materials systems and process and contextual understanding).

One example is the service learning that was implemented into the new curriculum. The underlying theory behind this was moral development, resolving a conflict internally with one's self. In service learning, students are faced with working with people who very different from themselves, and they had to reflect on this, and use moral reasoning. This helped the students grow morally which fits in with the program's mission of creating engineers that are socially conscious and to practice engineering to help to advance humanity.

Recruitment and retention of students

The DLR changes resulted in a quadrupling of the number of qualified applicants to the program from 2004 to 2006 as well as doubling the academic 'quality' of the students who applied to the program. An unintended consequence of this was that the program had a reduction in female freshmen because all female applicants were recruited with scholarship offers by research institutions. As a matter of policy, Cal Poly, does not offer scholarships to freshmen, so the program was at a disadvantage for recruiting female applicants. Prior to the DLR work, roughly 30% of the materials engineering department's graduates were female; this is significantly larger (statistical significance $p<.05$, 95% confidence interval) to the Cal Poly College of Engineering average which is approximately 18% female. The current female enrollment is ~10% at the freshmen level, growing to 20% at the sophomore level due to internal transfers. They continue to retain male students to graduation, so the current projects indicate that we will not increase the proportion or absolute numbers of female graduates from our program.

Since the start of the DLR project, there has been a 40% growth in the number of undergraduates, from 128 (Fall 2004) to over 200 (Fall 2008) students (freshmen through senior) in the Materials Engineering Department. The growth occurred during a period in which the three of four accredited undergraduate materials engineering programs at non-Ph.D.-granting universities in the US have either been disbanded or merged into other programs (Cal Poly is the fourth). Cal Poly's materials engineering program is currently the largest accredited undergraduate materials engineering program in the United States.

During 2006-2007, there was an influx of eighteen students transferring into the program, the majority of who are female. This influx is a reversal of a 15-year trend. Other engineering programs within the college continue to "export" students out of their majors at a rate of ~55%. Several of these students transferred into materials engineering from programs outside of engineering, for example, from economics, landscape architecture, speech communication. This is another first in 15 years. (The large influx in the number of women did not change the distribution of men and women because of retaining male students.)

Outreach has two components:

- Active outreach to a K-9 audience, but the pay off from this will not occur for many years.
- Outreach program at a local high school to help students with calculus. This outreach, involving roughly 160 students, had no measurable impact over the course of a year. In retrospect, the principle investigators believes part of the problem is that they did not involve the relevant high school stakeholders (students, faculty, administrators) in the design of the outreach solution.

Service Learning Projects

Service learning research questions:

- How has working with a client changed the way engineering students view themselves?
- In what ways does it change engineering students' view of the role of engineers in society?

Service learning was implemented within the second and third terms of a year-long freshmen sequence of laboratories. Freshmen meet once a week for a 3-hour period

During the first quarter, the 48 students enrolled in the course were broken into formal teams and given the task of designing a water heating system that used only renewable energy. At the beginning of the quarter, students completed a learning style inventory for the purpose of forming teams from individuals of diverse styles. Throughout this first quarter, students were guided through team-building exercises and reflection questions. The Twelve Principles of Green Engineering (Zimmerman and Anastas) was used as a guide for the design process and environmental design constraints were added to each project. Each team was successful in building and testing their system (a short video clip of one of the units can be viewed at http://edge.calpoly.edu/news-early.html).

The second quarter transitioned to the service learning projects where teams were allowed to choose from one of three clients: a local zoo, a local community center, a local children's museum. Student teams completed an in-depth analysis of the users' needs. Students were led through several activities geared toward enabling them to clearly articulate the users' needs. This involved several trips to the site and interviews with the clients.

The third quarter was a continuation of the second, with each team having completed an assessment of the users' needs. During the final quarter, students completed conceptual designs and built products on-site for the clients.

At the end of the year, students completed a battery of assessment instruments geared toward measuring the readiness for self-directed learning, the motivation profiles, level of self-efficacy, learning styles, moral and ethical reasoning.

Four faculty and one post-doctoral student were involved in the service learning projects. The post-doc was responsible for collecting qualitative data through reflection assignments.

The service learning component has been institutionalized as part of the freshmen learning experience within the materials engineering program. The faculty feel that there is convincing evidence that the freshmen experience, designed according to the learning theory, has been effective at changing the culture of the department. They cite as examples:

- Decreased net attrition rate from freshmen to sophomore years from 30-40% in years past to 10%
- Accelerated moral development of the freshmen compared to the national peer averages
- Department receiving the Cal Poly's President's Community Service Award in 2008.

Their award set a precedent as the only group of faculty to be honored by this award, which is initiated by the community.

Learning about student learning

- Create a "learning community" where everyone including students and faculty work, grow, and learn from each other. This boosts student resilience and gives them a sense of belonging, creating social identity, and meeting hierarchy of needs (basic, relationships, and desire to grow).
- How you teach is more important than what you teach, this relates to new learning culture and "learning community".
- Students must care about what they are learning in order to excel at it, therefore the sustainability, serving humanity, socially conscience aspects of new program has given the students something to care about.
- Start service learning projects and design projects in freshman year to give students a reason to care about what they are learning. The service learning projects helped them create a social identity and attract morally conscience students.

Accomplishments

- Developed a model of learning that is used as tool for designing learning experiences. The model is a synthesis of research from educational psychology and cognitive psychology. It emphasizes the fact that effective student learning requires holistic attention to all four domains of student development (cognitive, social, affective and psychomotor).
- Created a new learning culture, because the culture and atmosphere of a department affects how a student learns. This new culture was based on the concept of a "higher-self" to attract students that were tuned in morally
- Created a "learning community" where the students and faculty could all come together and openly communicate. Students help and learn from each other. This teaches them to be resilient through times of academic difficulty.
- Compared to students in other engineering departments, students involved in this program scored higher on motivation and more effective use of self-directed learning strategies. They also reported higher willingness and practice of collaborative learning with their peers.
- Developed and presented ten workshops and three university-wide seminars involving leaders in the sustainability movement so that the entire Engineering College could learn about current issues in engineering education research and sustainability in engineering.

Best Practices

The DLR project led to many successful collaborations and working relationships within the college, between Cal Poly colleges and between colleagues at other institutions.

The involvement of graduate students in DLR resulted in increased interest in teaching due to mentoring by faculty and students watching faculty work together.

University of Central Florida: Industrial Engineering

"Reengineering the Undergraduate Industrial Engineering Program"

September 15, 2003 through August 31, 2009

The DLR Project

The primary goal of the University of Central Florida's department level reform was to reformat the Industrial Engineering's curriculum to prepare students for careers in nontraditional manufacturing industries such as service industries and information technology industries. This reform included the addition of an Engineering Leadership & Management minor.

Curriculum Reform

The new curriculum uses an integrative Cognitive Learning Theory which emphasizes human information processing, as well as Instructional Design Theory which focuses on strategies of instruction.

The curriculum promotes the use of appropriate uses of technology to support classroom instruction goals and student learning objectives. Utilizing advanced technologies such as DAML, XML, and RDF, the new curriculum emphasizes core concepts of information systems and information technologies.

The new curriculum includes an Engineering Leadership & Management minor*.* This minor gives students the basic understanding of engineering management, project engineering, financial engineering, engineering leadership, and technology management.

Teaching Methods

Cognitive Learning Theory was introduced, which places emphasis on human information processing, with instructional design theory that emphasizes strategies of instruction.

The curriculum focuses heavily on utilizing technology advances to support the educational objectives of the courses. The faculty encourages technology use to create experiential learning opportunities and avenues for students to explore topics of significant relevance to the primary material of the course.

Recruitment and Retention

One of the primary objectives for the department was to increase awareness of Industrial Engineering careers among local high school students and encourage them to pursue careers in this area.

Much of the recruitment effort focused on underrepresented groups.

Several Industrial Engineering professors and students conducted camps for local high schools students to introduce them to classical industrial engineering topics and problems. There were over 100 participants. These camps have been held every summer since 2005.

However, they will be discontinued if the program cannot find additional funding after the DLR.

Learning about student learning

It is important to start involving students in leadership roles. It is a concept that should be taught from the very beginning and not at the very end with advance courses.

Having industry involved is key.

Advance topics have to be taught from general ideas to the details.

Accomplishments

New curriculum and the development of a Engineering Leadership & Management minor

Teaching advanced topics earlier in the curriculum.

Outreach activities such as providing summer camps for local high school students.

Collaborations with universities overseas

Fellowships from Progress Energy for students to minor in Engineering Leadership & Management

Best Practices Developed

Integrate industry and academia into the reform project.

Teach topics in a top down fashion.

Introduce advanced topics earlier in the undergraduate curriculum.

Provide retreats and seminars on the benefits of curricular changes to introduce new ideas to faculty.

City College of New York: Mechanical Engineering

"Redefining Mechanical Engineering: Systemic Reform of the Mechanical Engineering Program at City College"

September 15, 2003 through June 17, 2007

The DLR Project

In collaboration with the American Society of Mechanical Engineers (ASME), City College of New York's (CCNY) department level reform had three components, each designed to correspond to a current trend in the mechanical engineering profession.

- Incorporation of emerging technologies, such as, MEMS, Advanced Materials, Computer Aided Engineering (CAE), Intelligent Systems/ Electronics, Biotechnology, Nanotechnology and Nontraditional Energy, into the curriculum.
- Introduction of new teaching methodologies focused on student learning.
- Enhanced efforts at recruitment and retention of students.

Curriculum Reform

The overall goal was to undertake a systemic and integrated reform of the CCNY Mechanical Engineering (ME) program. The reform included the following objectives:

1. To revise the ME program curriculum by incorporating emerging technologies into the ME Program curriculum, that meets modern industry needs, have potential commercial applications, promotes technological literacy, relates intensely to research and is accepted by the engineering community.

    a. To modify courses within the curriculum by integrating interdisciplinary engineering materials experiences, increase and eliminate specific course topics, and incorporate hands on laboratory experiences, technical support and provide course time increases.

    b. To broaden students' perspective by revising courses that includes new teaching strategies and enhanced teaching methods.

    c. To add a new course in Micro/Nano Materials and Manufacturing that includes enhanced phenomena in science and engineering topics, and add an elective course that grants credit for undergraduate research or teaching experiences.

    d. To combine two existing courses, Thermodynamics II, and Energy Systems Design into a new Thermal Systems Design course.

    e. To reduce and adapt the science elective requirements to better provide the background needed for the subsequent study of emerging technologies.

2. To introduce new teaching strategies focused on student learning which incorporates industry needs, cognitive science research, and promote technological literacy, as well as

stimulates critical thinking, fosters the development of teamwork skills and provides opportunities for graphic, written, and oral communications.

a. To provide opportunities for cooperative student learning through participation in intellectual communities of practice.

b. To provide students with opportunities for project based learning which includes problem solving in uncertainties characterized in engineering practice, for analysis, simulation, and design in construction of prototypes.

c. To provide opportunities for students to participate in early research experiences that includes literature searches, experiments, simulations, data analysis and presentation of research outcomes.

d. To incorporate laboratory experiences in which students organize data, investigate data patterns, and draw inferences, as well as design entire experiments.

e. To provide projects for independent learning experiences that encourages self-teaching.

f. To expose students to interdisciplinary learning through participation in projects and teams which collaborate with other engineering areas through team design projects.

3. To enhance students services with the goal to retain students in the engineering program and improve student academic performance.

a. To explore new ways to reduce student graduation time from 6.3 years.

b. To incorporate special advisement on financial assistance for student retention.

c. To understand and respond to the experiences of female students by incorporating focus group meetings and developing strategies to address retention of females.

d. To provide team design projects which expose freshmen to engineering projects early in their academic careers.

e. To identify students who are likely to fail and provide early intervention support services to reduce dropout rate.

4. To increase recruitment of women, African Americans and Hispanics into the ME program.

a. To use design contest projects as tools to recruit diverse students into the engineering program.

b. To implement freshman and high school design contest teams.

c. To offer an elective course based ASME, SAE and AIAA design contest to community college students.

d. To provide a one-week summer Reverse Engineering workshop for high school students to participate in a team based engineering design contest, with winners receiving scholarships and awards.

5. To form a subcontracting partnership with the ASME in executing the ME program reform in order to achieve a broad national and international impact.

a. To incorporate ASME professional practice curriculum modules into the ME curriculum.

b. To conduct a series of effective teaching workshops

c. To provide feedback by establishing an Industrial Advisory Board

d. To disseminate and publicize the CCNY ME Program through electronic and other means.

Teaching methods

Each of the teaching strategies contributes to the overarching goals, which are to stimulate critical thinking, foster the development of teamwork skills, and provide many opportunities for written, graphic, and oral communication.

Other methods used include cooperative learning, project-based learning, research methods, laboratory experience, independent learning, and interdisciplinary learning.

Recruitment and Retention

Held design competitions community college students.

Took advantage of the college's honors program for outreach.

The program received a STEP grant to create an external advisory board that focuses on female recruitment.

Learning about student learning

Students learn better when curriculum involves more than just lectures.

The more students participate in their own learning, the better they actually understand the material.

Accomplishments

Incorporated emerging technologies i.e., the nanotechnology course.

Modified teaching methods to include more project base learning, team-based, inter-disciplinary learning, and implementation of computational methods. The materials course introduced hands on experience. A lab tech use to do the experiment, but now students are divided into groups and they conduct their own experiments.

Introduced a micronano technology course and changed the science requirements. Began offering a lecture series as part of the curriculum.

Best Practices

Hands on learning is time consuming and expensive, but is now a permanent component of the curriculum.

Ensure professors document the curriculum changes and teaching methods used.

Department level reform has become more expensive. Highlighting the success of the program has leveraged funds to pay for more people, supplies, and equipment.

Columbia University: Earth and Environmental Engineering

"Reforming Undergraduate Education in Environmental Engineering: Urban Studios as Knowledge Delivery Systems and Vehicles for Service Learning"

September 2004 through August 2008

THE DLR PROJECT

The Fu Foundation School of Engineering and Applied Science developed a new Studio based model of instruction for Environmental Engineering. The Department of Earth and Environmental Engineering (EEE) provides the focal point, with participation by the Departments of Civil Engineering and Engineering Mechanics (CEEM) and Mechanical Engineering (ME). Urban studios were chosen as the vehicle for reforming the curriculum for a number of reasons:

Urban problems provide the opportunity for depth (e.g., combustion processes and pollutant production from cars) and breadth (e.g., the link between flood control strategies, vector borne diseases, and cumulative ecological impact in receiving water bodies).

Columbia's setting lends itself to service learning project and interactions with engineering professional practice.

Urbanization is a global concern.

Collaboration with the Graduate School of Architecture, Planning, and Preservation made it possible to rapidly implement, re-evaluate, and refine the proposed curriculum, while providing interactions with urban planners and architects.

Curriculum Reform

The specific objectives of the project are to:

- Design a 4 year integrated undergraduate curriculum for Environmental Engineering that offers a systematic exposure to Urban Environmental problems for freshman and sophomores.
- Develop adaptable Studio classes that highlight prominent, current problems of the urban environment that are suitable for integrated analysis and provide students with service learning experiences. Adopt a modular approach to provide flexibility so that specific units can be revised or replaced as needed.
- Modify existing classes to include mini case studies and examples that support the material covered in the concurrent Studio classes.
- Integrate software tools and content into the Studio and existing classes.

- Systematically evaluate the curricular change to measure: its impacts upon enrollment in the civil and environmental disciplines; its impacts on gender and ethnicity differences in student attitudes; the influence of Studio-based service-learning on student behavior in teams; the success of Studio-based service-learning in culturing pro-social attitudes.

Inspired by the pedagogy of the Architectural and Design Studio, the department uses Urban Studios as a model for its department level reform. A Studio is an intensive environment for collaborative, goal-oriented problem solving that promotes the synthesis of materials and concepts and specifically encourages cooperation between faculty and students. The Studio Learning Suite is vertically integrated into the curriculum to complement and enhance the traditional curriculum.

Figure 1: Conceptual structure of the environmental and engineering curriculum after revision to incorporate Urban Studios.

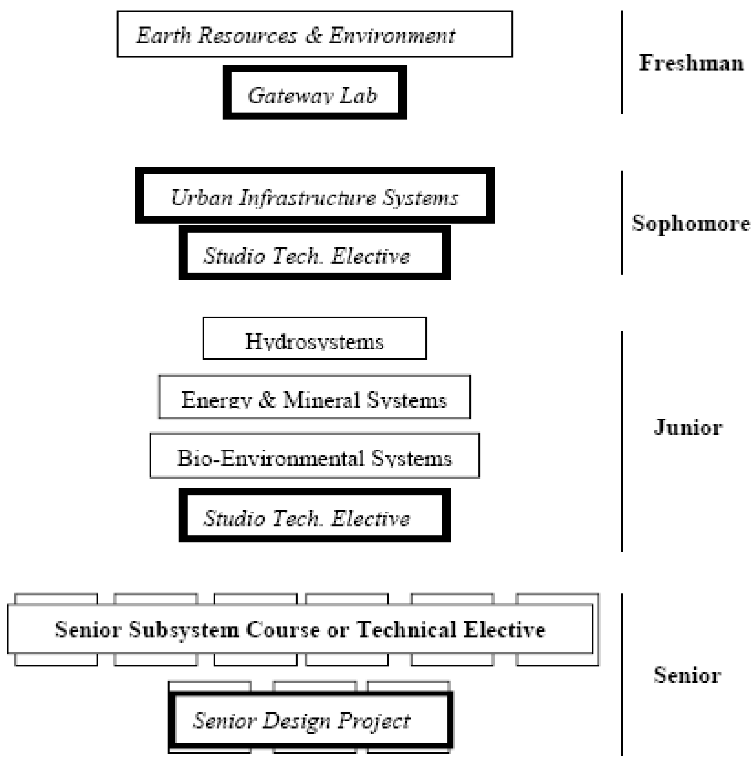
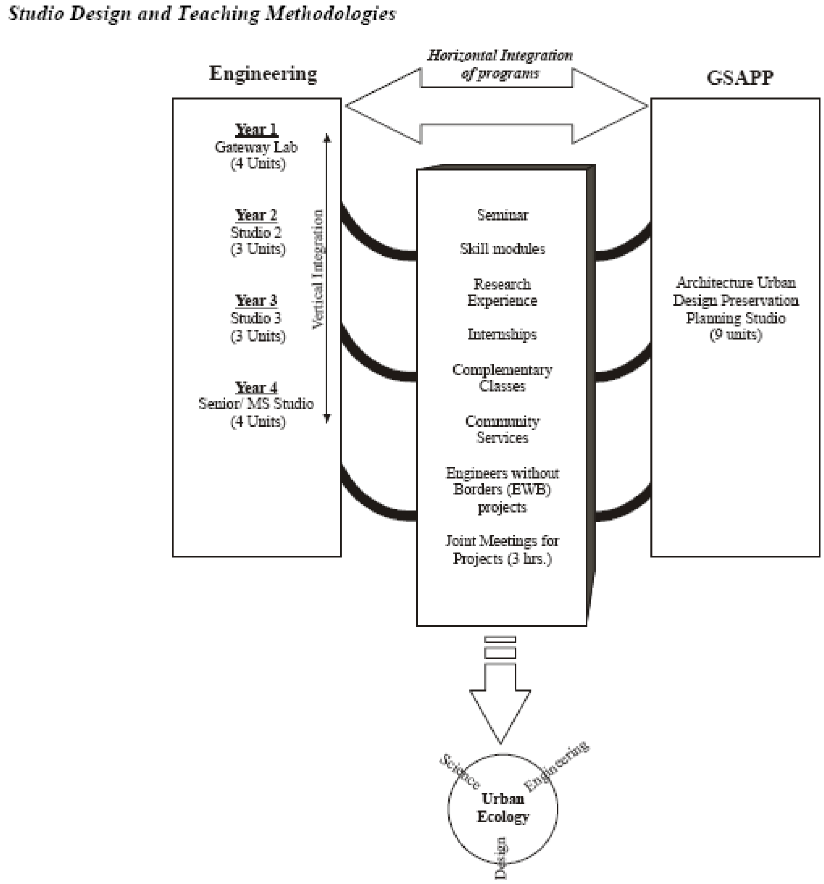


Figure 2. Conceptual schematics for the design of a Studio facilitated learning program across the School of Engineering and Applied Science and the Graduate School of Architecture, Planning, and Preservation



Example of an Urban Studio Project

In the academic year 2006-2007, the Senior level studios was CLIMB 155th Street [City Life is Moving Bodies], which examined the rejuvenation of the string of neglected Manhattan Parks that extends north of Central Park, toward the aim of engendering a culture of exercise, ecological restoration, education and economic development in disadvantaged communities bordering the parks. A specific focus was the Polo Grounds, a low income community of color located at 155th Street, and housed in one of the worst New York City Housing Authority's (NYCHA) projects. The Studios engaged 10 Engineering students working in conjunction with 8 architectural students to develop innovative urban design strategies for connecting the parks and the Polo Grounds. The Studio's community client was CLIMB, who is currently following up on several of the strategies proposed by the collaborative engineering/ architecture design teams.

Teaching Methods

The studio-based curriculum is implemented for all four years of the engineering program. The studios are designed to complement the traditional classes. Implementing a studio-based curriculum is based on research in engineering education that emphasizes the need to use a variety of cognitive learning styles, including activity and team based learning strategies, simulations, and case studies. These methods, when complemented by mentored practical experiences, enhance the learning experience.

Recruitment and Retention

The Urban Studios appeal to women and minority populations. Enrollment in 2007 increased from 7 to 40 in the freshman class and from 3 to 15 in the junior EEE classes. The students like the new modeling exercise and laboratory activities.

