Advances in Engineering Education

SUMMER 2011

The role of NSF's Department Level Reform program in engineering education practice and research

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APPENDIX

Engineering education directly supports the nation's capacity for economic growth, infrastructure renewal, and security, as well as environmental and human health. Numerous reports have recommended federal support to advance our understanding of how students learn, how faculty teach, and how teaching and learning are assessed. The U.S. National Science Foundation (NSF) funded eight Engineering Education Coalitions comprising 49 universities from 1990 to 2005 to encourage implementation of report findings. The NSF Department Level Reform (DLR) program was designed to build on the efforts of the coalitions with funding provided to 20 universities to reformulate and update their engineering programs from 2004-2008. In this paper, the authors provide a brief summary of the coalition effort, an overview of the DLR program, highlights from selected DLR implementation efforts and comments on future directions of engineering education and research.

Keywords: Department level reform, National Science Foundation

INTRODUCTION

The state of research and practice in engineering education is the result of many individuals and organizations. Jesiek et al. (2009) provided a summary of the history and origins of U.S. engineering education research, noting the intertwined influence of key authors, reports and activities, many of which were associated with the National Academies, National Science Board, National Science Foundation, ABET Inc., Engineering Deans Council and American Society of Engineering Education. Seely (2005) has summarized changes in the practice of engineering education, noting that periodic calls for reform have been documented since the latter part of the nineteenth century. A convergence of such calls in the late 1980s (e.g., NRC 1985, NSB 1986, ASEE 1986, 1987, ABET 1986) led to the Belmont Conference (Willenbrock 1989) at which significant federal investment into "the development of consortia of educational institutions" was recommended "as a national imperative." In response, the Division of Engineering Education and Centers within the Directorate for Engineering (EEC/ENG) and Division for Undergraduate Education in the Directorate for Education and Human Resources (DUE/EHR) at the NSF developed a program to fund several multi-institution Engineering Education Coalitions (NSF 1989). This funding model was changed in 2002 to focus on department level reform at individual institutions.

The primary purpose of this manuscript is to provide an overview of the Department Level Reform (DLR) program. This manuscript also briefly summarizes the Engineering Education Coalitions program because it immediately preceded and influenced the DLR program. Background discussion is limited to the coalitions and DLR, although other NSF investments through the EEC/ENG Engineering Research Centers (ERC) program, various programs in the DUE/EHR (e.g., Course, Curriculum, and Laboratory Improvement (CCLI)) as well as other federal support (e.g., Department of Education Fund for the Improvement of Postsecondary Education (FIPSE)) have all contributed to the development of engineering education.

BACKGROUND

Over the fifteen year period from 1990-2005 eight Engineering Education Coalitions comprising 49 universities were supported with approximately $157 million to develop and deploy systemic reform efforts. Generally, a given coalition received nearly $15 million for the first five years, with somewhat less support for a second five year term. The funding was in the form of a cooperative agreement with renewed support contingent upon periodic review and site visits. Each coalition typically involved 5-9 colleges and universities with various institutional profiles and Carnegie classifications. During this period, several smaller scale awards were also made to coalition and non-coalition members to further develop coalition-initiated innovations.

The collective progress of the coalitions was evaluated after five years, which was about midway through the anticipated program life (Coward et al. 2000). The coalitions have since been characterized in terms of content, expectations, methodology and systemic reform (Seely 2005) as well as through an evaluation of coalition contributions to the peer-reviewed literature and interviews with coalition and non-coalition personnel (Borrego 2007). Although the immediate impact of the coalition effort may have been more limited than initially planned, it developed a number of critical advances in engineering education that are considered fundamental today. It is clear that the coalition's activities were in alignment with the reports (Belmont Conference) that led to their original creation. It is equally clear that the nature of engineering education reform is such that the investment provided could not possibly have been expected to single handedly transform the status quo. And they did not. Coalition innovations were not fully used among the institutions within a given coalition much less adopted by the more than 300 other non-coalition ABET accredited colleges and universities across the U.S.. As Borrego (2007) reported, coalition critics contend that too large of an investment was concentrated within too small a number of institutions. Similarly, Coward et al. (2000) noted that coalition product penetration by this small group into the wider engineering education market has been attenuated by multiple factors. While coalition products are generally rated well, they were reportedly introduced with few opportunities for active dissemination, limited documentation and variable adaptability. Demand for such products is easily diminished if the barriers to adoption are perceived as high in terms of faculty time and logistical requirements. In terms of content, Seely (2005) observed that the coalitions "invested comparatively little effort in adding topics to engineering curricula or in reordering existing subject matter."