Service Learning

Service Leaning is integrated into the Urban Studios. The foundation of the Gateway Lab provides support and infrastructure for the expansion of the Community Service-Learning Program (CLSP). The CLSP is modeled on the Purdue EPICS program and Columbia is now a National EPICS partner. Teams of 8 to 11 students work on projects addressing community needs including public health, education, job training, environmental conservation, arts and culture, community economic development, parks and open spaces, and services to the elderly.

The Engineering School requires that all entering students take a four-credit engineering and applied science class learn to apply design skills including advanced three-dimensional graphical and computational applications. In collaboration with the Center for Technology, Innovation, and Community Engagement, engineering students participate in more than 70 community-based learning projects each year. The projects emphasize teamwork and project management, technical research, customer and market needs, open-ended problem solving, detailed design, budgeting, prototyping, and communication skills.

The Gateway Engineering Education Coalition is a consortium of seven universities focused on the reform of undergraduate engineering education. One of the primary activities at Columbia was the establishment of the Gateway Laboratory for undergraduate education. The Gateway Laboratory offers faculty and students a state-of-the-art computer studio for classroom use of technology in the service of engineering design-oriented work. The Gateway Lab is used for the Engineering School's first-year computer-studio-design course, Introduction to Engineering Design Using Advanced Computer Technologies.

Learning about student learning

To create a new generation of engineers requires that they understand the community perspective and that projects must have tangible results. Students learn how to create trust, to understand community needs, and to implement solutions that benefit the community.

Harlem provides many opportunities for community projects. The key for students is to learn to be consistent, to follow-up, and to sustain the community activity.

Accomplishments

The Engineering School has made service learning a priority. The DLR grant allowed the faculty to solidify their ideas and to implement them. The results have been an increase of students in the school, an improved curriculum, and full engagement of the faculty. From the students' perspective, the curriculum revisions have been effective.

Enrollment has increased dramatically since the initiation of the DLR project.

Service learning is now institutionalized. Faculty is involved in disseminating their approach to other departments. Service learning projects include interdisciplinary minors, studio, and upper division projects. More than Over 700 students have participated in service learning projects for credit. The effect has been to make Columbia University a better community partner.

The success of DLR-supported service-learning courses prompted the Engineering School to implement service-learning in non-technical courses. The School now supports two non-technical science, technology, and society courses – both taught in the Gateway Lab – that utilize service learning as a required part of coursework.

The Earth and Environmental Engineering (EEE) laboratory experience has been expanded to a two semester sequence with significant hands-on modules. The modules have been configured to reflect the three primary focus areas of EEE: Sustainable energy, water and climate and environmental health. This offering has attracted students from other School of Engineering and Applied Science (SEAS) departments (i.e., chemical, mechanical and applied physics) and Chemistry.

Best Practices Developed

The DLR project has benefited Columbia's Undergraduate Scholars' Program. Every scholar must do a community project under the Center for Technology, Innovation and Community Engagement (CTICE).

The DLR PI, Dean McGourty sees only positives in the Engineering School's involvement in the community. "We're helping our students learn, which is our primary goal," he says. "We're building real capacity among our neighbors. And we're creating a pipeline of future engineering students, many we hope at SEAS, among the local community."[25]

Freshman year: Students tour Harlem and complete an oral history project on urban leadership; sophomore year: students collect data through phone interviews working on a specific community issue; junior year: students are interns on a specific community project.

[25] http://www.engineering.columbia.edu/news/spring08/feature5.php

Duke University: Electrical and Computer Engineering (ECE)

"Theme-Based Redesign of the Electrical and Computer Engineering (ECE Undergraduate Curriculum at Duke University"

September 2004-August 2008

The DLR project

The goal of this project is to develop a new, innovative curriculum for the Duke University Electrical and Computer Engineering (ECE) department that focuses on ECE fundamentals within the construct of real-world integrated system design, analysis, and problem solving.

The new ECE curricular theme, Integrated Sensing and Information Processing (ISIP), was chosen because it encompasses many of the departmental research strengths while spanning ECE broadly. This theme bridges the disciplines of physics, devices, mathematics, electromagnetics, signal processing, computer engineering, communications and controls, drawing from all of these areas to build systems for specific applications. Within this theme, opportunities exist for exploration of each of these areas, independently and as integral components of the larger field. It introduces all of the major areas of ECE in the first year, using the theme concept to illustrate how each area contributes to multiple components of an entire system.

Curriculum Reform

Integrated Sensing and Information Processing (ISIP), provides a strong fundamental framework from which students can address problems in new and evolving areas, such as biological and biomedical applications. Successful implementation of the theme-based curriculum required integration and, therefore, collaboration horizontally (e.g., across core courses) and vertically (from core through design) throughout the curriculum. The revised curriculum also has a multidisciplinary impact as both electrical and biomedical engineering student take several of the courses.

By focusing on thematic coherence, rather than traditional topical boundaries, applications can be described in terms of overall functionality not subsystem boundaries. Introduction of the ISIP theme in the newly-designed introductory course (Fundamentals of ECE) lays the groundwork for the remainder of the curriculum. Once exposed to the theme, students are better able to meet the difficult challenge of integrating often-fragmented concepts into a meaningful, holistic view of ECE. They are better prepared to consider real-world design problems, especially how different aspects of ECE combine to support the design and functioning of a complete, realistic system.

An example of a new course entitled "Sensors: Devices and Integrated Systems" within the Microelectronics focus area fills a critical instructional gap within the ISIP-focused curriculum. It discusses the issues related to the integration of sensors into larger systems, including general requirements, performance, reliability, cost, applicability, and compatibility.

The goals for the curriculum reform are:

Rigorous, integrated introduction to ECE. Introduces core knowledge from different aspects of ECE in an integrated and rigorous manner. To meet this objective, topics from multiple areas circuits and devices, computer engineering, signals and systems, and electromagnetics—are considered synthetically, not sequentially.

Curriculum roadmap. Ensure that all ECE students—even those taking the introductory course—understand the breadth of ECE as a discipline and as a major. Traditional curricula compartmentalize knowledge by teaching a series of core courses, each of which presents an area of ECE in relative isolation (e.g., signal processing or computer engineering).

Real-world connection. Rather than teaching students material in abstraction, such as by having them simply build an arbitrary circuit to measure a current and voltage, the goal is to have students face a real-world problem and explore how to design and implement a system that can solve that problem.

Early design experience. Design is central to engineering. Students benefit from and desire earlier and more frequent real-world design experiences, but in a traditional curriculum many students do not complete a hands-on, comprehensive design project until a senior-year capstone design course.

Assist instructors in improving their teaching skills. Organize in depth pedagogical techniques workshops. Coordinate a 1-day roundtable event each year to draw upon educational ideas and best practices from leading ECE institutions.

Provide a handbook of "collective wisdom" that contains descriptions of teaching methods used by faculty in the department with consistently high teaching evaluations.

Provide assistance in developing online evaluation forms to provide feedback to individual instructors.

Hands-on learning experiences, especially through extensive laboratory explorations and design projects. Given the more complex nature of such projects (relative to the rote learning experiments prevalent in the prior curriculum), students participate in more team-based learning.

Teaching methods

Focus on students' early years when retention issues are most critical, by implementing a restructured set of core courses that focus on design, synthesis, and real-world aspects.

Concurrent with the introduction of this theme have been the incorporation of innovative pedagogical techniques and an increased emphasis on hands-on experience throughout the curriculum.

New learning about how students learn

Students are more engaged, and presumably learn better, when actively involved in the learning process. The DLR team observed a significant increase in the quality and complexity of design projects as a result of early and repeated exposure to extensive hands-on learning early in the curriculum.

Preliminary evidence indicates that incorporating active learning in the classroom has a positive impact on student learning (both students' subjective perception and objective measures such as exam scores), student perception of the difficulty of course material, and student attention during class.

Accomplishments

Students reported significant improvements in problem solving, design, and team-building criteria. These improvements directly reflect the pedagogical changes associated with the new course and laboratory. Reworked core courses were successful from both faculty and student point of view.

Faculty has adopted new technology in the classroom as a result of workshops on the topic.

Pedagogical workshops are received by faculty.

As the DLR process unfolded, there was a significant increase in the number of undergraduates who expressed the desire to be Teaching Assistants (TAs) as well as the actual number of TAs. Over 40 TAs developed the new labs, which contributed greatly to the success of the project.

Best Practices developed

Assessment of core courses.

Implementation of a meaningful freshman design course with breadth of ECE as focus.

Web-based surveys and focus groups.

Dedicated lab managers, technology workshops.

Hiring a Laboratory Manager, who works closely with faculty to design and implement new laboratory experiments and design projects. The Manager also trains and supervises all Teaching Assistants, assists students working on design projects in locating/ordering components, and with faculty to coordinate laboratory experiences and ensure continuity throughout the curriculum

Johns Hopkins Univeristy: Mechanical Engineering

"Enhancing Diversity in the Undergraduate Mechanical Engineering Population Through Curricular Change"

September 1, 2004-September 1, 2007

The DLR project

The goal of the Johns Hopkins University-led department level reform project is to increase the diversity of the mechanical engineering curriculum's student population reworking the curriculum content itself to increase the core materials' appeal to diverse student populations. Johns Hokins partnered with the American Society of Mechanical Engineers, Campbell-Kibler Associates, and seven other universities: California State University-Los Angeles, Howard University, Michigan State University, Smith College, Stevens Institute of Technology, Tuskegee University, and University of Washington. The team also collaborated with Michigan State, California State (Los Angeles) to create books of applications for specific courses, and with Stevens Institute of technology to continue to design course innovation and implementation.

The investigators focus primarily on curriculum content, under the hypothesis that:

> "engineering will attract and retain a more diverse set of students if the curriculum has: greater linkages between the fundamentals and applications and between technical and nontechnical topics, more teaming experiences, shorter critical path lengths, more focus on the impact of engineering on the human experience, and a general atmosphere of inclusivity rather than exclusivity."

The project's strategy is to:

1. Examine engineering curricula at the level of teaching topics, and consider radical realignments of content and sequencing.
2. Increase the linkages between fundamentals and applications and between technical and nontechnical topics.
3. Add novel applications that emphasize current technologies and social contexts.
4. Add more teamwork experiences and foster an inclusive atmosphere.

Curriculum Reform

Curricular reform is at the center of this project; the curricular revision introduces significant changes to many of the partner institutions' required mechanical engineering courses. The investigators conducted both a retrospective assessment of existing curricula and a prospective assessment of essential components to carry forward into formulating future curricula. These assessments included:

1. Dissecting the partner institutions' mechanical engineering curricula into a database of topics at a level approximately as granular as a course syllabus.

2. Evaluating the resultant list of topics, eliminating dated or non-contributing materials, and adjusting the topics to address future needs in the field. The final list included 856 topics.
3. Mapping prerequisites and associations between the topics, and associating technical topics with applications and with nontechnical material providing social context.
4. Grouping the topics into 31 thematic clusters, and optimizing the sequencing of the topics to address the project's specific curriculum reform goals:
    a. Minimize critical path lengths.
    b. Integrate across technical topics.
    c. Integrate across technical and nontechnical topics.
    d. Introduce more focus on applications.
    e. Emphasize the (positive) impact of engineering on society.
5. Assembling topics into course modules, piloting the new courses, and evaluating outcomes.

The assessment of the existing curricula found that:

- Some commonly required topics are not necessary, particularly in calculus courses.
- The mechanical engineering curriculum is not interdisciplinary enough.
- The curriculum should incorporate applications of breakthrough technologies in biology, ecology, IT, nanotechnology, and photonics, as described in "The Engineer of 2020" (National Academy of Engineering, http://www.nae.edu/nae/engeducom.nsf/weblinks/MCAA-5L3MNK).
- Many of the partner institutions' course titles look very similar, but the course content (choice of topics) varies widely. Of almost 2,000 topics found in current mechanical engineering curricula, only 70 topics were common to all 8 partner institutions.
- Some schools need to better define their teaching of ethics and the ABET "professional skills" requirements.

The initial set of new materials emphasized novel applications related to fluids, solids, and design. For evaluation purposes, these new applications were initially incorporated into design courses and fundamentals courses at four of the eight partner institutions.

Teaching Methods

Much of the project's focus was on curriculum content, rather than pedagogy. However, among the project's goals were two primarily pedagogical concerns:

- Adding more teamwork experiences.
- Fostering an atmosphere of inclusivity.

Toward these ends, specific pedagogical innovations were integrated into the overall project in two ways:

- A series of professional development workshops introducing faculty to research on modes of student cognition and the connection between content and pedagogy.
- Piloting new portions of the curriculum with multiple pedagogical approaches. This diversity of approaches to the new materials is intended to permit the teaching faculty to retain more autonomy, and permit an assessment of which pedagogical styles are most effective for the new curricular components.

Recruitment and Retention

Student interest in mechanical engineering was positively influenced by the addition of new applications creating closer linkages between nontechnical (social and ethical) and technical content.

Seventy-nine percent of students identified applications and labs as course features that increased their interest in the field.

Faculty decided to continue teaching 10 of the 14 new applications; six of the 10 were selected based on strong student interest.

Learning about student learning

The project found that a wide range of applications was needed, to offer materials that students of diverse backgrounds found accessible and interesting.

The project also found a strong relationship between student perceptions of learning and student interest. Students' ratings of their learning in a course were highly correlated with their levels of interest and and participation. Students' ratings of their learning in a course were not at all correlated with their ratings of the course's difficulty. Students' ratings for the degree to which an application contributed to their understanding exhibited similar patterns to their ratings for learning in a course. Incorporating new applications had no effect on students' grades (but the new materials constituted only a small part of the course).

Accomplishments

The project created an extensive and heavily annotated list of topics in mechanical engineering education. These materials, if widely disseminated, should be useful for mechanical engineering faculty in planning and updating courses.

The optimization and resulting schema should similarly help curriculum planners in sequencing course topics. Other products developed by this project may become instructor aids; for example, the project's assessment protocols can help faculty evaluate prerequisites and applications on an ongoing basis.

Best Practices developed

- Incorporate recent issues and applications (e.g. Hurricane Katrina) and technologies (e.g. nanotechnology).

- Require synthesis of nontechnical and technical material for social context, ethical considerations, and clear relevance.
- Develop the project in concert with a variety of partner institutions already focused on the core problem (diversity)

Lehigh University: Bioengineering

"Establishing a Cross-Disciplinary Bioengineering Program with a Technical Entrepreneurship Focus"

October 2003 through September 2008

The DLR Project

At Lehigh, the P.C. Rossin College of Engineering and Applied Science and College of Arts & Sciences collaborated to implement a bioengineering education program that provides students with a balance of science, humanity, technical and business foundation through an integrated experiential learning curriculum that includes traditional classroom lectures, research, industry, clinical and business internships, co-ops and projects.

The Bioengineering program was initially launched in 2002 which was prior to Lehigh's DLR grant. Once the program received the grant from NSF, it began to develop at a more rapid pace particularly with the set up of new labs. The Bioengineering Program was developed as part of a larger Bioscience program at Lehigh. Because it sits between the Arts and Science College (Biology) and the Engineering College, implementation required cooperation from faculty in all engineering departments to make this work.

Curriculum Reform

The four goals of the Bioengineering Program were to recruit high quality bioengineering students and open bio-related engineering degrees to students in traditional engineering departments; to develop a rigorous curriculum that emphasizes hands-on experiential learning and business aspects of bioengineering; to develop advanced laboratories for undergraduate learning; and to cultivate industrial partnerships and provide real-world problems through entrepreneurial projects.

The curriculum includes basic math, science, and engineering courses, as well as a number of required and elective bioengineering courses. Undergraduate students in the three tracks participate in hands-on research in three laboratories developed through the grant. The three tracks are:

- Biopharmaceutical engineering, which encompasses biochemistry and chemical engineering;
- Bioelectronics/biophotonics, which appeals to students interested in electrical engineering and physics; and,
- Cell and tissue engineering, which straddles the fields of molecular and cell biology, materials science, mechanical and electrical engineering.

Students in each track learn how biological systems work, develop analytical skills, and use advanced tools in experimentation, modeling and simulation. Students apply their knowledge to design, synthesis, manufacturing, and health care, develop strong communication skills, and learn to bring innovation and creativity to problem-solving.

Because the bioengineering program is not a distinct academic department, much has been done to ensure that Lehigh's bioengineering students develop a sense of identity within the program. Each cohort of students is assigned faculty advisors that remain with them throughout their time in the program.

Teaching Methods

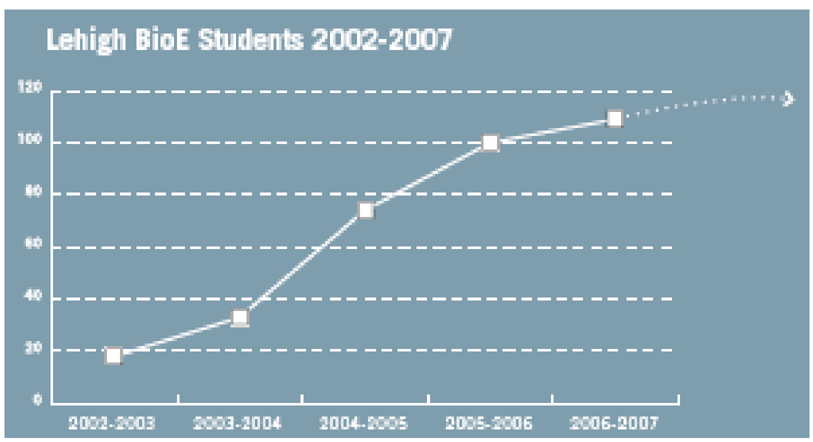
Using an integrated 4-year approach, the program incorporates mentoring, team-based, experienced based, computer-based, and distance learning into the curriculum.

The Experiential components include: research for credit (3-4 semesters); integrated Product Development (2 semesters); summer internships (Industry, Research (REU), Study Abroad); co-op participation

Recruitment and Retention

The program developed an integrated recruiting, admission, and advising strategy. It is promoted through flyers, catalog descriptions, and a web page on the Lehigh University website. The flyer gives a brief overview of the program and features the experiences of a recently graduated senior, who plans to continue graduate studies in biopharmacology.

According to admissions statistics from 2002 to 2007 there was a continual increase in the numbers of inquiries about the Bioengineering Program. Students who indicated an interest on their applications were offered admission into the Bioengineering Program.



Learning about student learning

Students could choose to undertake a research project but it was not required. This allowed a student to make choices that fit with their interests.

Students are required to take Integrated Product Development (IPD) courses. Teams of bioengineering, engineering, design arts, and business students work on a wide range of industry-sponsored bioengineering projects - from the development of entirely new products, to the redesign of existing products, to the improvement of manufacturing processes.

The importance of strong hands-on experiences and teaching students to synthesize learning and skills is important for teaching them how to solve problems.

Accomplishments

Recruited high quality engineering students into the Bioengineering Program through active outreach (printed materials, website, and presentations).

Developed rigorous curriculum with three tracks.

Developed three advanced laboratories for undergraduate training. Initiated planning for a new building for classrooms and labs. Created three new labs: (1) Integrated Biotechnology Lab, (2) the Biostructural Mechanics Lab, and (3) the Integrated Bioelectronics and Photonics Lab. These were supplied with state-of-the-art equipment to conduct experiments.

Cultivated industrial partnerships.

Launched the development of a Master's degree program.

Brought the faculty together to create a new program. The increase in communications and enthusiasm created a sense of accomplishment.

The Figure below shows the vision, goals, program components, and evaluation mechanism for the DLR program at Lehigh University.

Lehigh's Vision	Goals	Program	Evaluation
To provide world-class researchers and practitioners in bioengineering through an exceptional, entrepreneurial-oriented program with state-of-the-art laboratories	Recruit high quality bioengineering students and open bio-related engineering degrees to students in traditional engineering departments	Develop an integrated recruiting, admission, and advising strategy Create a document to delineate options and provide roadmap for interested students Implement interdisciplinary bioengineering curriculum Explore possibility of bio-related degrees in traditional engineering departments Establish computational biology minor	Document recruiting strategies # of students applying to the bioengineering program # of students admitted Breakdown of students by gender and ethnicity # of students in bio-related degrees in traditional engineering departments # of students with minors in computational biology
	Develop a rigorous curriculum that emphasizes hands-on experiential learning and business aspects of bioengineering	Build on strong science and technology courses Incorporate IPD Capstone bio-engineering projects Provide faculty with entrepreneurship training Establish bioengineering entrepreneurial club	# of new courses Annual review of program by biotech company leaders and partner institutions Course evaluations #, career orientation, and performance of students participating in bioengineering program # of students working on bio-engineering projects # of faculty papers, presentations, and funded projects # of participants in entrepreneurial club
	Develop advanced laboratories for undergraduate learning	Form partnership between Colleges of Engineering and Arts and Science Create new labs supporting: bio pharmaceutical engineering cell and tissue engineering bioelectronics/ photonics Install Internet II learning network	Size, equipment, and availability of labs # of student/hour usage Faculty and student feedback about usefulness # and quality of industry projects utilizing facilities # publications/presentations based on research # conferences/workshops/ demos using network
	Cultivate industrial partnerships to mentor students and provide real-world problems through entrepreneurial projects	Implement industrial internships Secure industrial mentors Provide industry project for student team Establish partnership Ben Franklin start-up companies	# of student internships Feedback from industrial mentors # and quality of industry projects Feedback from firms sponsoring projects Faculty interaction with biotech firms

University of Massachusetts-Lowell: College of Engineering

"Service-Learning Integrated throughout a College of Engineering (SLICE)"

September 2005 through September 2009

The DLR Project

The goal of the project is to revitalize the University of Massachusetts-Lowell's College of Engineering through the pedagogy of service learning. Faculty and students are challenged to take on real world service-based projects and find real solutions, helping the student learn the engineering content in a real, engaging and meaningful way.

Curriculum Reform

Service-learning (S-L) is a hands-on learning approach in which students achieve academic objectives in a credit-bearing course by meeting real community needs. S-L has been shown to be effective in a large number of cognitive and affective measures, including critical thinking and tolerance for diversity, and leads to better knowledge of course subject matter, cooperative learning, and recruitment of under-represented groups in engineering; it also leads to better retention of students and citizenship as well as helping meet the well-known ABET criteria (a)-(k). (See Appendix B.) Service-Learning Integrated throughout Colleges of Engineering (SLICE) is a program with the broad aim of developing better engineers and better citizens and the strategic goal of integrating S-L into core required courses so that every semester students have at least one course containing a S-L project throughout the entire undergraduate curricula in five majors. Faculty members were advised to "start small rather than not at all" and if possible to replace existing "paper" projects with S-L projects instead of adding extra work for the students. Over forty of them did try S-L over the last four years in over 50 courses. Last academic year almost 90% of the undergraduate students had courses with S-L projects. Repeated questionnaires and some interviews revealed: that over two-thirds of the students rated S-L with having a positive impact on their staying in engineering with only 3% rating it as a negative impact; that two-thirds agree in principle with integrating service and subject matter in courses (the same fraction of faculty also agree); and that 25% of first year students agree that S-L was one of the reasons for their coming to UML.

The advantages of this approach are that S-L is available to essentially all the students in the college for a significant number of semesters, that no extra courses need to be taken to get the benefits of S-L (saving time and money for the students), that core subject matter is reinforced with the S-L projects (not just teamwork and communication), that the students are exposed to a variety of projects and community partners, that a large number of faculty are involved (increasing the benefits to them), and that a significant number of community projects can be undertaken. In general, civic engagement becomes an interwoven part of the profession. As one faculty member said in an interview, "It [service-learning] will change the way we think about engineering. It adds an additional dimension."

Examples of classes include Energy Around Us, Bridge Building Design Project, Renewable Energy Teaching, Campus Recycling Improvement, Water Purification, WiFi Communication, Lowell Green Roof Project, and many others. See http://slice.uml.edu/project_examples/

Teaching Methods

Service Learning has been shown to be effective in enhancing critical thinking and tolerance for diversity. As a result, service learning leads to better knowledge of course subject matter, cooperative learning, recruitment of underrepresented groups in engineering, retention of students, and problem-based learning.

Learning about student learning

Service Learning as pedagogy motivates students and faculty.

Accomplishments

The strategic objective of SLICE is to have every undergraduate participate every semester in at least one course with a service-learning project. Over half the faculty have incorporated service learning into their courses. The Engineering School has over fifty courses that incorporate service learning.

Almost 90 percent of students have worked on service learning projects in the last year. Importantly, two-thirds of students report staying in engineering in part because of service learning projects and one-fourth of new students report coming to UML in part because of the service-learning component of engineering classes.

The feedback from students (mostly positive) is that they are more motivated in their studies as a result of the application of their learning through service learning projects.

The university applied for the Carnegie Institute for Civic Engagement. If the application is approved, University of Massachusetts-Lowell will have a special designation for community service.

A new council on community outreach at the university level was established.

Best Practices

Convincing faculty to find appropriate Service Learning projects.

Delivering actual results to the Service Learning partners.

Changing the culture so that faculty view Service Learning projects in a positive light.

University of North Texas: Electrical Engineering

"A Project- and Design-Oriented Innovative Electrical Engineering Program"

September 15, 2004 through July 10, 2006

The DLR Project

The University of North Texas Electrical Engineering (EE) department utilized its Department Level Reform grant to integrate project-based EE education and life-long learning pedagogy into its curriculum. Based on the belief that learning of design skills is a continuous process, the EE department adopted the "project every semester" model. The main objectives of this approach are: to instill strong design skills in the students by through real-life projects team-taught with UNT faculty and industrial partners; to develop in the students the art of learning to learn (L2L) and thereby foster their life-long learning skills; and to provide them with business and entrepreneurship education.

Curriculum Reform

Using the "project every semester" model, projects start in the freshman year. During freshman year, students develop theoretical skills and analytical background needed for executing technical projects later on. Students also learn principles of learning to learn (L2L) and ethics through two separate project-oriented courses. The projects provide an opportunity to learn early on that they are responsible for their technical learning as well as their approaches to ethical questions that arise in their student and professional life.

Additionally, the department has remodeled regular classroom courses to integrate L2L principles and project-orientation. The complete course package includes subjects in both core EE and humanities and social sciences. The goal is to promote a well-rounded development curriculum that will benefit their future careers.

In freshman year, the curriculum involves 80 percent of time teaching and 20 percent projects; by senior year, the curriculum involves 10 percent teaching and 90 percent on projects.

Teaching Methods

As a result of the department-level reform, the Electrical Engineering Department now:

Integrates business approaches relevant to engineering in the curriculum; through partnerships between university and industry in teaching project-oriented laboratories (See www.ee.unt.edu/DLR)

Table 1. Sample student feedback on UNT's L2L and Ethics Classes

Appreciative Comments on L2L Class	Constructive Criticism on L2L Class
1. The class participation approach with thinking exercises in the L2L class was enjoyable. 2. Liked the Rube Goldberg activity, the lectures on memory and learning processes, and the learning quiz to know my learning type. 3. My favorite exercise was remembering words and pictures after seeing them. 4. Learning my own learning style was very interesting and illuminating. 5. Liked the class participation stuff with thinking exercises.	1. More of unique and hands-on projects like the news paper tower and the thirteen pennies problems are needed. 2. Group effort should be more encouraged. For example, the second time we did a Rube Goldberg, it was in a small group but for a limited time. 3. More organized assignments will help to improve the course. 4. We should have more group projects. 5. There were too many problem solving exercises to complete. 6. A presentation on how engineers work, think, and live could help.

Table 2. Sample student feedback on UNT's ethics course

Appreciative Comments on Ethics Class	Constructive Criticism on Ethics Class
1. Very interesting course that helped me to deal with some critical issues frequently arising in the society nowadays. 2. Very enjoyable class. 3. Distinction between ethics and professionalism was clearly made. 4. Case studies and eventual group discussions were very helpful. 5. Teaching style and methods are very effective. 6. Very interesting part of the course was learning about patent issues from the real-life patent lawyers.	1. Could be more effective if the students get opportunity to work in an engineering company and have the first-hand experience of those issues. 2. Less time could be spent in the initial weeks on the discussion of the program as a whole. 3. The tip on how to suggest to a junior colleague the need for improvement politely and professionally (*e.g.,* you are doing good, but could do better) may not work on people like me who need clear-cut feedback on whether the way I am going is right or wrong. 4. Discussions with smaller groups (3 or 4 people) could be helpful. 5. Discussion on the history of electrical engineering in the initial weeks could be replaced by more case studies. EE history warrants its own class. 6. At the beginning of the semester, each student should be assigned a different case study to research upon. In each class, a student should present the case study and initiate a discussion. Each member of the audience must have a comment or question in each presentation. 7. Prefer to have 2 1-hour classes instead of 1 2-hour class per week.

Uses “Learning to learn” – (L2L) active learning; to develop an understanding of how engineering is learned and how faculty can facilitate and encourage learning. Topics include: consciousness and self awareness, meta-cognition, learning styles, memory language, reading, writing, problem solving, creativity, and biological aspects of learning. (See www.ee.unt.edu/L2L) The Department requires all faculty and students to take the L2L class.

Recruitment and Retention

The DLR team used about 25% of DLR grant to provide scholarships at University of North Texas (UNT), Richland Community College, and Texas Women's College. The goal is to encourage students to consider Electrical Engineering at UNT. They created 2+2 and 2+3 programs with each school to allow students to transfer with minimum disruption.

Retention: 70% of EE students who enter as freshman, graduate with an EE degree. (Other engineering departments have 40% retention rate.)

Learning about student learning

Students love teams, especially small project teams. They learn by example. By the time they graduate, they have completed 8 projects, 8 presentations, and 8 reports. All projects are team projects and each member of the team must participate in the presentation.

Students learn better (1) if you tell them that you are building on what they know; (2) if they explain things to each other; not just the instructor

Accomplishments

Successfully built an Electrical Engineering program that focuses on active learning and learning to learn, integrates business approaches relevant to Engineering in the curriculum, and uses project-based education methods.

Received funding from the university to construct five laboratories and acquire lab equipment.

The Electrical Engineering Department is diverse and produces successful graduates who receive the highest salaries of all students at UNT. There is an increase in students who are interested in going to graduate school.

Accelerated the development of the M.S. program in EE by two years. The methods developed as part of the DLR grant will be incorporated into the M.S. Program.

Achieved expected enrollment of 25 students per year, 4 years ahead of schedule (2007 instead of 2011).

DLR created a ‘high intensity of enthusiasm to try new things.” The result for faculty was a large increase in satisfaction.

Best Practices Developed:

Incorporating student projects into the curriculum every semester.

Requiring that all students and faculty take a Learning-2-Learn (L2L), which teaches them about learning styles, ethics, and other topics to improve their learning.

Retired engineers who join as adjunct staff are tremendous resource to students. They are patient, donate a lot of their own time, and contribute to program. All adjuncts receive teacher training.

Oklahoma State University: Chemical and Electrical Engineering

"Collaborative Research: Engineering Students for the 21st Century"

October 1, 2005 through May 31, 2009

The DLR project

To create a more effective, engaged, and efficient curriculum, the School of Electrical and Computer Engineering (ECE) department changed the degree program from a knowledge-based paradigm (acquiring a set of concepts) to development-based (emphasizing students' development). This change required faculty to redefine their roles from lecturers to mentors and scholars. This reform represents a fundamental shift in the focus of an engineering degree, and meets the NSF program goals of developing plans to streamline and update engineering degree programs, developing department-wide transformational change of student learning experiences to meet the needs of U.S. industry, and to integrate research and teaching.

Curriculum Reform

Before the Planning Grant and DLR grant, the last curricula reform was in the 1990s. This did not go well so faculty was initially resistant to change when they received the planning grant in 2004. Now the department had 9 new faculty and 3 to 4 new positions, so there was a readiness to accept new ideas.

After the downturn in early 2000, the Provost set new priorities to transform university from a land-grant, service-oriented university to a research university. The DLR fit in as research so was supported by the Provost. (The DLR is considered research because learning is conceptualized around real projects and can be aligned with faculty's research interests, as well as prepares undergraduate students to become graduate students.)

In the 1990s, the culture only encouraged obtaining grants (research dollars) at any cost. This resulted in poor design of engineering courses. The culture also emphasized that a student is first an engineer and then an electrical engineer. Breadth, rather than depth, was important.

The DLR grant allowed the department to reform their curriculum to emphasize depth. For example, engineers use to learn all aspects of physics but many aspects are not needed for engineering (e.g., particle physics, nuclear physics, relativity). Therefore, they introduced a new Semiconductor Physics course that emphasized topics of interest to engineers, such as quantum mechanics. A second class on Solid State Devices was also developed to give students a choice.

The DLR project is called ES21C, which stands for Engineering Student for the 21st Century. The DLR allowed the department to take risks in reforming curriculum. (The PI noted that there is a natural tendency to resist change because it is hard to quantify what you gain when you change people, beliefs, or society. It is easy to quantify what you lose.)

A modular approach is used to design classes: lectures, quizzes, and modules that account for 1 to 5 weeks of the semester. Online quizzes are used to test student knowledge before the class and to ensure that they do the reading. The student can retake the online quiz as many times as they like. (The goal is to prepare the student for the class.)

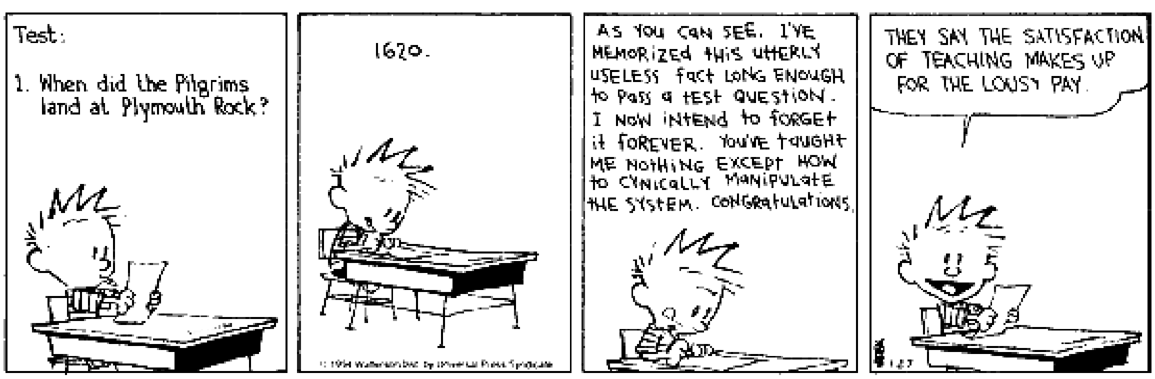
The Electrical Engineering Department developed 15 to 20 minute video lectures using PowerPoint. Students can review concepts when they feel they need more information.

15 to 20 Students were involved in developing materials for the DLR grant projects and other activities, such as:

- Conducted outreach to Middle School Students
- Being a TA for Senior Design class
- Data analysis for ABET criteria
- Developed peer review system so students can give each other feedback (based on effectiveness ratios and effort scores). The goal is to change behavior and increase accountability.
- Restructured laser component for the second optics class
- Developed in-class exercises
- Developed AutoCad class to make more freshman friendly
- Developed revision process for senior design class
- Developed evaluation plan.

Teaching Methods

Goal: To integrate design into classes by increasing number of team projects starting with freshman year. The focus is to increase real learning rather than rote learning; that is, train students to be an engineer, not train students to take tests. (Results were better than expected.)



Developed 10 new courses to focus on experiential development of students. The intent is that a student would take one course per semester over 5 years. These 10 courses result in a cognitive apprenticeship where students learn to document, analyze data, and report on work. These are design courses that broaden skills based on common things that engineers should do. These four things are for students to be: factual, meta-cognitive, procedural, and conceptual.

Students are expected to take responsibility for many facets of their own learning. Not all work is directly assigned.

Freshmen are taught to analyze and apply concepts and by their senior year they have evolved to synthesizers and evaluators. Applications are authentic problems, not made-up problems.

Active learning and team projects are integral parts of the program.

Each professor adapts the methods best suited to their teaching style and the topics discussed. Lectures may be the most appropriate method for some classes (assuming the Socratic method is used as opposed to Ferris Buehler's Sage on the Stage approach). Faculty development is as important as student development in using the new methods.

The DLR has stimulated significant interest in faculty becoming better teachers. Almost 40% of the 24 faculty have been significantly affected by the DLR. About 5% are curious.

Initially monthly faculty meetings were held to share new methods, but this did not work well; instead, semi-annual mini-workshops are held to share best practices and lessons learned and one-on-one meetings with individual faculty are held to develop new curriculum; e.g., develop physics class for engineers.

Tenure process is realigned to focus on sustainability in adopting new teaching across engineering. Excellence in teaching is now valued. Tenure is based on multiple components: (1) Measures of national competitiveness (grants, publications, citations), (2) Teaching excellence and student learning based on development of new classes, involving students in active learning, and assessment of learning, (3) Service.

The Regents approved an Engineering Education teaching certificate: graduate students can use up to 12 hours (out of 90) of their degree requirements to take education (teaching methods) classes. (6 hours in college of education on the psychology of learning and instructional curriculum, 4 hours in college teaching, 1 hours of teaching within own discipline, and 1 hour practicum, which is overseen by faculty mentor.)

These 12 credits are tuition free. Up to 12 students a year can take these classes.

Recruitment and retention of students

The Department conducts outreach to low income high school students

The Board of Visitors noted that students need to learn to showcase their design skills when interviewing for jobs. They should talk about their project accomplishments and failures and what they learned from it. Therefore, the department set up an annual Electrical Engineering Design Day every Spring, so that students could present their work.

Over 300 visitors including high school students attend. The goal is to make engineering fun. It is a celebration of the student and faculty's accomplishments.

The Design Day led to cultural change that resulted in recognition for the department as well as additional funds for the department

Industry attended and talked to students about job opportunities

A Recruiting Day is held every Fall. Over 1400 emails are sent to high schools, middle schools, home schools, and engineering programs at community colleges.

Learning about student learning

Students benefited and liked team work.

Starting design projects in freshman year improves skills.

Over 40% of students get a D when they take calculus in their freshman year. The DLR team is proposing that some students take calculus in their junior year when they have more experience under their belt. An online quiz would be used to determine when a student can/should take calculus. The goal is to retain more students in engineering, since currently, only 43% of freshman that enter the engineering program graduate in engineering.

Accomplishments

The most significant accomplishment, still under development, is creating a taxonomy to analyze engineering programs and courses and to understand effective practices for teaching design and how to evaluate engineering design teams.

Engineering faculty has now accepted role of educators in improving electrical engineering curriculum. As a result, the dialogue among staff and across departments has increased and led to a breaking down of stove pipes. Now regular meetings with faculty work (although they did not initially).

Faculty development has been huge. The introduction of teaching and assessment methods has changed faculty culture.

New found appreciation for collaborating with other disciplines, primarily education, but also computer science, business, and other liberal arts (relates back to increased dialogue).

Best Practices Developed:

Developing effective procedures for adopting new pedagogies in existing courses.

Developing effective methods for teaching engineering design.

Developed a new course that will focus on translating math into engineering concepts and examples. TAs and faculty will receive training on how to teach math.

Involvement of graduate students in DLR which resulted in increased interest in teaching. This resulted from faculty mentoring students and students watching faculty work together.

Email from Principal Investigator

Stephanie and Nyema-

Thanks for creating an environment that allowed everyone to talk during the visit. The visit has actually helped participants to get a bigger picture of the project and become more involved. I need to follow up on the visit while everyone's excitement level is still high. Also many of the students commented on the fact they learned a lot from simply observing the interactions.

I would actually recommend to NSF that if they have future DLR programs that annual site visits by an external team (perhaps professional evaluators as well as previous DLR recipients) be a mandatory part of the project. If we had had such a visit annually I think it would have helped provide more focus for the project and helped energize participants. I think a longitudinal study of DLR projects would provide invaluable data as well.

Alan Cheville

Oklahoma State University

Old Dominion University: Electrical, Civil, and Mechanical Engineering

"Simulation and Visualization Enhanced Engineering Education"

October 2005 to September 2009

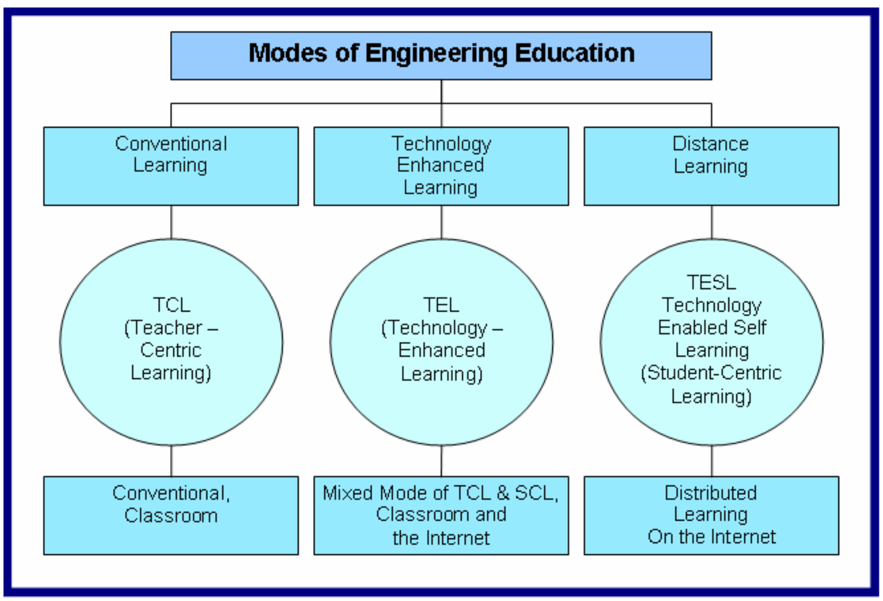
The DLR Project

The primary goal of the Old Dominion University DLR project is to demonstrate that pedagogical improvements can be made in engineering education integrating of interactive simulation and visualization throughout the curriculum (technology enhanced learning). Initially the transformation was applied to selected engineering science and core engineering courses in the three disciplines: Civil and Environmental Engineering, Electrical and Computer Engineering, and Mechanical Engineering.

Curriculum Reform

A web-based virtual experiment module was developed using simulation and visualization. This module has been used as a prelab practice tool for students to learn about lab procedures, measurements and errors in physical experiments. The module has bee

Figure: Old Dominion University Models for Engineering Education



Teaching Methods

The emphasis is on incorporating interactive modules that use simulation and visualization to enhance student learning. In development of modules, the pedagogy of "learning-by-doing in virtual environments" is being employed (technology enabled self learning, or student-centric learning).

One of the important ways engineers learn is through hands-on activities in physical laboratories. The web based modules complement student learning achieved through physical laboratories and conventional classroom instruction.

The emphasis is on enhancing quality of student learning by embedding web-based interactive modules in conventional on-campus classes.

Thirteen of the thirty modules are described at http://www.mem.odu.edu/visualization/modules.html

Twenty-two of the thirty modules are completed.

Accomplishments

Transformation is possible and is happening. The initially most skeptical faculty is now the most enthusiastic.

Students are benefiting from the modules based on outcomes measured on tests and feedback from students.

Faculty has embraced scholarship about learning and teaching and as a result has adopted new educational techniques.

Best Practices

Learning to do systematic assessments and to using this information to improve the modules.

University of Pittsburgh: Chemical Engineering and Biology

"Pillars of Chemical Engineering: A Block Scheduled Curriculum"

September 15, 2003 through August 15, 2007

The DLR Project

The University of Pittsburgh's Chemical Engineering department utilized its DLR grant to reform its curriculum using block scheduling. Block Scheduling calls for courses with considerably longer contact hours than a traditional University course so that: (1) students may gain systems insight through integration of their core knowledge; (2) the instructors have the time to include multi-scale descriptions of Chemical Engineering content; and (3) the instructors have the flexibility to accommodate diverse learning styles and incorporate active learning more effectively.

Curriculum Reform

This curriculum reform introduced emerging Chemical Engineering knowledge/practice (molecular and multi-scale focus as well as track-based case studies/electives)

It also exposed students to practical computational methods, including integration of CAD-based macroscopically focused software, (e.g., ASPEN), as well as molecularly focused software (e.g., Accelrys) into most courses.

The most significant change in the proposed curriculum lies in the shift from smaller, course-centered classes (classes designed with credit hour restrictions as the focus) to more comprehensive topically-centered classes. These topic-centered, Pillar Courses range from 5-7 credits with most including a 1-credit complementary experimental laboratory, and in some cases a 1-credit computational laboratory as well. The typical class meets every day for 1 to 2 hours. The Pillar Course (+ labs) is the only Chemical Engineering core course taken by the student in a given semester – relieving the distraction of coordinating multiple Chemical Engineering workloads, as well as allowing the student to immerse themselves in the current topic.

Faculty who to teach the undergraduate core are very involved. To design a class for the first time requires a lot of effort. The pillar course approach allows faculty to teach for four months and they can then focus on research for the next eight months.

Teaching Methods

Integrated Block Scheduling into the University environment.

Block scheduling has allowed for extensive team-based learning for both faculty and students.

Labs are now vertically integrated into each pillar. Classes are combined with sets of experiments that match to each pillar. Previously lab courses were only taken in senior year.

Recruitment and Retention:

The program uses the DLR reform as a selling point to high school students.

The 2008 incoming class is 50% female. In 2003, it was 39% female

Retention is relatively high

New learning about student learning

The DLR team underestimated the impact of team-based activities. Students really like this mode of learning.

The use of concept maps has increased student motivation to learn—they know why they are learning the material. (Concept maps are used to measure knowledge integration using a rubric to determine if students have properly integrated their knowledge across courses and within courses – one of the project's pedagogical objectives.)

Block scheduling allows time for students to focus and improve comprehension.

Integrating the labs works well from both a technical and learning perspective.

Accomplishments

Successfully implemented block scheduling, which allowed students to learn topics in-depth and efficiently uses faculty time. "The curriculum as it was designed, proposed, and implemented works! In addition, it fits all the requirements."

Electronic dissemination of course notes (still working on this).

Producing graduates who have a more integrated understanding of engineering.

Best Practices

Be prepared to work with people (specifically the administration) who may be resistant to change. Start early and look at the problem from their perspective first.

Purdue University

"Reforming Engineering Education: Multidisciplinary Engineering (MDE)"

October 1, 2004 to September 30, 2009

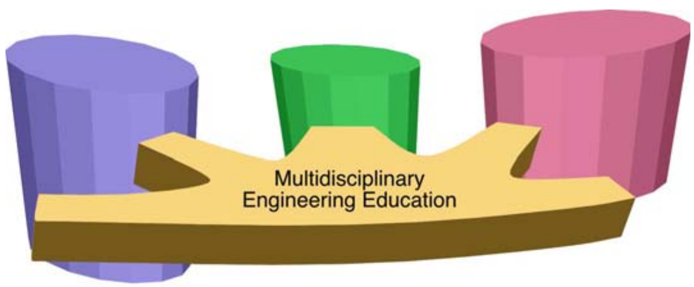
The DLR Project

Purdue did not have a planning grant but they had done much preparatory work for the planning and establishment of the Department Engineering Education (DEED) in Spring 2004. The DLR proposal was an outgrowth of extensive efforts by the School of Engineering to transform the Department of Freshman Engineering into a Department of Engineering Education. A task force of 20 faculty members from five engineering schools, science, agriculture, and education as well as industrial advisors met for 9 months and produced a white paper outlining the new Engineering Education Department. About half of the faculty in DEED is trained as engineers and half are trained as educators.

Curriculum Reform

The Multidisciplinary Engineering (MDE) program integrates science and engineering classes to focus on a topic. For example, physics, chemistry, and biology are synthesized into a photosynthesis class. This gives students a broader and deeper understanding to solve complex problems.

Purdue University's Approach to Department-level Reform,
Vertical silos with horizontal MDE



New technical areas: Biology and Nanotechnology are systematically introduced into the first year and senior courses through signature areas and center activities. The MDE program also includes a new computational methods class that exposes students to modern methods and tools used in workplace; for example, the use of the statistical software package, SAS, MathLAB, and other tools.

New engineering programs: Integration of five different engineering fields. Eight new signature areas introduced are advanced materials and manufacturing; global sustainable industrial systems; information communications, and perception technologies; intelligent infrastructure systems; nanotechnologies and nanophotonics; renewable energy and power systems; system of systems; and tissue and cellular engineering.

Teaching methods used

Implemented a new Multidisciplinary Engineering (MDE) program of study that expands student's disciplinary breadth and range of problem solving, integrates rather compartmentalizes research and teaching experiences, and builds interfaces between new and existing engineering and science programs.

Teaching methods incorporated into the MDE track include active collaboration, teaming, and service learning projects.

The use of teaming in the classroom and among faculty was pervasive. Faculty taught classes as a team, which required tremendous coordination and planning time. For example, the Integrated Science Course required the faculty to build on each other's work and to coordinate the delivery of lecture and hands-on projects.

Recruitment and retention of students:

Two members of the DLR team recruit for the Engineering School and describe the DLR MDE approach, highlighting the unique approach that the program follows.

The Multidisciplinary Engineering (MDE) track has 14 students (13 males, and 1 female; all Caucasians). Since it is a new program, the change in student composition cannot be measured. Three cohorts have started the MDE track.

Service Learning Projects

Service learning is an integral part of the Purdue culture. The focus is on ethics and community learning. There are 30 to 40 service learning projects on campus. The MDE curriculum developed as part of the DLR grant requires students to participate in service learning projects. It is the student responsibility to seek out projects and discuss with their advisor how they fit into their course of study.

Students receive credit for participating in the service learning projects and they are aligned with meeting the ABET requirements.

Learning about student learning

Team work among students and faculty is important and critical to increasing learning.

The team work among the faculty involved a true pedagogical change in how they teach classes

Accomplishments

Starting students to think in a multidisciplinary way starting freshman year is a success factor! Students learn how to interpret engineering and scientific concepts from multiple perspectives.

Industry is now requesting students who have participated in a multidisciplinary approach. "This is exciting! Purdue can now demonstrate to parents and students that industry wants students with a MDE background." (PI: Haghighi)

Best Practices

Use of active collaboration practices and hands on projects is imperative to more effective learning.

Rochester Institute of Technology: Microelectronic Engineering

"Leading Microelectronic Engineering Education to New Horizons"

September 1, 2005 through July 31, 2009

The DLR Project

The Microelectronic Engineering Department of the Kate Gleason College of Engineering department-level reform addresses the need for a highly educated, multidisciplinary workforce to ensure the future of US high tech industries that are on the verge of nanotechnology revolution. RIT was the first institution to offer a BS program in microelectronic engineering.

Curriculum Reform

The new Microelectronic Engineering (ME) program at RIT:

- Offers a Microelectronics and Nanofabrication minor for non-Microelectronic engineering science and engineering programs promoting access to state-of-the art semiconductor fabrication facilities to students from other programs;
- Develops a concentration program in nanotechnology and MEMS;
- Crafts a five course elective sequence within the existing ME curriculum by eliminating legacy material and course consolidation;
- Builds outreach programs for targeting larger and diverse participation, particularly from women and underrepresented minority students, in preparing the workforce for the nation's future high tech industry; and
- Enhances student learning through co-op employment and multidisciplinary projects that includes service-learning.

K-12 Forum on Microelectronics and Nanotechnology participants and faculty (left); participants experiencing laboratory in the RIT microelectronics cleanroom (right).

Teaching Methods

The philosophy of the department-level reform is to add new courses and teach nanotechnology using a bottom up approach based on hands on lab experiments. The DLR team developed new processes to expose students to nanotechnologies. They reached out to multidisciplinary teams of faculty and students from various disciplines such as mechanical, physics, chemistry and imagining sciences. Industry strongly supports the nanofabrication lab at RIT

Recruitment and Retention:

The Principal Investigator hired two personnel: an outreach specialist and a high school physics teacher part-time to access local teachers. They held a K-12 forum for 68 teachers (7th to 12th grade) giving them optics and electronic kits. This project is intended to demonstrate how to bring engineering into their classrooms. Microelectronic engineering students have provided hundreds of field trips for middle and high school students, but they have found that focusing on the teachers is more successful. All the students participate in this project as well. This has helped a lot with exposure.

Community college outreach focuses more on the students; recruiting them specifically to microelectronics.

Accomplishments

Added a Microelectronics and Nanofabrication minor to the curriculum.

Revised the curriculum to include a nanotechnology course and nanotechnology laboratory experiments.

Established an outreach office to undertake systematic program to recruit high school and community college students. Reached out to almost 70 teachers and students in the community

The Semiconductor Industry Association (SIA) invited the DLR Principal Investigator to participate in a public policy debate on Capital Hill about the importance of engineering education for the health of US. She was invited to present at the University Working Group of SIA at Capital Hill in January 2007 and 2008.

Best Practices Developed

Developing a vision and mission to describe goals so that faculty and student understand purpose of reforming the department.

University of South Florida: Chemical Engineering

"Transforming the Educational Experience of Transfer Students in Chemical Engineering using a Multi-Dimensional Spiral Curriculum"

September 1, 2005 through July 2009

The DLR Project

The objective of the University of South Florida DLR project is to transform the educational experience of undergraduate students (especially transfer students) in Chemical Engineering (ChME) by developing and implementing a multidimensional spiral curriculum. The central thesis is that an engineering curriculum needs to be more than an aggregate of individual courses but rather a coherent and continuous program of study that transforms a student into a professional capable of integrating core concepts in a specific discipline. They should be able to synthesize, analyze, and design a product or process that benefits society.

Curriculum Reform

New technologies in engineering were integrated into course content, using chemical systems drawn from new and emerging fields and by introducing fields earlier in the curriculum.

Multi-dimensional spiral curriculum model uses three interlocking spiral paths to deliver a student-centered curriculum that allows integration of core chemical engineering courses, incorporation of traditional and new technological applications, and threading of process and product design concepts over the complete curriculum.

Each part of the spiral curriculum involves a lead instructor, a supporting instructor, and two graduate students from the departments.

Students move from the conceptually simple steady state systems and equilibrium units to the more complex task of large-scale systems integration.

Teaching Methods

The DLR team is using strategies that promote an active learning atmosphere and utilize technology for more efficient delivery of the core concepts, virtual modules, team-oriented, hands-on exercises that reinforce the concepts being covered in class.

New learning about student learning

Learning depends on the attitude of the instructor and the student.

It is important to have a good relationship with the students and to be transparent about curriculum changes.

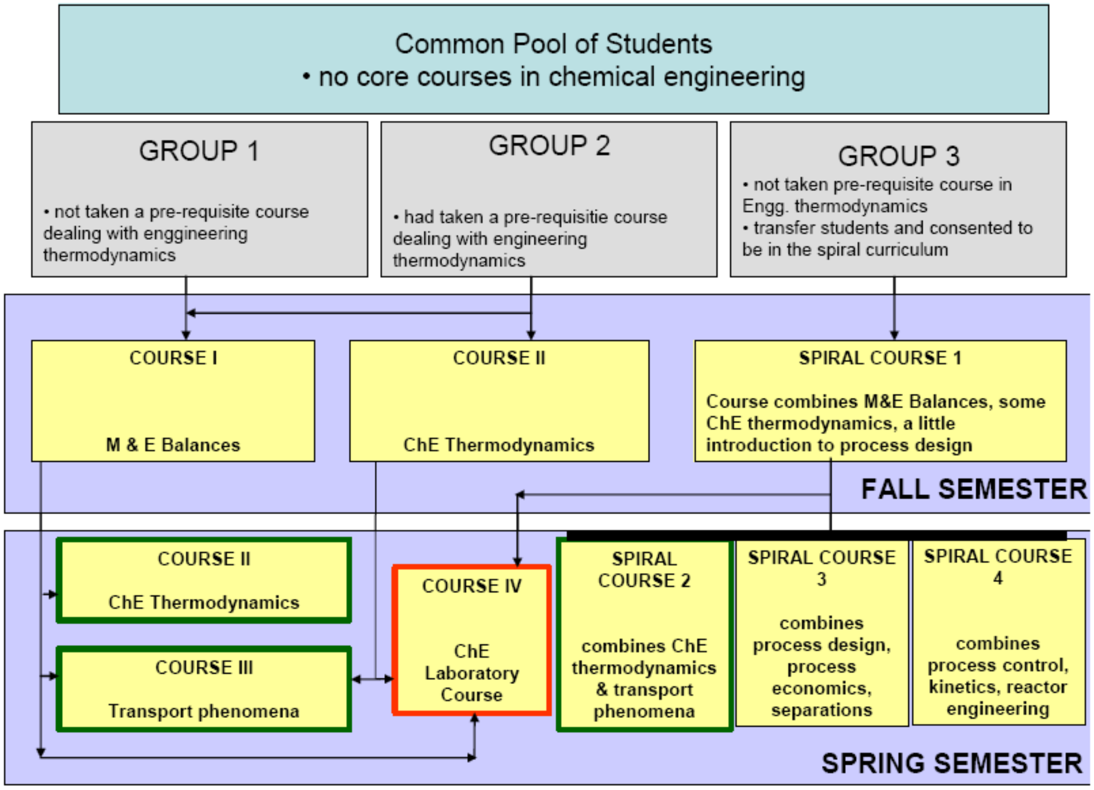


Figure 1: Schematic of student groups that took courses under the department level curriculum reform effort and the traditional sequential curriuculum. Performance of students in courses outlined by red and green borders were used for comparative assessment.

Accomplishments

The goal is to have transfer students graduate in 2 to 2-1/2 years. Early indications are that the department is succeeding in doing this.

On average, the students in the spiral curriculum performed better and got better jobs.

Transfer students are working together as teams. The bonding of these students is an important outcome.

Faculty is now open to new teaching methods and is sharing ideas and experiences with each other.

Best Practices Developed

Explaining the curriculum to students at the beginning of each semester and why changes are being made is important for buy-in.

Sweet Briar College: Engineering Science

"Reform of the Engineering Program at Sweet Briar College"

June 2004 through June 2007

The DLR Project

The Engineering Science Department's objective for its department level reform was to develop an extensive engineering curriculum at Sweet Briar College, which is the second such program in the nation at a liberal arts institution for women. Faculty from several departments including Physics, Chemistry, Mathematical Science, and Environmental Science worked to establish the Engineering Science and Engineering Management degree programs.

Curriculum Reform

The engineering curriculum consists of eight new courses and four physics and environmental studies courses upgraded to include more applied science and engineering components. The new engineering courses are Introduction to Engineering, Introduction to Engineering Design, Integrated Experience in Engineering, Continuum Mechanics, and Engineering Topics Course, Research in Engineering, and Design Capstone I & II. The upgraded courses are Electronics, Optics, Materials Science, and Environmental Technology. (See http://www.engineering.sbc.edu) Since June 2007 we have further revised our curriculum adding a technical emphasis in electromechanical systems.

Teaching Methods

The engineering program is primarily a mechanical engineering program (about 80%) with an electrical engineering component (20%). The program emphasizes:

- Small class sizes
- A hands-on approach to learning
- Focus on projects that directly benefit society
- Mandatory industrial internships – facilitated via connections with local companies.

Service Learning

There are two classes with a service-learning component. These classes are for credit and open to any upper-class student at Sweet Briar

One focused on an international design project where they designed a water supply system for a village in Guatemala. In spring 2007 about 11 students went to Guatemala to build the system.

The second course focuses on a regional engineering design project that is being developed for spring 2009.

Recruitment and Retention

The Engineering Science faculty visit Community Colleges across Virginia that have an Associate of Arts degree as outreach for the program.

They also developed engineering kits to use in outreach to high schools. Each kit allowed the student to make choices to design and construct a speaker for their IPOD. They also used the exercise as advertising by putting the Sweet Briar logo on the materials. This is a time intensive activity as the visits to high schools take a lot of time. During 2007-2008, Sweet Briar talked to over 400 high school students. Sweet Briar wants to change the approach so that high school students visit Sweet Briar to undertake a hands-on design project, visit labs, and talk to students.

The primary goal is to increase the number of women completing bachelor's degrees in engineering disciplines. Seventeen of the 210 students in the 2007-2008 incoming class indicated strong interest in engineering as a major. The target is to have five percent of the graduating class receive a major or minor in engineering by the fifth year of the program with a continuing effort to increase this percentage.

Accomplishments

The first class of 3 students will graduate in the Spring of 2009 with a Bachelors of Science (B.S.) in Engineering Science.

The DLR grant was important for convincing the Sweet Briar President and faculty to support the creation of the Engineering Science program.

Sweet Briar gave space and paid for infrastructure for the Engineering Science program. This includes Machine Shop, Materials Testing Lab with a Hardness Tester and Tensile Test machine, a Concrete Tester and Impact Tester, Heat Transfer lab with Air Flow Demonstration, Fluid Mechanics lab with a Wind Tunnel, Electrical Circuits lab, Design Studio, two offices, and two classroom

Best Practices

Obtaining cooperation from faculty takes a lot of work and time. Conducting one-on-one meetings to explain why creating a new department would not take away resources from the other departments was key.

It is important for the President of the school to be involved in the process as well as school's Board of Directors.

Texas A&M University: Chemical Engineering

“Chemical Engineering Undergraduate Curriculum Reform”

September 1, 2005 through September 1, 2009

The DLR Project

Three chemical engineering departments at Texas A&M University (TAMU, College Station), Prairie View Campus (PVAMU), and Kingsville Campus (TAMUK) are continuing their efforts to restructure their four-year undergraduate curricula to achieve four objectives. Students will be able to:

- Apply fundamental ideas in chemical engineering over a greatly expanded range of time and length scales;
- Apply Chemical Engineering (CHEN) fundamental ideas to emerging application areas;
- Construct solutions for more complex, more open-ended synthesis tasks; and
- Transfer fundamentals and knowledge to novel challenges.

Three major strategies for project implementation include (1) curriculum content reform and development; (2) student assessment activities, and (3) faculty development initiatives. The three strategies are being implemented through six key mechanisms:

- Identifying and organizing curriculum development activities around four course strings to improve integration of learning outcomes and activities;
- Developing interlinked curriculum components to organize and reinforce core ideas in chemical engineering curricula;
- Using service learning in required chemical engineering courses;
- Integrating assessment plans and processes throughout the chemical engineering curriculum;
- Offering faculty development activities to offer knowledge and development opportunities for chemical engineering faculty members;
- Implement dissemination to share our experiences with an audience beyond Texas A&M University.

Curriculum Reform

To restructure the curriculum, the DLR team examined changes in chemical engineering practice (e.g., product design, sustainability), chemical engineering education, unts are referred to as course strings. Course string faculty committees have assessed the content, unity, and coherence of four strings:

- Thermodynamics and Kinetics;
- Fundamentals and Applications;
- Unit Operations/Transport; and
- Systems Design.

As a result of course string faculty committees' working sessions, the department faculty had an opportunity to review the undergraduate curriculum in depth and to affect the following changes: construct integrated learning outcomes for the four course strings and for all CHEN courses; new assessment techniques; and course portfolios. Content changes are currently under discussion.

The department introduced an Interlinked Curriculum Components (ICC), which is a web-based learning site for students that addresses new technologies, non-traditional applications, and common foundations that span all courses. Students use the ICCs to review concepts and applications, to learn new applications, and to develop an appreciation and understanding of the common threads and methods of the various courses. The ICCs that are being developed address the following topics: conservation principles; materials; system synthesis and integration; microchemical systems; molecular modeling; and environment and sustainability.

ICCs reinforce extended conceptual framework, promote lifelong learning , and contribute to a diverse learning environment, and employ technology to enhance learning. For more information about ICC development, see http://che.tamu.edu/orgs/NSFCR/

The curricular plan focused on three categories: students, curriculum, and faculty.

Implementation Strategies	Implementation Activities	Assessment Methods	Assessment Metrics
1.1. Curriculum content reform and development	Course Strings ICCs Service learning projects Tracks Developing a curriculum map of the beginning curriculum to provide an overview of the entire curriculum	Faculty Course Evaluation Plant Design Final Project Evaluations ICC Pre- and post-tests ICC usability study: students ICC usability study: faculty Final project evaluation CASEE Exit Surveys Additional student survey Concept inventory to evaluate students' prior knowledge	Class achievement of course outcomes 3.0 "Adequate Ability" or better. 100 % of assessed students will be rated at 2 (meets expectations) and above on ability to apply students learning outcomes 1-7 80% of students taking the post-test will pass the first time Qualitative information from faculty and student survey 100% of developed ICCs will be adopted by TAMU'CHEN courses 100 % of assessed students will be rated at 2 (meets expectations) and above on ability to apply students learning outcomes 1-7 2 courses are planned to be taught # of students enrolled A new curriculum map reviewed and approved by faculty 85 % of students will indicate they have Good-Excellent ability to apply students learning outcomes 1-7

Implementation Strategies	Implementation Activities	Assessment Methods	Assessment Metrics
			50% of students will pass at the beginning of a course
1.2. Student development and assessment	Course Strings ICCs Tracks Service learning projects	Comprehensive assessment plan for undergraduate program evaluation Faculty Course Evaluation Plant Design Final Project Evaluations ICC Pre- and post-tests ICC usability study: students ICC usability study: faculty Final project evaluation CASEE Exit Surveys Additional student survey Concept inventory to evaluate students' prior knowledge	Class achievement of course outcomes 3.0 "Adequate Ability" or better. 100 % of assessed students will be rated at 2 (meets expectations) and above on ability to apply students learning outcomes 1-7 80% of students taking the post-test will pass the first time Qualitative information from faculty and student survey 100% of developed ICCs will be adopted by TAMU'CHEN courses 2 courses are planned to be taught # of students enrolled 100 % of assessed students will be rated at 2 (meets expectations) and above on ability to apply students learning outcomes 1-7 85 % of students will indicate they have Good-Excellent ability to apply students learning outcomes 1-7 50% of students will pass at the beginning of a course
1.3. Faculty development	Course Strings ICCs Tracks Publications Designing a new curriculum map Faculty development workshops	Faculty Course Evaluation Plant Design Final Project Evaluations ICC Pre- and post-tests ICC usability study: students ICC usability study: faculty Conference presentations and publications Concept inventory to evaluate students' prior knowledge	Overall class achievement of the course outcomes 3.5/5. 100 % of assessed students will be rated at 2 (meets expectations) and above on ability to apply students learning outcomes 1-7 80% of students taking the post-test will pass the first time Qualitative information from faculty and student survey 100% of developed ICCs will be adopted by TAMU'CHEN courses 2 courses are planned to be taught # of students enrolled A new curriculum map reviewed and approved by faculty Five faculty development workshops offered by the end of the project 50% of students will pass at the beginning of a course

Teaching Methods

Restructuring of the curriculum is based on principles from the science of learning. The goal is to enhance and enrich student experiences through experiential learning, problem based learning, inquiry guided learning, internship and co-op programs and service learning.

Concept mapping and inventories are developed and used to assess conceptual understanding of a specific subject.

Service Learning

To enrich student experiences, service learning has been implemented in the first CHEN sophomore-level course by a collaborative student and faculty effort. The projects were given several times to the introductory level material and energy balances classes during fall 2006, spring 2007, fall 2007, and fall 2008. Students have worked with Habitat for Humanity, and Department of Recycling and Public Works, College Station, TX. The projects are to design a “green” home focusing on conservation aspects such as energy, water and waste. The overall process included four major stages: formulation of the project, project promotion, designing and project completion, and project reflection. The fall 2008 class was assigned a more focused project to investigate the environmental impacts of compact fluorescence light bulbs and incandescent light bulbs through life cycle assessment for the City of College Station. At the end of the semester, students complete assessment instruments to evaluate achievement of project learning outcomes.

Recruitment and retention

Retention: 70% of freshman stay in Engineering. The College Station campus does not need to recruit as they have as many students as they can handle. The Prairie View campus is actively recruiting more students.

The Kingsville campus has a Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP) grant to recruit and retain engineering students.

New learning about student learning

Active and team learning are valuable components of a curriculum.

The Integrated Curriculum Components help students accept greater responsibility for enhancing their learning.

Accomplishments

The department-level reform has been very effective. Through the project, the entire department faculty has reviewed the four-year curriculum, developed a comprehensive assessment plan to understand the extent to which students are achieving the learning outcomes, developed web-based materials to support student learning of existing chemical engineering fundamentals as well as emerging topics, and worked on approaches such as course portfolios to provide better documentation of the curriculum.

The DLR grant has enhanced collaboration between faculty and graduate students, especially with respect to undergraduate education.

More students are motivated to go to graduate school.

Best practices

Engineering education has become a more formal research area in the Chemical Engineering department.

Comprehensive assessment plan has been recommended as a model for the entire college of engineering.

Producing and using department curriculum maps, course folders, and interlinked curriculum components has enhanced learning.

University of Utah: Electrical and Computer Engineering

"Integrated System-Level Design in Electrical Engineering"

September 1, 2004-September 1, 2008

The DLR project

The goal of the University of Utah's department-level reform is to transform the Electrical Engineering laboratory experiences into system-oriented design projects where each week's lab exercise is part of a functional final design. Electrical Engineering students typically receive an excellent education in how transistors, diodes, capacitors, transmission lines, Fourier transforms, amplifiers, filters, lasers, digital circuits, and op amps work. They do a lot of homework that includes design of these individual components, and they experiment with each one individually in a laboratory or two, and compare the measured responses with theory. As each concept is "passed off" on the midterm or final, the students often forget what they have learned. Only sporadically throughout the curriculum do students have the opportunity to put these disparate ideas together into a system level design and experiment with how each part impacts the design of the others and the system as a whole. Yet, when they reach the engineering workforce, this is exactly what they are expected to do. The DLR grant accelerated the adoption of the system-level design curriculum to improve student understanding, motivation, and capability.

Curriculum

The goal the department-level reform is to incorporate system-level design and understanding at all levels of the curriculum. This involves:

- Integrating individual topics into system-level design experiences through lab projects and teaming on projects.
- Enhancing the junior-level design experience with formal training in project management.
- Integrating entrepreneurship and systems design. (This is an interdisciplinary initiative between the Colleges of Business and Engineering spearheaded by ECE as a result of the NSF Planning Grant.)
- Encouraging professors to emphasize system design throughout their normal teaching.

Teaching methods

The teaching goal for department-level reform is to enhance the quality of teaching and the student learning environment through seminars, discussions, and shared experience for professors on:

- Team learning and learning by teaching;
- Understanding learning styles and how to teach for everyone;
- Mentoring and encouraging minority and women students;
- Enhancing hands-on laboratory experiences at all levels;

- Implementing improved assessment methods, alternative and novel assessment methods, methods for assessing students, projects, and curriculum.

The DLR team worked with the College of Engineering Center for Engineering Leadership to formally teach and improve written and oral communication skills and team work throughout the curriculum. Each year, two Ph.D. students from the Department of Communications work directly with ECE students to improve lab and final reports and formal and informal presentations. This fits in with the project-oriented enhancements to the curriculum, and may be a catalyst for learning that helps students better understand the systems themselves.

Communication is an essential component of engineering education. Integrating communication within engineering classes helps students use writing to learn engineering. This "write-to-learn" concept enables a more in-depth understanding of engineering concepts whilst simultaneously improving students' writing skills. Included are the resources available to students, assessment methods and the results obtained. Through the use of a writing lab, a grading rubric, and a writing teaching assistant (TA) with engineering background, students' average grades on lab reports were significantly higher than in previous years and improved by 2% over the course of the semester.[26]

Service Learning

The Engineering LEAP (E-LEAP) courses emphasizes team learning, written and oral communication, societal impacts and opportunities for engineering, creative design, and problem solving skills. The students in these courses volunteer time as science teachers and mentors for K-12 students in disadvantaged city schools, which provides a positive service learning opportunity.[27] The motto for the E-LEAP course is "Make a successful LEAP from high school to college. Find your place at the University." E-LEAP is a 2-course series that serves as the humanities and social sciences general education for ECE students.

Other aspects of this grant that are still in the planning stage are a collaboration with the College of Fine Arts to create a project-oriented Technology-Enabled Art course. Students would create a moving/flashing/communicating art project that could be displayed in a public place as sort of an "electronic ambassador" for the University of Utah. They are also anticipating establishing a Service Learning course where students could design projects to help disadvantaged, handicapped, elderly, or other segments of our community that could benefit from engineering projects.

New learning about student learning

Students will engage once the faculty is engaged. (Faculty are so busy that money for teaching release is critical. The DLR is essential for this.)

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[26] Improving Communication Skills Using Project-Based Write-to-Learn Approach, Alyssa Magleby, Cynthia, Draft. Paper being prepared for IEEE Trans Education. Work presented at ASEE 2008. http://www.ece.utah.edu/facilities/ugradlabs.html

[27] http://www.ece.utah.edu/upgrm/BSEE%20Handbook/eleap%20info%20sheet.pdf

Students must have good writing skills to document and describe their labs. Therefore it is important to spend time teaching students to write.

Accomplishments

The department-level reform had a significant impact on the educational infrastructure at the University of Utah. As a result of this grant, the Vice-President for Education has committed funds for a permanent lab design engineer position, a position that is already having a large impact on the resources available for laboratory support in the department. Multiple new laboratory projects are already implemented as a result of this resource.

The ECE department teamed with the 'CLEAR' Program[28] for improving the writing and speaking skills of the ECE students. Two full-time graduate TAs from the department of communication, and access to communication-related facilities (video lab, etc.) are enhancing their ability to improve student writing. (The CLEAR Program focuses on communication, leadership, ethics, and research in the College of Engineering. The program has two goals. The first is to focus on research and faculty development. The second is to focus on the improving the communication and leadership skills of students.)

The department received support from the college of business for a business and engineering course that is now in its second semester. This includes full time TAs who are professional MBA students and biweekly lectures by business professors.

Best Practices

Education efforts are undertaken by people who are excited by what they teach. The DLR grant got all faculty involved. When only one faculty or a few faculty are involved, there is not as much support within the department. Because everyone was involved, it was easier to get support from administration (policy, tenure evaluation, and funds for lab equipment, etc.)

Because the whole department was involved, ATTITUDE was a major factor. The DLR project was a major contributor to improved collegiality, and most faculty pursued related methods as well as undergraduate research, collaborative research, and outreach. There were, therefore, many changes implemented at the same time.

The PI hired an ECE graduate who is working on an MBA to market and advertise the newly reformed ECE program. Many of the faculty have taken an interest in mentoring younger faculty in both research and teaching, so this attitude may continue to propagate within the department and trickling into the college. A few modules have transitioned to other schools. For example, one lab has been commercialized in Korea.

[28] http://www.ece.utah.edu/~cfurse/CLEAR/writing/index.htm

University of Vermont: Civil Engineering

"A Systems Approach to Civil and Environmental Engineering Education: Integrating Systems Thinking, Inquiry-Based Learning and Catamount Community Service-Learning Projects"

October 1, 2005 through September 30, 2009

The DLR Project

The goal of the University of Vermont's DLR project is to implement an educational framework that shifts from addressing problems in isolation to one that adopts a systems approach cutting across traditional disciplinary lines and fostering an integrated systems approach to both the problem definition and problem solution.

The fundamental goal for the curriculum reform is to incorporate Systems Thinking into the curricula. "Engineers need to understand the interrelationship between engineered solutions and the environmental, social, economic and other components in which they are placed. Furthermore, engineers must consider these non-technical components during the problem definition stage, with the design process, and then in the final solution. The crux of this matter, however is how to teach this to students."

Curriculum Reform

The department-level reform focused on:

- Reformulating and repackaging existing courses in Environmental Engineering, Transportation, and Engineering Economics into a unique sequence of three interrelated Systems courses (Environmental and Transportation Systems, Decision Making in the Environment and Transportation, Modeling Environmental and Transportation Systems). These courses combine systems thinking and systems analysis for understanding and developing solution for civil and environmental problems.
- Incorporating service-learning projects into required course in each year of the programs as a way of practicing the systems approach as well as gaining other technical and nontechnical skills. Service-learning also helps to motivate students since they know the work they do is useful to others.
- Infusing inquiry-based learning into core laboratory courses.
- Retraining the faculty in areas of systems, teaching, and learning, teamwork, and other personal/interpersonal skills and service learning.

Teaching Methods

Service-learning in required engineering courses including first year introductory course and senior capstone course as well as others. Faculty trained in service-learning through university-wide workshops and seminars. Critical reflection exercises to enhance experience and learning.

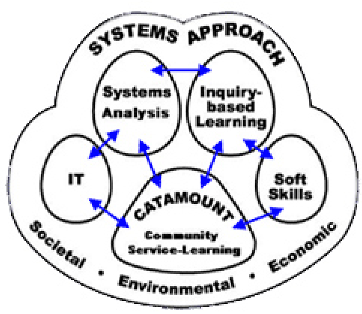
Co-teaching in systems courses initially to develop a more integrated approach to teaching systems.

Inquiry-based learning integrated into two junior-level laboratory courses (geotechnical engineering, a requirement for civil engineering and environmental engineering students) and an environmental lab course required of environmental engineering students). These included open-ended experimental exercises that involve designing, conducting, and analyzing experiments as well as writing a research paper in a paper template.

Use of Bloom's Taxonomy to develop and evaluate exam, homework, lab, and project exercises.

University of Vermont Students in lab

University of Vermont Systems Approach



University of Vermont Students do field work as part of a service-learning project

Recruitment and Retention

Hands on introductory engineering course in first semester of program helps retain students including diverse students.

Brochures and website used in recruitment efforts.

Undergraduate summer research program for civil and environmental students funded through a private donor and individual faculty research grants used to recruit students into the programs.

Service Learning Projects (SLPs)

One of the highlights of the curricular reform is the implementation of service learning projects into required courses (one per year). In the senior year, the capstone design course is entirely the service-learning project.

SLPs are a critical part of courses, ranging from 20% in the Introductory course to 100% in the Senior Capstone Design class.

One of the main reasons for SLPs is to practice the systems approach. The engineering service-learning projects contain multiple constraints (economic, political, environmental, technical) with multiple feasible solutions. For example: A community has a water drainage problem and needs technical support with a limited budget. The students learn about politics (part of the community does not want to fix the water problem), social (understanding who benefits and who does not), regulations (obtaining permits), and historical preservation. In addition SLPs encourage students to think about service to their communities and the civil or environmental engineer's role and responsibility in affecting society. They also learn about working in teams to solve a problem and other interpersonal skills. Structured critical reflection is also a key component of the service-learning.

Convincing other faculty and students of the benefits of service-learning has sometimes been difficult for the DLR team.

New learning about student learning

Engineering students liked hands on learning experiences. They also liked learning about the different kinds of learners and how they learned best.

"You cannot really change people but you can enhance their learning. You cannot get a student who is uninterested in engineering to become interested; but you can help students who are interested in engineering to learn in a more integrated, interesting and hands-on way."

Accomplishments

Developing and implementing the three Systems classes into the curriculum. There are still things to work out but the concepts and sequences are in place. The bulk of the work is done.

Integrating the service learning into the engineering curricula.

DLR grant has led to more interaction with DLR faculty leading to work and research on other projects.

Networking with local communities and community partners has been stronger leading to additional opportunities for students and faculty.

Getting the faculty to think more about a student's educational experience and to work together to design and teach classes. "Creating the whole educational experience for students, faculty, and the community. This is a huge accomplishment!"

Virginia Tech: General Engineering and Biological Systems Engineering

"Reformulating General Engineering and Biological Systems Engineering (BSE) Programs at Virginia Tech"

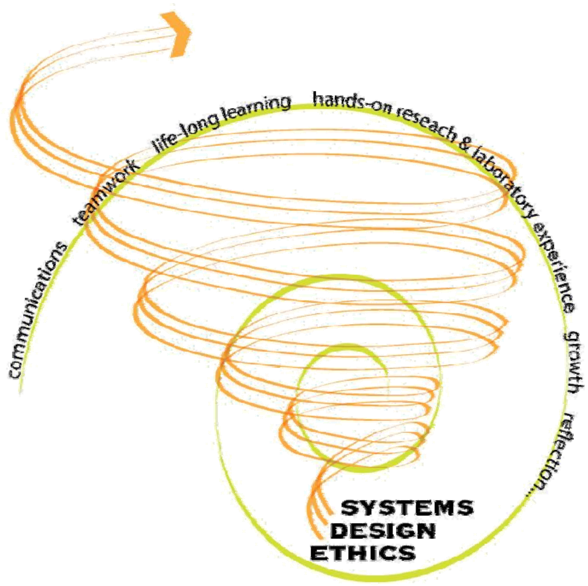
September 15, 2004 through August 21, 2009

The DLR Project

Virginia Tech is the 6th largest engineering college in the United States. Until April 2004, there was a Division of Engineering Fundamentals (EF) within the engineering college, which primarily focused on activities related to teaching and advising engineering freshmen. In May 2004, the EF was transformed to an Engineering Education Department (EngE), which is now responsible for the freshman curriculum (also called General Engineering), engineering education research, and a PhD program in engineering education. The DLR grant was the first major curriculum reform and engineering education research grant in EngE and BSE. The DLR investigators (i.e., faculty members primarily from EngE, BSE, and School of Education) adopted a spiral curriculum approach to reformulate curricula in general engineering and bioprocess engineering (within BSE) programs. The DLR project was the catalyst that allowed EngE and BSE departments to work together to rethink the content, sequencing, and support provided to engineering students as they negotiate the four-year curriculum beginning in Engineering Education (year 1) and continuing in Biological Systems Engineering (years 2-4). This work was guided by the *spiral curriculum* concept that recognizes the inherently recursive nature of learning. The main features of the spiral model are as follows:

- Students first encounter fundamental concepts of the target discipline through active engagement suitable for entry-level learners.
- In Virginia Tech's DLR project this early engagement was accomplished at the freshman level through action projects in the EngE department, and again at the sophomore level as students began their specialization in BSE.
- At each <u>next</u> level in the curriculum students engage the *same concepts*, but with increasing inclusiveness, sophistication, and generalization. During this recursive process students elaborate and strengthen earlier learning, correct misconceptions, develop a more holistic picture of their discipline, and become increasingly self-sufficient as learners.
- In terms of cognitive outcomes the aim is for students to become more *efficient* in knowledge representation, and more *powerful* in knowledge utilization and transfer. Efficiency (i.e., more knowledge in the same "space") is gained as cognitive representations move from being tied to concrete examples to abstract formulations supported by mathematics and theory. Power is gained as abstract generalizations can be used to actually generate new knowledge that does not have to be directly taught.

The spiral curriculum adopted the supporting principles of design, ethics, and systems approach and cross cutting skills of communication, teamwork, life-long learning, research experience, and laboratory experience are woven throughout the curricula.



Curriculum Reform

Faculty in EngE and BSE departments worked together to reform the curriculum by taking a number of important design steps.

- In BSE a critical initial step was to create a new map of the curriculum. Through collaborative analysis four curriculum domains were identified as central to the education of a bioprocess engineer—designing a process, designing a reactor, controlling the process, and designing a plant scaled for production.
- Each domain was subjected to further analysis, resulting in a complete map of the content and process requirements and expectations in that domain.
- Content maps were then utilized to design the spiral trajectory, that is, how students would need to engage topics with increasing sophistication.
- Finally, activity structures such as projects, simulations, lectures, and labs were designed to work together to support student exploration at levels suitable to their growing expertise and awareness of themselves as engineers.

One of the first modules (group of activity structures) that was developed concerned teaching students about systems. The module includes a number of activities: lectures, readings, in-class activities, labs, and defining what systems mean, for example, a hydrologic system, system for extracting oil, etc. BSE faculty integrated this module into the existing Introduction to BSE course (BSE 2105) taught at the sophomore level.

One theme that has been developed through the curriculum is ethics. Ethics modules have been developed and integrated into existing courses at the freshman (ENGE 1024), sophomore (BSE 2105-2106), and senior (BSE 4604 Food Process Engineering) levels. (See http://www.dlr.enge.vt.edu/index.php?p=project_improving_ethics_studies)

Graduate students are involved in developing learning modules. A graduate student introduced instrumentation into the sophomore BSE class. Now he and others are developing instrumentation modules into junior and senior classes.

In freshman year, students take math, English, science, and 2 engineering courses (one per semester). The first engineering course (i.e., Engineering Exploration EngE1024) now integrates a 5-8 week design project that focuses on energy sustainability with BSE subthemes. In addition, a number of hands-on learning modules (i.e., mechatronics, world map activity, LabVIEW programming and Data Acquisition, Systems, Ethics, etc.) have been implemented in EngE1024 to enhance students' learning experiences in their first engineering course.

Historically, the freshman program was isolated from the rest of the engineering programs. The DLR team modified the required Engineering Exploration class that incorporates the new concepts of spiral curriculum, systems module, team work and communication activities, and early design experiences. Assessment of students' learning experiences is conducted using online surveys, pre-and post-tests, and focus groups. In addition, the DLR project facilitated in obtaining another NSF grant under nanotechnology in undergraduate education (NUE) in engineering that introduced nanotechnology concepts in freshman year. Thus, the DLR has benefited all 1300+ engineering students by introducing the new approaches in their first year.

Teaching Methods

The theme based spiral curriculum approach teaches a student to think broadly and introduces a systems approach to problem-solving by allowing one to back off the detail and take a broader perspective. With this wider look it is often possible to see interconnections and effects that can be tested and tried so that detailed attention can be focused on what matters most to the system.

Encourage students to work on teams on various open-ended projects. This could help develop inter-personal skills and problem-solving ability in students.

In Fall 2006, Tablet PC based instruction was introduced in freshman engineering program. In Fall 2007, a Tablet friendly software (i.e., DyKnow) was implemented in freshman engineering to enhance classroom interaction. These technologies allow instructors to collect students' feedback including engineering sketches in class instantly to assess their "prior knowledge." For example, the professor will ask students to draw on their Tablets sketches that show all forces that act on a plane as it flies. The professor can then collect all sketches anonymously from all students using Tablet/DyKnow capabilities and select a few students' sketches to teach the involved concepts. The Tablet PC/ DyKnow technologies have also been combined with Skype and Webcam technologies to teach from a distance. Use of Tablet PCs and DyKnow technologies is growing beyond freshman engineering for enhancing learning experiences of students. The assessment activities developed under DLR project are being used to assess effectiveness of TabletPC/DyKnow based instruction.

Recruitment and Retention

The DLR team worked through existing channels to recruit high school students. They highlight the changes that have resulted from the DLR project as a selling point for the engineering school.

Some team members participated in recruitment fairs, study abroad fairs, open houses, and articulation meetings with community college faculty at VA Tech.

New learning about student learning

Team work: Students like and learn more from working on projects and problems as a team.

Start design projects in freshman year.

Obtain students' feedback on a regular basis and use feedback for designing next semester courses.

Obtain in-class feedback using the Tablet pc and DyKnow technologies and use this to develop a "feedback loop" in class.

Graduate and undergraduate students developed learning modules, software, exercises, and labs. Learning increased by having students involved in preparation of teaching materials.

Introduce students to "study abroad" opportunities from the freshman year for effective recruitment.

Accomplishments

The department-level reform pushed faculty to adopt student-centric methods, including teaming, interactive learning, and integrating lectures with team-based hands on exercises by encouraging risk taking in teaching. Faculty became increasingly comfortable with taking risks. The reform efforts also increased the dialogue among engineering and education faculty. The department-level reform provided context and focus and brought faculty together. The Freshman Engineering program is better integrated with the curricula of engineering departments.

The faculty have a new found appreciation for collaborating with other disciplines, primarily education, but also computer science, business, and other liberal arts (relates back to increased dialogue)

A number of graduate and undergraduate students have been / are being provided with training and development opportunities as various objectives of the project are being implemented.

DLR project activities are supporting two PhD level research projects in the Department of Engineering Education.

Acknowledgement of reform efforts through awards, including Best student paper award at 2007 ASEE Annual Conference, Exemplary Department Award to Engineering Education Department in 2006, Faculty Fellow Award to PI, and Assessment Poster Award

Best Practices

Relate technical objectives to professional skills, including ethics.

Appendix E: Publications, Conferences, and Workshops

Table E-1: Count of Publications, Conference Presentations, and Workshops

University	Publications	Conference Presentations	Workshops
California Polytechnic	6	1	4
Central Florida	5	3	2
City College of New York	0	3	0
Columbia	6	11	0
Duke	1	5	0
Johns Hopkins University	4	10	9
Lehigh[1]	0	4	0
Massachusetts Lowell	15	27	0
North Texas	0	5	4
Oklahoma State	3	6	0
Old Dominion	11	6	2
Pittsburgh	2	0	0
Purdue	0	3	0
Rochester Institute of Technology	3	6	0
South Florida	12	2	0
Sweet Briar College	2	3	0
Texas A&M	6	6	7
Utah	11	1	0
Vermont	6	9	4
Virginia Tech	28	20	4
TOTALS	121	131	36

[1] Estimated based on discussion with PI.

Publications include journal publications, book chapters, and conference proceedings. Presentations include conference presentations and posters. Workshops are generally held at the school for faculty.

California Polytechnic Institute

http://www.mate.calpoly.edu/quest/triad.php

Journals/books

Vanasupa, L., J. Stolk, T. Harding, and R. Savage, "A Systemic Model of Development: Strategically Enhancing Students' Cognitive, Psychomotor, Affective and Social Development," submitted to J. Eng. Educ. in February 2007, accepted at the First International Conference on Research in Engineering Education, and pending resubmission to J. Eng. Educ. in July 2007.

Savage,R., K.C. Chen, L. Vanasupa, "Integrating Project-based Learning Throughout the Undergraduate Engineering Curriculum," submitted to the J. STEM Education, October 2006.

Chen, K. , B. London, "Work in Progress – Crossing the Engineering Border into Art and Society with a Materials Selection for the Life Cycle course," Proc. Frontiers in Education, October 28-31, 2006; San Diego, CA.

Harding, T., L. Vanasupa, R. Savage and J. Stolk, "Work-in-Progress - Self-Directed Learning and Motivation in a Project-based Learning Environment," Proc. Frontiers in Education, October 10-13, 2007.

Vanasupa, L. Slivovsky, and K. Chen, "Global challenges as inspiration: A classroom strategy to foster social responsibility," Science and Engineering Ethics, Volume 12, Issue 2, 2006

Vanasupa, L., K. Chen, and F. Splitt, "Cultivating Sustainable Thinking in Engineering Students: Effective methods to inspire sustainable engineering solutions," Submitted to the International Journal of Engineering Education Special Issue on Sustainability in Engineering on 6/22/05

Conference Presentations

Savage, R., J. Stolk, L. Vanasupa, "Collaborative design of project-based learning courses: How to implement a mode of learning that effectively builds skills for the global engineer," Proc. American Society of Engineering Educators Annual Conference, June 24-27, 2007; Honolulu, HI.

Workshops

Four college-wide "micro-workshops" (for busy people) on scholarship in engineering education. These workshops (summaries available at http://edge.calpoly.edu/news.html) were geared toward the novice and designed to be an entry point for those who are not currently engaged in the scholarship of engineering education or engineering education research.

These workshops were attended by 40% of Cal Poly's tenure track faculty (20/50), a handful of the tenured faculty (6/83) and three individuals outside the college of engineering. Building on the findings from the fall research, one subtle purpose of the workshops is to engage participants' intrinsic motivation and identified regulation in order to fuel their internal drive for learning and implementing new methods of teaching.

http://www.mate.calpoly.edu/quest/triad.php

Description: This site describes the NSF work and makes available a number of documents related to the work.

Another website that the DLR team developed (and has some overlap) is www.csine.calpoly.edu.

The CSinE website (Center for Sustainability in Engineering) was developed in coordination with two co-directors. This site is meant for a wider audience. NSF is not acknowledged on the CSinE website.

http://edge.calpoly.edu

Description: This site is geared toward a faculty audience. It tracks the development of our research methodology and findings. It also makes available presentations and other information helpful to those who are beginning work on research in engineering education.

http://www.nclt.us/conferencing_archive2005.htm

Description: Invited by the National Center for Learning and Teaching Nanoscale Science and Engineering to broadcast our course design (Nanotechnology, Biology, Ethics and Society) on their web-based seminar series. The archive of the broadcast can be found under the "Education" section, entitled "Team-based learning in a nanotechnology course: Enhancing critical thinking through course structure."

University of Central Florida

Journal Articles

Eskandari, H., Sala-Diakanda, S., Furterer, S., Rabelo, L., Crumpton-Young, L. and Williams, K., 'Determining the desired education characteristics and emerging topics needed in the IE curriculum to better prepare future undergraduates: A National Delphi Study,' Journal of Education + Training, Emerald Journal, Year: 2007 Volume: 49 Issue: 1 pp. 45 - 55.

Furterer, Crumpton-Young, Rabelo, Williams, Alexander-Snow, "ReEngineering the Undergraduate Industrial Engineering Curriculum to better prepare future graduates," American Society of Engineering Education, p. , vol. , ( ). Final Editing (in progress),

Eskandari, Furterer, Rabelo, Crumpton-Young, Williams, "Enhancing Undergraduate Industrial Engineering Curriculum: A National Delphi Study," Journal of Education and Training. Final Editing (In progress),

Conference Proceedings

Furterer, Sandra, Sharawi, Abeer, Crumpton-Young, Lesia L., Rabelo, Luis, Williams, Kent, and St. John, H. Gregg (2007), "A Departmental Reform Strategy and the Resultant National Model for an Undergraduate Industrial Engineering Curriculum." Hundred and Fourteenth Annual American Society for Engineering Education Conference, Honolulu, Hawaii.

Ferreras, Ana, Crumpton-Young, Lesia L., Furterer, Sandra, Rabelo, Luis, and Williams, Kent (2006) "Developing a Curriculum that Teaches Engineering Leadership & Management Principles to High Performing Students." Thirty Sixth Frontiers in Education Conference, San Diego, California.

Conference Presentations

Furterer, Sandra, Sharawi, Abeer, Crumpton-Young, Lesia L., Rabelo, Luis, Williams, Kent, and St. John, H. Gregg (2007) A Departmental Reform Strategy and the Resultant National Model for an Undergraduate Industrial Engineering Curriculum. Hundred and Fourteenth Annual American Society for Engineering Education Conference, Honolulu, Hawaii.

Furterer, Sandra, Sharawi, Abeer, Rabelo, Luis, Crumpton-Young, Lesia L., Williams, Kent, and St. John, Gregg (2007) National Model for an Industrial Engineering Undergraduate Curriculum. Sixteenth Annual Institute of Industrial Engineering Research Conference, Nashville, Tennessee.

Ferreras, Ana, Crumpton-Young, Lesia L., Furterer, Sandra, Rabelo, Luis, and Williams, Kent (2006) Developing a Curriculum that Teaches Engineering Leadership & Management Principles to High Performing Students. Thirty Sixth Frontiers in Education Conference, San Diego, California. City College of New York

Workshop

Held retreats and seminars for faculty on curriculum changes.

City College of New York

http://www-me.engr.ccny.cuny.edu/cur-reform/index.html

Conference Presentations

I. Voiculescu and B.M. Liaw, "A Novel Labwork Approach for Teaching a Mechatronics Course," (2007). Conference Paper, Published Collection: ASEE Proceedings Bibliography: ASEE Proceedings

B.M. Liaw and I. Voiculescu, "An Integral Analytical-Numerical-Experimental Pedagogy for a System Dynamics and Control Course," (2007). Conference Paper, Published Collection: ASEE Proceedings

H. Yu and F. Delale, “Introduction of Emerging Technologies in Mechanics of Materials,” (2007). Conference Paper, Published Collection: ASEE Proceedings Bibliography: ASEE Proceedings

Columbia University

www.columbia.edu/cu/earth/studio

Publications

McGourty, J., Sebastian, C., and Swart, W. (1998). “Development of a comprehensive assessment program in engineering education.” Journal of Engineering Education, Vol. 87, No. 4. 355-361

McGourty, J, Shuman, L., Besterfield-Sacre, M., Wolfe, H., C.J. Atman, J. McGourty, R. Miller, B. Olds, and G. Rogers. (2002). Preparing for ABET 2000: Research-based assessment methods and processes. International Journal of Engineering Education . Vol. 18 (2).

McGourty, J. (2000). Assessing and enhancing student learning through multi-source feedback. IEEE Transactions in Education, Special Issue on Assessment.

McGourty, J. and DeMeuse, K. (2000). The Team Developer: An Assessment and Skill Building Program. New York: J. Wiley and Company.

McGourty, J. (1999). Four integrated strategies to embed assessment into the engineering educational environment. Journal of Engineering Education, 88, 391-296.

U. Lall, M.J. Castaldi, P.J. Culligan, G. Gong, K.S. Lackner, J., McGourty, N.J. Themelis, T.M. Yegulalp, (2005)”An Environmental engineering undergraduate curriculum for the 21st century.

Plunz, R.A and P.J. Culligan, (2007) “Eco-Gowanus: Urban Remediation by Design,” MSAUD New Urbanisms 8, Columbia GSAPP Architectural Press, 160 pages.ISBN 978-1-883584-46-7

Presentations

Sacre, M., Lovell, M., McGourty, J., Shuman, L., & Wolfe, H. (2002). An interdisciplinary certificate in product realization: Meeting the challenges of industry and engineering criteria. Published in Proceedings of 2002 Frontiers in Education Conference, Boston, MA.

McGourty, J., Scoles, K., & Thorpe, S. (2002). Web-based course evaluation: Comparing the experience at two universities. Published in Proceedings of 2002 Frontiers in Education Conference, Boston, MA.

McGourty, J. (2002). Web-based course evaluation: A whole new look. Published in the American Society for Engineering Education Conference Proceedings, Montreal, CA

McGourty, J., Shuman, L., Besterfield-sacre, M., Wolfe, H., Olds, B., and Miller, R. (2001). Using technology to enhance assessment in engineering education. Published in Proceedings, 2001 Frontiers in Education Conference, Reno, NV.

Fromm, E., and McGourty, J. (2001). Measuring culture change in engineering education. Published in the American Society for Engineering Education Conference Proceedings, Albuquerque, NM

McGourty, J. Besterfield-Sacre, M., Shuman, L., and Wolfe, H. (1999). Improving academic programs by capitalizing on alumni's perceptions and experiences. Published in proceedings, 1999 Frontiers in Education Conference, San Juan, PR

McMartin, F. and McGourty, J. (1999). Involving industry in the assessment process: Preliminary findings. Published in proceedings, 1999 Frontiers in Education Conference, San Juan, PR

McGourty, J., Besterfield-Sacre, M., & Shuman, L. (1999). ABET's eleven student learning outcomes (a-k): Have we considered the implications. Published in the American Society for Engineering Education Conference Proceedings, Charlotte, NC.

McGourty, J. & DeMeuse, K.P. (1999). Integrating instructional technology into the k-12 classroom. Paper presented in the 14th Annual Conference of the Society for Industrial and Organizational Psychology, Atlanta, GA.

McGourty, J. (1998). "Four strategies towards effective assessment and continuous improvement in the educational environment." Proceedings, 1998 Frontiers in Education Conference, Tempe, AZ.

McGourty, J., Dominick, P., and Reilly, R. (1998). Incorporating student peer review and feedback into the assessment process. Published in the Frontiers in Education 1998 Proceedings. Proceedings of the ASEE New England Section Conference: The Value of Engineering Education and Practice in the 21st Century, Fairfield, CT April 8-9, 2005. Bibliography: Pages in proceedings.

Duke University

Journals

Huettel, L.G., Brown, A.S., Coonley, K.D., Gustafson, M.R., Kim, J., Ybarra, G.A., and Collins, L.M. (2007). Fundamentals of ECE: A Rigorous, Integrated Introduction to Electrical and Computer Engineering. /IEEE Trans. Education, 50(3), 174-181.

Conference presentations

Huettel, L.G, Coonley, K.D., Gustafson, M.R., Kim, J., Ybarra, G.A., and Collins, L.M. (2007, June). Experiment, Explore, Design: A Sensor-based Introductory ECE Laboratory. 2007 Annual Conference of the American Society of Engineering Education.

Huettel, L.G., Brown, A.S., Collins, L.M., Coonley, K.D., Gustafson, M.R., Kim, J., and Ybarra, G.A. (2006, June). A Novel Introductory Course for Teaching the Fundamentals of Electrical and Computer Engineering. 2006 Annual Conference of the American Society of Engineering Education.

Collins, L.M., Brown, A.S., Board, J.A., Coonley, K.D., Cummer, S.A., Gustafson, M.R., Huettel, L.G., Massoud, H.Z., and Ybarra, G.A. (2006, June). Redesign of the ECE Core Curriculum at Duke University. 2006 Annual Conference of the American Society of Engineering Education.

Collins, L.M., Huettel, L.G., Brown, A.S., Ybarra, G.A., Holmes, J.S., Board, J.A., Cummer, S.A., Gustafson, M.R., Kim, J., Massoud, H.Z. (2005, June). Theme-Based Redesign of the Duke University ECE Curriculum: The First Steps. 2005 Annual Conference of the American Society of Engineering Education.

Huettel, L.G., Brown, A., Gustafson, M.R., Massoud, H., Ybarra, G., and Collins, L.M. (2004, October). Work In Progress: Theme-based Redesign of an Electrical and Computer Engineering Curriculum. 2004 Frontiers in Education Conference.

Johns Hopkins Univeristy: Mechanical Engineering

Journals/books

Lucena, J.C. (2005). *Defending the Nation: US Policymaking to Create Scientists and Engineers from Sputnik to the "War Against Terrorism"* (conclusion). University Press of America.

Busch-Vishniac, I. J. and Jarosz, J. P. (2006). "Can Diversity in the Undergraduate Engineering Population Be Enhanced Through Curricular Change," *Journal of Women and Minorities in Science and Engineering,* 10:255.

Jarosz, J.P. and Busch-Vishniac, I.J. (2006). "A Topical Analysis of Mechanical Engineering Curricula," *Journal of Engineering Education*, 95:241. Also featured on the web portal *Annals of Research on Engineering Education*, 2(3), http://www.areeonline.org.

Busch-Vishniac, I. J. and Jarosz, J. P. (2007). "Achieving greater diversity through curricular change," in *Women and Minorities in Science, Technology, Engineering and Mathematics: Opening the Pipeline*, M. Mattis and R. Burke, eds. Edward Elgar Publishing.

Conference Presentations

Busch-Vishniac, I.J. (Mar 2003). "Diversity: Are we making progress?," *in* ASEE Engineering Deans Institute, Newport Beach, CA.

Jarosz, J.P. and Busch-Vishniac, I.J. (Jun 2003). "Deconstructing engineering education programs to foster diversity," *in* ASEE Annual Conference, Nashville, TN.

Busch-Vishniac, I.J. (Jun 2003). “Toward more diversity in engineering faculty,” *keynote address*, Women in Engineering Program Advocates Network Meeting, Chicago, IL.

Busch-Vishniac, I.J. (Jul 2003). “Accountability in higher education: Framing the debate on the Higher Education Authorization Act,” *in* General Electric Foundation Meeting, Math Excellence Program, Atlanta.

Busch-Vishniac, I.J. (Sep 2003). “Accountability in higher education: Framing the debate on the Higher Education Authorization Act,” *in* Engineering Societies Diversity Summit, Washington DC.

Jarosz, J.P. (1 Nov 2005). “Native Americans in higher education,” *concurrent session in* Second Annual Diversity Conference, Johns Hopkins University.

Jarosz, J.P. (1 Nov 2006). “Women, Blacks, Hispanics and Natives in science – Why so few?” *in* Third Annual Diversity Conference, Johns Hopkins University.

Busch-Vishniac, I.J., Campbell, P., Chassapid, C., Guillaume, D., and Patterson, E. (25 Mar 2007). “Attracting, retaining and advancing broader student populations,” *in* ASME Chair meeting, Puerto Rico.

Busch-Vishniac, I.J. (14 Apr 2007). Report on project, *plenary session in* ASEE Regional Meeting.

Campbell, P. (11 Jun 2007). “Teaching Women Engineering: A Double Standard,” *in* ASME Think Tank Summit.

Workshops

Busch-Vishniac, I.J. and Jarosz, J.P. (14 Oct 2004). Mandatory three-hour seminar for Johns Hopkins University Department of Mechanical Engineering, “Denconstructing ME Curriculum with an Aim to Attract and Retain a more Diverse Community”.

Busch-Vishniac, I.J. and Chassapis, C. (7 Nov 2005). “Curriculum Redesign to Enhance Greater Student Diversity,” *invited seminar*, Stevens Institute of Technology, College of Engineering.

Metz, S., Stevens Institute of Technology (23 Jan 2006). Professional development workshop, “Developing Engineering Curriculum to Engage Women and Minorities,” presented to the 8 partner institutions plus guests.

(24 Jan 2006). Guided tour for all 8 partner institutions of Howard University mechanical engineering labs and MRSEC labs.

Brenninkmeyer, J., Boston Museum of Science (27 Apr 2006). Professional developoment workshop, “Designing a High School Pre-Engineering Curriculum,” presented to the 8 partner institutions.

Busch-Vishniac, I.J. and Jarosz, J.P. (17 May 2006). Poster at Department-Level Reform Grantee Meeting, National Science Foundation headquarters.

Rodriguez-Falcon, E., University of Sheffield (12 Sep 2006). Professional development workshop, “Embedding Enterprise Education in the ME Curriculum,” presented to the 9 partner institutions.

(12 Apr 2007). Guided tour for all 8 partner institutions of the University of Washington mechanical engineering and biomechanical engineering labs.

Mescher, A., University of Washington (13 Apr 2007). Professional development workshop, “ADVANCE Transformation Grant,” presented to the 8 partner institutions.

Busch-Vishniac , I.J. (20 Apr 2007). “Curriculum change to enhance diversity in mechanical engineering,” *invited plenary*, 150th anniversary celebration for the Mechanical Engineering Department of Ohio State University.

Website

The 9/2006–8/2007 annual report suggested that there would be two significant electronic products:

- A publicly available website of 36 new lesson plans with updated applications.
- A database of 856 mechanical engineering topics with required time for presentation, prerequisites, postrequisites (topics that follow naturally), technical applications, and related nontechnical material.

The project’s funding was insufficient for this database effort; new lessons plans have been published in book form, but are not available online.

University of Massachusetts-Lowell

http://www.uml.edu/college/engineering/Community/Service_Learning.html

Conference presentations

Duffy, J., 2005, “Service-Learning in Mechanical Engineering: What, Why, How,” invited seminar, MIT, February.

Duffy, J., three invited presentations on SLICE and the Village Empowerment Peru Project at the annual conference of Engineers for a Sustainable World at the University of Texas in October, 2005.

Duffy, J., invited seminar on the Village Empowerment Project, Penn State, March, 2006.

Duffy, J., John Ting, Carol Barry, Jackie Zhang, Dave Kazmer, Donn Clark, and Alan Rux, 2006, “Service-Learning Integrated throughout a College of Engineering (SLICE),” The National Service-Learning in Engineering Conference, May 2006

Duffy, J., 2006, “Village Empowerment: Sustainable International Service-Learning,” National Service-Learning in Engineering Conference, May 2006

Zhang, X., Nathan Gartner, Oguz Gunes, and John Ting, 2006, “Undergraduate Curriculum Reform in Civil Engineering by Integrating Service-Learning Projects,” National Service-Learning in Engineering Conference, May 2006

Duffy, J., 2006, Village Empowerment Project, invited presentation, Merrimack Valley Venture Forum, Lowell, MA, December.

Duffy, J., 2007, “Village Empowerment Service-Learning Project,” invited seminar, Ill. Inst. Tech., Chicago, March.

Duffy, J., 2007, “Village Empowerment: Peru Project,” invited presentation, Boston University, March.

Duffy, J., 2007, “Solar Systems for Developing Countries,” invited presentation, MIT Energy Forum Thought Leaders Seminar, March.

Duffy, J. and five students, 2007, subjects in “Village Empowerment Partnership,” video produced by Jane Pikor, Emerson College, for the MA Campus Compact Carter Award Presentation, April,

Duffy, J., 2007, “Sustainability in International Service-Learning Projects,” invited presentation and panel discussion, Engineers Without Borders International Annual Conference, U Mass Amherst, April.

Duffy, J., 2007, invited presentation, “Recruiting, Developing and Guiding Faculty as Team Project Coaches,” Best Practices of Interdisciplinary Team Project Programs Conference, Ill. Inst. Tech., Chicago, April.

Duffy, J., 2007, “Village Empowerment: Toward Sustainability in International Service-Learning Projects,” workshop, annual conference of the Community College National Center for Community Engagement, Phoenix, May.

Duffy, John, Linda Barrington, Cheryl West, John McKelliget, Eugene Niemi, Sammy Shina, Hongwei Sun, Chris Niezrecki, Robert Parkin, Majid Charmchi, Peter Avitabile, 2007, “Service-Learning in Core Courses Throughout a Mechanical Engineering Curriculum,” American Society of Engineering Education Annual Conference.

Duffy, J., D. Kazmer, L. Barrington, J. Ting, C. Barry, Z. Zhang, D. Clark, A. Rux, 2007, “Service-Learning Integrated into Existing Core Courses throughout a College of Engineering,” American Society of Engineering Education Annual Conference.

Barrington, L., and J. Duffy, 2007, “Attracting Underrepresented Groups to Engineering with Service-Learning,” American Society of Engineering Education Annual Conference.

Kazmer, D., J. Duffy, L. Barrington, B. Perna, 2007, "Introduction to Engineering through Service-Learning," American Society of Mechanical Engineers International Design Engineering Technical Conference.

Duffy, J., 2007, "Village Empowerment: Toward Sustainability in International Service-Learning Projects," workshop, annual conference of the Community College National Center for Community Engagement, Phoenix, May.

Duffy, J., 2007, "Village Empowerment Project: Collaboration with Indigenous Peoples," invited presentation, Tohono O'odham Community College, Sells, AZ.

Kazmer, D., and Johnston, S., 2008, "Lions and Tigers and Freshmen," Society of Plastics Engineers Annual Technical Conference.

Bhattacharjee, U., C. Lin, R. Williams, and J. Duffy, 2008, "Solar Energy Education with Service-Learning: Case Study of a Freshman Engineering Course," Annual Meeting American Solar Energy Society.

Duffy, J., 2008, "Village Empowerment: International Service-Learning," Paper AC 2008-1163, American Society of Engineering Education Annual Meeting. ASEE.

Duffy, J., C. Barry, L. Barrington, D. Kazmer, W. Moeller, and C. West, 2008, "Service-Learning Projects in 35 Core Undergraduate Engineering Courses," Paper AC 2008-1525, American Society of Engineering Education Annual Meeting. ASEE.

Burack, C., J. Duffy, A. Melchior, and E. Morgan, 2008, "Engineering Faculty Attitudes Toward Service-Learning," Paper AC 2008-1521, American Society of Engineering Education Annual Meeting. ASEE.

Ting, J.M., "Institutionalizing your Service-Learning Program," Opening Plenary Panel, National EPICS Conference, Purdue University, W. Lafayette, Indiana, May 2008.

Ting, J.M., "Perspectives on Integrating Service-Learning in a College of Engineering," invited keynote address, Workshop on Integrating Appropriate Sustainable Technology and Service Learning in Engineering Education, Sustainable Resources 2004, University of Colorado, Boulder, Colorado, Sept. 2004.

Publications (refereed)

Duffy, J.J., 2005, "Village Empowerment : Sustainable Solar Solutions," *Proceedings of the 2005 Solar World Congress*, International Solar Energy Society.

Banzaert, Amy, John Duffy, and David Wallace, 2006, "Integration of Service-Learning into the Engineering Core at U Mass Lowell and MIT," *American Society of Engineering Education 2006 Annual Conference*

Conference Proceedings

Kazmer, David, John Duffy, and Beverly Perna, 2006, "Learning through Service: Analysis of a First College Wide Service Learning Course," *American Society of Engineering Education Annual Conference Proceedings.*

Zhang, Xiaoqi, Oguz Gones, and John Ting, 2006, "Undergraduate Curriculum Reform in Civil Engineering by Integrating Service-Learning Projects," *American Society of Engineering Education Annual Conference Proceedings.*

Zhang, X., N. Gartner, O. Gunes, J. Ting, 2007, "Integrating Service-Learning Projects into Civil Engineering Courses," *International Journal for Service Learning in Engineering*, p. 44, vol. 2.

Duffy, John, Linda Barrington, Cheryl West, John McKelliget, Eugene Niemi, Sammy Shina, Hongwei Sun, Chris Niezrecki, Robert Parkin, Majid Charmchi, Peter Avitabile, 2007, "Service-Learning in Core Courses throughout a Mechanical Engineering Curriculum," Proceedings American Society of Engineering Education Annual Conference.

Duffy, J., D. Kazmer, L. Barrington, J. Ting, C. Barry, Z. Zhang, D. Clark, A. Rux, 2007, "Service-Learning Integrated into Existing Core Courses throughout a College of Engineering," Proceedings American Society of Engineering Education Annual Conference.

Barrington, L, and J. Duffy, 2007, "Attracting Underrepresented Groups to Engineering with Service-Learning," Proceedings American Society of Engineering Education Annual Conference.

Kazmer, D., J. Duffy, L. Barrington, and B. Perna, 2007, "Introduction to Engineering through Service-Learning," Proceedings of the ASME 2007 International Design Engineering Technical Conferences, IDETC/DEC- 34491.

Bhattacharjee, U., C. Lin, R. Williams, and J. Duffy, 2008, "Solar Energy Education with Service-Learning: Case Study of a Freshman Engineering Course," Proceedings Annual Meeting American Solar Energy Society (peer reviewed section).

Duffy, J., 2008, Village Empowerment: International Service-Learning. Paper AC 2008-1163 Proceedings of the American Society of Engineering Education Annual Meeting. ASEE.

Duffy, J., C. Barry, L. Barrington, D. Kazmer, W. Moeller, and C. West, 2008, Service-Learning Projects in 35 Core Undergraduate Engineering Courses. Paper AC 2008-1525, Proceedings of the American Society of Engineering Education Annual Meeting. ASEE.

Burack, C., J. Duffy, A. Melchior, and E. Morgan, 2008, Engineering Faculty Attitudes Toward Service-Learning, Paper AC 2008-1521, Proceedings of the American Society of Engineering Education Annual Meeting. ASEE.

Duffy, J., L. Barrington, W. Moeller, C. Barry, D. Kazmer, C. West, V. Crespo, 2008, Service-Learning Projects in Core Undergraduate Engineering Courses. *International Journal of Service-Learning in Engineering*, Vol. 3, No. 2, pp. 18-41.

Duffy, J., 2008, Village Empowerment: Service-Learning with Continuity, *International Journal of Service-Learning in Engineering*, Vol. 3, No. 2, pp. 1-17.

University of North Texas

http://www.ee.unt.edu/dlr/index.htm

Conference presentations

Murali R. Varanasi, Oscar N. Garcia, Parthasarathy Guturu, Hai Deng, Xinrong Li, and Shengli Fu, "Work In Progress: An Innovative Electrical Engineering Program Integrating Project-oriented and Lifelong Learning Pedagogies," Proceedings of the 2006 ASEE/IEEE Frontiers in Education Conference, San Diego, California, USA, Oct. 28-31, 2006

Parthasarathy Guturu, Murali R. Varanasi, and Oscar N. Garcia, "Course Remodeling by Integration of Project-based Education with L2L Principles for Enhanced Student Learning Experience," Proceedings of the International Conference on Engineering Education (ICEE) 2006, San Juan, Puerto Rico, USA, July 23-28, 2006.

Murali R. Varanasi, Oscar N. Garcia, and Parthasarathy Guturu, "Innovative Approaches to Electrical Engineering Education," presented at the ASEE South Gulf West Conference, Baton Rouge, Louisiana, USA, March 15-17, 2006.

E. Ayeh, K. Agbedanu, Y. Morita, O. Adamo, and P. Guturu, "FPGA Implementation of an 8-bit Simple Processor," in Proceedings of the IEEE Region 5 Technical, Professional and Students Conference, Accepted April 2008.

Vijay Vaidyanathan, Murali Varanasi, Elias Kougianos, Shuping Wang, and Hari Raman, "RFID Student Educational Experiences at the UNT College of Engineering: A sequential approach to creating a Project-based RFID Course," IEEE Transactions on Education, forthcoming.

Workshops & Other Dissemination

All faculty, including tenured and tenure-track faculty whose research focus is more on technical aspects of ECE and related disciplines, had the opportunity to attend training workshops hosted by education experts to learn about topics such as active learning techniques and learning styles

The DLR team has submitted an NSF Research Experience for Teachers (RET) proposal to share their practices more broadly among North Texas high schools. They hope that the school teachers can stimulate their students to pursue STEM disciplines when they attend college. They plan to disseminate their best practices through workshops for the benefit of organizers of “Boosting Engineering, Science, and Technology (BEST)” competition for high school students.

Oklahoma State University

http://es21c.okstate.edu/

Publications

Charles Bunting, Alan Cheville, “Engineering Students for the 21st Century,” Proceedings of the American Society for Engineering Education Annual Meeting- “Advancing Scholarship in Engineering Education,” p. 1475, vol. , (2006). Published,

Charles Bunting, Alan Cheville, James West, “VECTOR: A Hands-on approach that makes electromagnetics relevant to students,” Proceedings of the American Society for Engineering Education Annual Meeting- “Advancing Scholarship in Engineering Education,” p. 1544, vol. , (2006). Published,

Alan Cheville, “THE LASER CULT: HANDS-ON LABORATORY IN PHOTONICS,” Proceedings of the American Society for Engineering Education Annual Meeting- “Advancing Scholarship in Engineering Education,” p. 1496, vol. , (2006). Published,

Old Dominion University

http://www.mem.odu.edu/visualization/

Journal publications

S K Chaturvedi, T Abdel-Salam, Sai S. Sreedharan, A A. Chandorkar and Sivakumar Hariharan. “A Web-Based Virtual Supersonic Nozzle Module as an Interactive Visualization Tool for teaching concepts related to One-Dimensional Gas Dynamics,” Computers in Education Journal, Vol.16, No.2, April 2006, pp 80-89.

Duc Nguyen and Subhash Kadiam, “Simulation, Visualization and Self-Assessment Enhanced engineering Education: the stiffness Matrix Method Module for Structural Analysis Course,” Computers in Education Journal, Accepted for publication.

Sushil Chaturvedi, and Tarek Abdel Salam, “A Web-based Module for Teaching Engineering Students About Environmental Effects of Fossil Fuel Combustion,” Computers in Education Journal. Vol. 17, No. 4, 2007.

Book Chapters

“ A Web-Based Interactive Student Learning Tool for Visualization, Simulation and Knowledge Integration in the Undergraduate Thermodynamics Course,” Book Chapter, Innovations 2006, World Innovations in Engineering Education and Research, ISBN 0-9741252-5-3, July 2006, Chaturvedi, T Abdel-Salam and Sai S Sreedharan.

Sushil Chaturvedi, Tarek Abdel-Salam, “Virtual Assembly” – A Web-Based Student Learning Tool for Thermodynamics Concepts Related to Multistaging in Compressors and Turbines INNOVATIONS 2008: World Innovations in Engineering Education and Research, August 2008. in press

“Mapping of a Thermo-fluids Laboratory Experiment into a Web-based Virtual Experiment for Application as a Prelab Practice Tool,” Book Chapter, Innovations 2007, World Innovations in Engineering Education and Research, to appear in July 2007, Chaturvedi, Abdel-Salam, Muthoju, Shrinivas and Gagrani.

“ A Web-Based Module For Teaching Engineering Students about Environmental Effects of Fossil Fuel Combustion,” Accepted for publication in Computers and Education Journal, To appear in July 2007, Chaturvedi, Abdel-Salam and Kasinadhuni.

Conference Proceedings

“A Web-Based Multimedia Virtual Experiment,” Proceedings of Frontiers in Education, 2003, Boulder, Colorado. S K. Chaurvedi, O. Akan, S. Bawab, Abdel-Salam, and Venkatraman.

“Mapping of a Thermo-Fluids Laboratory experiment,” Proceedings of 2004 ASEE Annual Conference, June 2004, Salt Lake City, Utah, S K. Chaturvedi, O. Akan and McKenzie.

“Development of a methodology to Visualize and Conduct a Physical Experiment as a Web-Based Virtual Experiment,” Proceedings of 2005 Web-Based Education Conference, Grindelwald, Switzerland, Feb 2005. S K. Chaturvedi, Abdel-Salam and S. Bawab.

“A Web-based Module for Teaching Engineering Students about Environmental Effects of Fossil Fuel Combustion ,” Conference Proceedings of 5th Global Colloquium on Engineering Education, Oct 7-12 2006, Rio de Janeiro, Brazil. Chaturvedi, Abdel Salam and Kasinadhuni.

Conference presentations

“Virtual Assembly - A Web-based Student Learning Tool for Thermodynamics Concepts Related to Multistaging in Compressors and Turnbines, “ Proceedings of 2007 International Conference on Engineering Education, Sept 3-7 2007, Coimbra, Portugal. Chaturvedi.

“Development of Building Blocks for Internet-based Interactive Courses for Engineering Education,” Accepted for presentation in the 6th International Internet Education Conference, Sep 2-4 2007, Cairo, Egypt. Chaturvedi and Abdel Salam.

“Simulation and Visualization Enhanced Engineering Education : The Stiffness Matrix Method Module for Structural Analysis 1 Course ,” Accepted for presentation in the Modsim World 2007 Conference, Sep 11-13 2007, Norfolk, Virginia. Mohammed, Nguyen and Chaturvedi.

"Virtualization of Physical Experiments Using Modeling, Simulation and Visualization ," Accepted for presentation in the 6th Global Colloquium on Engineering Education, Oct 1-4 2007, Istanbul, Turkey. Chaturvedi, Kasinadhuni

"Transforming Engineering Curricula through Web-Based Interactive Visualization and Simulation Modules," Proceedings of 4'th ASEE/AAEE Global Colloquium on Engineering Education, S K. Chaturvedi and O. Akan.

"Simulation and Visualization Enhanced Engineering Education," ASME International Conference on Engineering Education, Mar 2006, Beijing, China. S. K. Chaturvedi and O. Akan.

Workshops

"Simulation and Visualization Enhanced Engineering Education Workshop," Old Dominion University, July 13, 2007 and August 2008. These workshops are for engineering faculty from local and regional engineering colleges.

University of Pittsburgh

http://www.engr.pitt.edu/chemical/undergraduate/Curriculum/

Joseph J. McCarthy and Robert S. Parker, "Pillars of Chemical Engineering: A Block Scheduled Curriculum," Chemical Engineering Education, p. 292, vol. Fall, (2004). Published,

Joseph J. McCarthy, Adetola A. Abatan, Robert S. Parker, and Mary Besterfield-Sacre, "Work In Progress: Pillars of Chemical Engineering," Proceedings of the 35th ASEE/IEEE Frontiers in Education Conference, p. F3H-15, (2005). Published,

Purdue University

https://engineering.purdue.edu/ENE

Conference Proceedings

Bowman, K., (2006) "Physical Properties And Problem Solving In Engineering: Broadening the Effectiveness of Traditional Engineering Courses," Proceedings of the 2006 ASEE Annual Conference, Chicago, Illinois.

Imbrie, P., Haghighi, K., Wankat, P., and Oakes, W., (2005) "Creating a Model Multidisciplinary Engineering Program," Proceedings of the 2005 ASEE/AaeE 4th Global Colloquium, Sidney Australia,

Noonan, J., Oakes, W., and Imbrie, P. (2006), "First-Year Engineering Students' Choice Of A Major: When It Is Made And What Influences It," 2006 ASEE Illinois- Indiana and North

Central Joint Section Conference, Indiana University Purdue University Fort Wayne (IPFW), March 31-April 1, 2006,

Rochester Institute of Technology

http://www.rit.edu/kgcoe/ue/research/nanotechnology/

Publications

Mariotti D, Jackson M, Lewis E, Schulte T, Kurinec S. "Nanotechnology in education: top-down and bottom-up approach," " iNEER Special Volume: Innovations 2008, World innovations in engineering education and research (2008) 261

Santosh Kurinec, Dale Ewbank, Lynn Fuller, Karl Hirschman, Michael Jackson, Robert Pearson, Sean Rommel Bruce Smith and Surendra Gupta Maureen Arquette and Maria Wiegand, "Microelectronic Engineering Education for Emerging Frontiers," 9th International Conference on Engineering Education, San Juan, Puerto Rico, July 2006, TIA1-5., p. T1A1-5, (2006).

Santosh Kurinec, Lynn Fuller, Bruce Smith, Richard Lane, Karl Hirschman, Michael Jackson, Robert Pearson, Dale Ewbank, Sean Rommel, Sara Widlund, Joan Tierney, Maria Wiegand, Maureen Arquette, Charles Gruener and Scott Blondell, "25 Years of Microelectronic Engineering Education," 16th Biennial University Government Industry Microelectronics Symposium, San Jose State University, San Jose, CA, June 2006, p. 23-31, (2006).

Presentations

"Nanotechnology not-for-profit: modern art & architecture" Mariotti D, invited speaker at the 31st Annual Activities IEEE-Electron Devices Society/CAS in Western New York Conference, 7 November 2007, Rochester (NY), USA

Santosh K. Kurinec, Surendra K. Gupta, Raymond Krom, Thomas Schulte and Michael A. Jackson, "Curriculum Innovations in Microelectronic Engineering," Proceedings of the 2006 Annual Meeting of the St. Lawrence Section of ASEE, Cornell University, Ithaca, NY, (2006).

"Individual Capstone Design Projects in the Multidisciplinary Fields of Microelectronic Engineering, MEMS and Nanotechnology, Santosh Kurinec, Michael Jackson, Sean Rommel, Karl Hirschman and Lynn Fuller, Ist National Capstone Conference June 13-15 2007, University of Colorado, Boulder, CO

Posters

Microelectronic engineering for the future of energy, Jackson M, Mariotti D, Kurinec S poster at the 2008 Harrison Howe Award Event, 18 March 2008, Rochester (NY), USA

Self-organized Nanopatterning by Block Copolymer, Takahashi Y, Mariotti D, Lu YW poster at the SMFL Symposium, 20 February 2008, Rochester (NY)

Development of a Linear Source, Atmospheric-Pressure, Non-Thermal RF Glow Discharge Plasma , Wagner A, Mariotti D, poster at the SMFL Symposium, 20 February 2008, Rochester (NY), USA

University of South Florida

Conference Proceedings

Vinay K. Gupta*, Babu Joseph, Norma Alcantar, Ryan Toomey and Aydin Sunol, "*A Spiral Curriculum for Chemical Engineering*," Proceedings of the Annual Meeting of the AIChE, November 2008.

"A Spiral Curriculum for Chemical Engineering," American Institute of Chemical Engineers, Annual Meeting, Philadelphia (PA), November 2008.

"Transforming the Educational Experience of Chemical Engineering Transfer Students," American Society of Engineering Education (ASEE), Annual Meeting, Pittsburgh, June 2008.

"Chemical Engineering Curriculum - Spiraling out of Control OR Spiraling into Control," American Institute of Chemical Engineers, Annual Meeting, Salt Lake City (UT), November 2007.

Poster Presentations

NSF-Engineering Education Awardees conference, "Building Connections within the Engineering Education Research Community" September 26-28, 2007.

NSF-DLR Grantees Conference, "Path Forward Workshop," May 15, 2008

Journal / Conference Papers

C. A. C*c Degradation*," Proceedings of the Annual Meeting of the AIChE, November 2008.

C. A. Coutinho, Subrahmanya R. Mudhivarthi, Ashok Kumar, and V. K. Gupta*, *"Novel Slurries of Hybrid Inorganic-Organic Abrasive Microparticles for Oxide CMP*," Proceedings of the 13th International Chemical-Mechanical Planarization for ULSI Multilevel Interconnection Conference (CMP-MIC), March 2008.

Cecil Coutinho, Subrahmanya R. Mudhivarthi, Ashok Kumar, and V. K. Gupta*, "*Hybrid Inorganic-Organic Microparticles for Chemical Mechanical Polishing*," Proceedings of the Annual Meeting of the AIChE, November 2007.

Cecil Coutinho and Vinay K. Gupta*, "*Synthesis And Properties Of Functional Composites Formed From A Responsive Polymer And Titania Nanoparticles*," Polymer Preprints (American Chemical Society, Division of Polymer Chemistry) (2007).

Sweet Briar

Presentations

Schulz, K., Kander, R., Ming, I., Papadakis, M., Burnett, R., and McGraw, D., "Integrating Social Sciences in Engineering," (2005). Panel, Editor(s): Altaii, Karim, Bibliography: James Madison University, Integrated Science and Technology, Harrisonburg, VA, February 23, 2005

Lindemann, C., Schulz, K., Greff, M., Heugatter, A., Poole, D., and Sink, S., "Creative Engineering Design and Delivery for 9-12 Grades +First Year Undergraduates," (2005). Panel Discussion, Bibliography: National Consortium for Specialized Secondary Schools of Mathematics, Science & Technology Professional Conference, St. Louis, Missouri, March 9-12, 2005

Conference Proceedings

Schulz, K.C. and Durand, J., "*Engineering at Sweet Briar College: A New Program for and about Women,*" WEPAN 2006 National Conference, Pittsburgh, PA, June 11-14, 2006.

Schulz, K.C., Hyman, S., Yochum, H., and Kasarda, M., "*Engineering at Sweet Briar College: A Global Perspective in a Liberal Arts Context*," Proceedings of the 2005 American Society for Engineering Education Southeast Section Conference, Chattanooga, TN, April 3-5, 2005.

Schulz, Kurt C., Hyman, S., Youchum, H., and Kasarda, M., "Engineering at Sweet Briar: A Global Perspective in a Liberal Arts Context," Proceedings of the 2005 American Society for Engineering Education Southeast Section Conference, p. 5132, (2005). Published

Texas A&M

http://www.che.tamu.edu/curriculum-reform

Conference Proceedings

Yurttas, L., Pchenitchnaia, L., Froyd, J., et al. (June 2009). *An Integrated Approach to Chemical Engineering Undergraduate Curriculum Reform.* Paper submitted and approved for The Foundations of Computer-Aided Process Design Conference Proceedings Book, Taylor & Francis Publishing Group.

Christensen, J., & Yurttas, L. (2009). Service-Learning and Sustainability: Striving for Better Future. Proceedings, ASEE Annual Conference and Exposition, Austin, TX.

Froyd, J., Layne, J., Ford, D., & Yurttas, L. (2006). Designing a process for department curricular reform. Proceedings, ASEE Annual Conference and Exposition, Chicago, IL, Retrieved January 21, 2009, from http://soa.asee.org/paper/conference/paper-view.cfm?id=1321.

Pchenitchnaia, L., Froyd, J., & Yurttas, L. (2008). Sustaining chemical engineering undergraduate curriculum reform. Proceedings, ASEE Annual Conference and Exposition, Pittsburgh, PA.

Yurttas, L., Christensen, J., Haney, J., El-Halwagi, M., Froyd, J., and Glover, C. (2007) Enhancement of Chemical Engineering Introductory Curriculum through Service-Learning Implementation. Proceedings, ASEE Annual Conference and Exposition, Honolulu, HI, Retrieved December 5, 2008, from http://papers.asee.org/conferences/paper-view.cfm?id=4246.

Yurttas, L., Kraus, Z., Froyd, J., Layne, J., El-Halwagi, M., and Glover, C. (2007). A web-based Complement to Teaching Conservation of Mass in a Chemical Engineering Curriculum. Proceedings, ASEE Annual Conference and Exposition, Honolulu, HI, Retrieved December 5, 2008, from http://papers.asee.org/conferences/paper-view.cfm?id=3510.

Posters and Presentations

Pchenitchnaia, L. & Yurttas, L. (February 2009). *Implementing an Assessment and Continuous Improvement Process: An Example from and Engineering Department.* Paper submitted and approved for an Annual Assessment Conference, Texas A&M University, College Station, TX.

Yurttas, L. & Pchenitchnaia, L. (2008). *Chemical Engineering Undergraduate Curriculum Reform, Development and Assessment: A"Strings" Approach.* A paper submitted and approved for and annual AIChE Conference, Philadelphia, PA.

Carvajal J., Pchenitchnaia, L., Yurttas, L., & Cagin, T. (2008). A web-based resource for teaching molecular modeling and simulation methods in chemical engineering. Proceedings, ASEE Annual Conference and Exposition, Pittsburgh, PA.

Pchenitchnaia, L., Froyd, J.E., Yurttas, L. (2008). *Sustaining chemical engineering undergraduate curriculum reform.* A research paper submitted and approved for a presentation at American Society for Engineering Education 2008 Annual Conference and Exposition, Pittsburgh, PA, USA

Glover, C., El-Halwagi, M., Froyd, J., Pchenitchnaia, L.V. (2007). *Chemical engineering undergraduate curriculum reform.* A poster presentation at Engineering Education Division of National Science Foundation Awardees Conference, Arlington, Virginia, USA

Glover, C., Kraus, Z. (2006). *Chemical engineering undergraduate curriculum reform.* A poster presentation at Engineering Education Division of National Science Foundation Awardees Conference, Arlington, Virginia, USA

Workshops

Using Flash Software to Enhance ICC Implementation Process , *ICCs Coordinators, June 2007*

Interlinked Curriculum Components as Web-based Resource for Teaching and Learning, *March 2007, May 2007, TAMU faculty*

CHEN Curriculum Reform Project Overview, *December 2006, TAMU faculty*

Curriculum Mapping, Course Strings and Interlinked Curriculum Components, April 2006, PVAMU faculty

CHEN Curriculum Reform Project Overview, February 2006, TAMUK faculty

CHEN Course Folders and Curriculum Map Practical Applications, October 2005, TAMU faculty

University of Utah

http://www.ece.utah.edu/NSF

Summary of Projects: http://www.ece.utah.edu/NSF/projects/index_html

Publications

Damon Hall and Cynthia Furse, "Take a Stand: Speaking to Learn about RF Safety," IEEE Antennas and Propagation Magazine, December 2004, pp. 146-150

Cynthia Furse, Lance Griffiths, Behrouz Farhang, and Geeta Pasrija, "Integration of Signals/Systems and Electromagnetics Courses through the Design of a Communication System for a Cardiac Pacemaker," *IEEE Antennas and Propagation Magazine,* Volume 47, Issue 2, April 2005 Page(s):117 - 119

(INVITED PAPER) April Kedrowicz, Sundy Watanabe, Damon Hall, Cynthia Furse, "Infusing Technical Communication and Teamwork within the ECE Curriculum," Turkish Journal, ELEKTRIK, special issue on Engineering education, Vol. 14, Issue 1, 2006

C. Furse, R.Woodward, M. Jensen, "Wireless Local Area Network Laboratory for Microwave Engineering Courses," *IEEE Trans. Education,* Vol. 47, No. 1, Feb2004, pp.18-25

A. Magleby, C. Furse, "Lab Report Writing (and Teaching!) Made Easy," 2008 ASEE Annual Conference & Exposition in Pittsburgh, Pennsylvania, June 22-25, 2008

Alyssa Magleby, Cynthia Furse, "Improving Communication Skills Through Project-Based Learning, *IEEE Antennas and Propagation Symposium (APS),* Honolulu, HI June 9-16, 2007

Cynthia Furse, Brian Stenquist, Behrouz Farhang-Boroujeny, April Kedrowitz, Stephanie Richardson, "Integrated System-Level Design in Electrical Engineering," 2006 ASEE Annual Conference & Exposition in Chicago, Illinois, June 18-22, 2006, Nominated for Best Paper Award

Roland Kempter, Cynthia Furse, Neil E. Cotter, Nick M. Safai and Lee Brinton, "On Undergraduate Education in Electrical Engineering across Colleges: Transfer Students and Challenges in Curriculum Adaptation," Best Paper Award (International Division) 2006 ASEE Annual Conference & Exposition in Chicago, Illinois, June 18-22, 2006

Rohit Verma, Cynthia Furse, "A Multidisciplinary Approach to Teaching Technology Entrepreneurship and Product Innovation to Engineering and Business Administration Students," 2006 ASEE Annual Conference & Exposition in Chicago, Illinois, June 18-22, 2006

Conference Proceedings

Cynthia Furse, Lance Griffiths, Behrouz Farhang, and Geeta Pasrija, "Integration of Signals/Systems and Electromagnetics Courses through the Design of a Communication System for a Cardiac Pacemaker," submitted to IEEE Antennas and Propagation Magazine

Conference Presentations

Alyssa Magleby, Cynthia Furse , "Improving Communication Skills Using Project-Based Write-to-Learn Approach," Draft. Paper being prepared for IEEE Trans Education. Work presented at ASEE 2008. http://www.ece.utah.edu/facilities/ugradlabs.html

University of Vermont

Publications:

Dewoolkar, M. M., George, L. A., and Hayden, N. J., "Vertical integration of service-learning into civil and environmental engineering curricula," In review, International Journal of Engineering Education.

Dewoolkar, M. M., George, L. A., and Hayden, N. J., "Hands-on undergraduate geotechnical engineering modules in the context of effective learning pedagogies, ABET outcomes, and curricular reform," In revision, J. of Professional Issues in Engineering Education and Practice. (Tracking # EI/2008/023870).

Dewoolkar, M. M., Porter, D., and Hayden, N., "Service-learning in engineering education and heritage preservation," In review, International Journal of Architectural Heritage Conservation, Analysis and Restoration. (Tracking # UARC-2008-0101).

Porter, D., Dewoolkar, M. M., and Hayden, N. J. (2008), "The role of service-learning in heritage preservation and engineering education," 6th International Conference on Structural Analysis of Historical Construction, SAHC08, D'Ayala and Fodde (eds), July 2-4, Bath, United Kingdom, Vol. 2, 1369-1374.

Dewoolkar, M. M., George, L. A., and Hayden, N. J. (2008), "Research-based and service-learning modules for undergraduate geotechnical engineering courses," GeoCongress 2008, Geosustainability and Geohazard Mitigation, ASCE Geotechnical Special Publication

No. 178, Reddy, Khire, and Alshawabkeh (eds), March 9-12, New Orleans, Louisiana, 813-820.

Hayden, N.J., M. Neumann, D.M. Rizzo, M. Dewoolkar, A. Sadek. (2006), "Integrating Catamount Community Service-Learning Projects within Civil and Environmental Engineering Programs at the University of Vermont," Proceedings of the Northeast Region American Society of Engineering Educators (ASEE) Conference, WPI, Worcester, MA.

Presentations:

Hayden, N. J., Dewoolkar, M. M., Rizzo, D. M., Sadek, A., Neumann, M., and George, L. (2007), "Service-learning projects in civil and environmental engineering senior capstone design course," Poster presentation, EPICS Conference, San Diego, CA.

George, L., Hayden, N. J., Dewoolkar, M. M., Rizzo, D. M., Sadek, A., and Neumann, M. (2007), "Service-learning projects in the first-year introduction to civil and environmental engineering course," Poster presentation, EPICS Conference San Diego, CA.

Dewoolkar, M. M., Hayden, N. J., Rizzo, D. M., Sadek, A., Neumann, M., and George, L. (2007), "'Implementing service-learning vertically in civil and environmental engineering curricula at the University of Vermont," Abstract, EPICS Conference San Diego, CA, presentation given by Dewoolkar.

Dewoolkar, M., Hayden, N., Rizzo, D., Sadek, A., and Neumann, M. (2006), "Catamount communities: integrated service-learning projects within civil and environmental engineering curricula at the University of Vermont," (2006). Poster, Published Bibliography: National Conference on Service Learning in Engineering, May, Washington DC.

"The role of service-learning in heritage preservation and engineering education," *6th Int. Conf. on Structural Analysis of Historical Construction*, *SAHC08*, Bath, UK, July 2008 – Presented by Mandar Dewoolkar.

"Research-based and service-learning modules for undergraduate geotechnical engineering courses," *GeoCongress 2008, Geosustainability and Geohazard Mitigation Conference*, New Orleans, Louisiana March 2008 – Presented by Mandar Dewoolkar.

"Implementing service-learning vertically in civil and environmental engineering curricula at the University of Vermont," EPICS Conference, San Diego, CA, May 2007 – Presented by Mandar Dewoolkar.

"Integrating Catamount Community Service-Learning Projects within Civil and Environmental Engineering Programs at the University of Vermont," Proceedings of the Northeast Region American Society of Engineering Educators (ASEE) Conference, WPI, Worcester, MA, 2006 – Presented by Nancy Hayden.

"Curricular reform of CEE Programs," School of Engineering Seminar Series, The University of Vermont, Novermber 2007 – Presented by Nancy Hayden.

Workshops

Integrating Reflection and Assessment to Improve and Capture Student Learning Workshop by Profs. Patti Clayton and Myra Moses (North Carolina State University) at the University of Vermont, September 26-27, 2005.

Student and Faculty Assessments Workshop by Prof. Dianne May Ebert (Michigan State University) at the University of Vermont, February 24, 2006.

Case Study Teaching in the Sciences Workshop by Prof. Clyde Freeman Herreid (University of Buffalo) on May 8-9, 2006.

Department Level Reform Workshop at the National Science Foundation on May 15, 2008.

Virginia Tech

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Publications

Journal / Magazine Articles

Robson, V., Lohani, V. K., and Muffo, J., 2008. "Assessment in Engineering Education, Book Chapter in Assessment in the Disciplines," Vol. 3, Assessment in Engineering Programs: Evolving Best Practices, Editor: William E. Kelly, pp. 173-192, Association for Institutional Research, Tallahassee, FL.

Lohani, V.K., Castles, R., Lo, J., and Griffin, H., 2008. "Tablet PC Applications in a Large Engineering Program," Computers in Education Journal, ASEE, vol. 3, pp. 52-63.

Terpenny, J., Goff, R., Lohani, V. K., Mullin, J., and Lo, J., 2008. "Preparing Globally and Socially Conscious Engineers: International and Human-Centered Design Projects and Activities in the First Year," International Journal of Engineering Education, vol. 24, no. 2, 11 pages.

Kim, J., J. Mullin, and V. Lohani. 2007. Effect of Sustainable Energy Design Project on Achievement for Engineering Freshmen at Virginia Tech in the United States. Journal of Engineering Education Research (March): 60-77. [In Korean]

Snook, J., Lohani, V.K., Lo, J., Sirvole, K., Mullins, J., Kaeli, J., and Griffin, H., 2006. "Incorporation of a 3-D Interactive Graphics Programming Language into an Introductory Engineering Course," Computers in Education Journal, ASEE, July

September, 2006.

Wolfe, M.L. and K. Mallikarjunan. 2005. NSF Million for Virginia Tech - Theme-based spiral curriculum: new framework for teaching and learning. Resource (January/February): 13-14

Invited Papers

Muffo, J., Lohani, V.K., Mullin, J., Backert, R., and Griffin, O.H. (2005). From Engineering Fundamentals to Engineering Education – What's in a Name, Proceedings of the International Conference on Engineering Education & Research (iCEER05), Tainan, Taiwan, March 1-5, 2005.

Lohani, V.K. and Grifin, M., 2005. A New Department of Engineering Education-Accomplishments in first year and Near-term Goals. Invited Paper, International conference on Engineering Education (ICEE 05), July 25-29,2005, Gliwice, Poland

Reviewed Conference Proceedings

Lohani, V. K., Castles, R., Johri, A., Spangler, D., and Kibler, D., 2008. "Analysis of Tablet PC Based Learning Experiences in Freshman to Junior Level Engineering Courses," Proc. 2008 ASEE Annual Conference, June 22-25, 2008, Pittsburgh.

Jayaraman, P., Lohani, V. K., Bradley, G., Griffin, H., and Dooley, J., 2008. "Enhancement of International Activities in a Large Engineering Curriculum," Proc. 2008 ASEE Annual Conference, June 22-25, 2008, Pittsburgh

Johri, A. and Lohani, V. K., 2008. "Representational Literacy and Participatory Learning in Large Engineering Classes Using Pen-Based Computing," Proc. Frontiers in Education Conference, Oct. 22-25, 2008, Saratoga Springs, New York.

Castles, R., Lohani,V.K., and Kachroo, P., 2008. "Knowledge Maps and Their Application to Student and Faculty Assessment," Proc. Frontiers in Education Conference, Oct. 22-25, 2008, Saratoga Springs, New York

Mallikarjunan, K., Laksmikanth, A., Wolfe, M.L., Lohani, V.K., and Connor, J., 2007. "Introduction to System Approach Using Bio-energy Resources as a Tool for Freshman Engineering Education," Proc. International Conference on Engineering Education (iCEE07), University of Coimbra, Portugal, Sep. 03-07, 2007.

Lo, J., Lohani, V.K., Gregg, M., and Goff, R. 2007. "Multiple Perspectives on Implementing a Team-Teaching Model." Proceedings of the 2007 Annual Conference and Exposition, Honolulu, Hawaii, June 24-27, 2007

Lohani, V., Castles, R., Lo, J., and Griffin, H. 2007. "Tablet PC Applications in a Large Engineering Program," *Proceedings of the 2007 Annual Conference and Exposition*, Honolulu, Hawaii, June 24-27, 13 pages.

Robson, V., Lohani, V.K., and Bateman, T. 2007," Foundational Predictors of Success in the Collegiate Engineering Program," *Proceedings of the 2007 Annual Conference and Exposition*, Honolulu, Hawaii, June 24-27, 2007.

Whysong, C.Y., Lo, J., and Mallikarjunan, P. 2007, "Improving Ethics Studies through a Spiral Themed Curriculum: Implementing Ethics Discussion at the Sophomore Level," *Proceedings of the 2007 ASEE Annual Conference and Exposition*, Honolulu, Hawaii, June 24-27, 2007.

Lo, J.L., Lohani, V.K. and Griffin, Jr., O.H., 2006, "Full Implementation of a New Format for Freshmen Engineering Course," *Proceedings of the 2006 ASEE Annual Conference and Exposition*, Chicago, IL, June 18-21, 2006

Lohani, V., Mullin, J., Lo, J., and Griffin, H. 2006. "Implementation of international activities in a freshman engineering course," *Proceedings 2006 ASEE Global Colloquium on Engineering Education*, Rio de Janeiro, Brazil, October 9-12, 2006.

Lohani, V.K., Kachroo, P., Chandrachood, S., Zephirin, T. Loganathan, G.V., and Lo, J.L., 2006. "Mechatronics Experiment in a Freshman Year Course," *Proceedings of the 2006 International Conference on Engineering Education*, Puerto Rico, July 23-28, 2006.

Whysong, C.Y., Lo, J., and Mallikarjunan, P. 2006, "Improving Ethics Studies through a Spiral Themed Curriculum in Biological Systems Engineering," *Proceedings of the 2006 ASEE Annual Conference and Exposition*, Chicago, Illinois, June 18-21, 2006.

Connor, J., Lohani, V.K., Mallikarjunan, K., Loganathan, G.V., and Lo, J.L 2006. "Multiple Models of a Freshman Engineering Experiment," *Proceedings of the 2006 ASEE Annual Conference and Exposition*, Chicago, IL, June 18-21, 2006, 8 pages.

Knott, M., Lohani, V.K., Griffin, O.H., Loganathan, G.V., Adel, G., Paretti, M., Wolfe, M., Mallikajunan, K., and Wildman, T. 2005, "Using e-portfolios in a large engineering program," *Proceedings of the 2005 ASEE Annual Conference and Exposition*, Portland, Oregon, June 12-15, 2005.

Lohani, V.K., Sanders, M., Wildman, T., Connor, J., Mallikarjunan, K., Dillaha, T., Muffo, J., Knott, T.W., Lo, J., Loganathan, G.V., Adel, G., Wolfe, M.L., Goff, R., Gregg, M., Chang, M., Agblevor, F., Vaughan, D., Cundiff, J., Fox, E., Griffin, H., and Magliaro, S. 2005, "From BEEVT to DLR - NSF Supported Engineering Education Projects at Virginia Tech," *Proceedings of the 2005 American Society for Engineering Education Annual Conference and Exposition*, June 12-15, 2005.

Snook, J.S., Lohani, V. K., Lo, J., Sirvole, K., Mullin, J., Kaeli, J., Griffin, H. 2005, Incorporation of a 3D Interactive Graphics Programming Language into an Introductory Engineering Course. Proc. 2005 ASEE Annual Conference, June 12-15, Portland, Oregon.

Lo, J., Goff, R., Lohani, V., Walker, T., Knott, T., and Griffin, H., 2005, New Paradigm for Foundational Engineering Education, *Proc. 2005 ASEE Annual Conference*, Portland, Oregon.

Knott, T. W., Lohani, V. K., Griffin, O. H., Loganathan, G. V., Adel, G., and Wildman, T. 2004, "Bridges for Engineering Education: Exploring e-Portfolios in Engineering Education at Virginia Tech," *Proceedings of the 2004 ASEE Annual Conference and Exposition*, Salt Lake City, Utah, June 20-23, 2004

Connor, J., Lohani, V.K., Bull, E., Wildman, T.M., Magliaro, S.G., Knott, T. W., Griffin, O.H., Muffo, J.A., 2004, "An Analysis of Freshman Engineering: A Cross-College Perspective," *Proc. 2004 ASEE Annual Conference*, June 20-23, 2004, Salt Lake City, Utah.

Workshops

Workshop "Advances in Engineering Education: Workshops and discussions in support of collaboration between Virginia Tech and National Cheng Kung University," August 05-07, 2008, Tainan, Taiwan (Organziers: DLR/NSF project investigators: Vinod K Lohani, Mary Leigh Wolfe, Jeff Connor, Kumar Mallikarjunan, Terry Wildman).

DLR/NSF project workshop, Jan. 07, 2008, EngE – BSE Faculty/Graduate Students' Meeting; 30 participants, Virginia Tech campus.

Workshop on Spiral Curriculum- Theory and Application in Engineering, June 24, 2007, 2007 Annual Conference of ASEE, Honolulu, Hawaii (Organizers: DLR/NSF project investigators: Vinod K Lohani, Mary Leigh Wolfe, Kumar Mallikarjunan, Terry Wildman, and Jenny Lo).

"Spiral Curriculum in Engineering Education," Presentation at Engineering Education Workshop at Univ. of Texas, El Paso (UTEP), Aug. 24, 2007 (Speakers: Vinod K Lohani and Kumar Mallikarjunan

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14. ABSTRACT

The National Science Foundation (NSF) established the Department-Level Reform (DLR) of Undergraduate Engineering Education to provide funding to engineering schools and departments for three specific developmental functions: 1) to reformulate, streamline, and update their degree programs, 2) to develop new curricula for emerging engineering disciplines, and 3) to meet the emerging workforce and educational needs of U.S. industry. NSF asked STPI to evaluate the NSF's Engineering Education program through a systematic review of the outcomes and impacts of the Department Level Reform program. The study sought to answer three fundamental questions: Is the DLR program accomplishing its goals? Is the DLR program the best way to encourage engineering departments to update their programs to incorporate new teaching methods? What are the indicators of success for individual projects as well as the portfolio of DLR projects?

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