A central contribution of the coalitions has been their efforts to improve assessments of student outcomes, work which strategically informed the development of ABET EC 2000 criteria. Indeed Seely (2005) observed that the coalitions had to "start from ground zero" to develop the instruments and processes to assess most of the desired student outcomes in engineering design courses. It is significant that at the time the coalition program was initiated, virtually no infrastructure was in place to evaluate the efficacy of interventions in engineering education. A second important coalition contribution was the demonstration of the relevance of active, experiential learning environments, the importance of teamwork as well as using a variety of instructional technologies to make concepts accessible by a greater fraction of the student population (Seely 2005). So as a fundamental first step, coalition efforts were characterized, if not prioritized, according to improvements to content delivery (e.g., teaching) and assessment of content consumption (e.g., learning) with less focus on the content itself.

DEPARTMENT LEVEL REFORM

The coalitions contributed to systemic advances in the practice of engineering education while leaving many motivating and discipline-specific challenges of undergraduate engineering education intact. The NSF sought to build on the efforts of the coalitions through a new Department Level Reform (DLR) funding model. The DLR program was initiated in 2002 with a solicitation for planning grants from institutions to "update and reconstitute elements of the core curricula in existing engineering disciplines or invent elements of completely new curricula for emerging engineering disciplines or cross-disciplines" (NSF 2002). The desired attributes of DLR projects were refined slightly each year (2002-2005) with the following guidance as to how engineering programs might be improved (NSF 2005):

- *"Introducing emerging knowledge related to information technology, bioengineering, microelectronics, microelectromechanical systems (MEMS), nanotechnology, product design and realization, advanced materials, manufacturing, etc.*
- *Using cognitive theory and latest pedagogical concepts to improve learning outcomes.*
- *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 and design practices employed by practicing engineers to solve engineering problems, preferably in collaboration with industry leaders in developing tools implementing such methods.*
- *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.*
- *Making full use of modern teaching methods, including mentoring, team-based and experience-based learning, computer simulation, and distance learning.*
- *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*

Overview of DLR

Solicitations in 2003-2005 provided opportunities for both planning and implementation of proposed reform activities. In total, approximately 80 Department Level Reform (DLR) awards (~$26 million) were made from 2002 to 2005 with expiration dates from 2007 to 2009. Of the total number of awards, 20 were funded at a higher level, ranging from $400,000 to $1.5 million for each institution over a period of approximately 3-4 years, commensurate with the effort required for full implementation of proposed changes. The remaining awards were funded at a lower level of about $100,000, consistent with efforts devoted toward planning possible changes for a given department or college. It was clear that not all recipients of planning grants would successfully secure subsequent funding from NSF for implementation, according to budget limitations and the level of competition. However in these instances the intent was to encourage principal investigators to leverage the plans developed with NSF support to attract institutional and/or other external interest for partial or full implementation, as appropriate. In all cases and independent of the scope and level of funding provided, the NSF seeks to be catalytic, reducing the activation energy required for institutions to effect change. The goal is for such changes to be sustainably institutionalized without indefinite NSF support, and it is expected that other stakeholders are willing and able to contribute to DLR goals. In particular, the desired outcomes of DLR projects were to enhance the alignment of the engineering curriculum with modern engineering practice as well as to deepen the pool of undergraduates interested in such curricula. Such features are entirely consonant with engineering programs and the accreditation process in US universities and colleges.

This special issue focuses on DLR implementation projects, as they most fully illustrate the nature and extent of program activities. In Table 1 a complete list of principal investigator, title and institution for each DLR implementation grant are provided. This information is provided to enable the reader to obtain more details from the individuals leading these activities.

As shown in Figure 1, DLR funding was used primarily to reconstitute existing programs in individual departments, namely, civil and environmental, mechanical, electrical, chemical, industrial and materials science engineering. Of the 20 implementation projects, two involved multiple departments at a given institution. The University of Massachusetts at Lowell vertically integrated service learning throughout all departments within the College of Engineering. Old Dominion University incorporated simulation and visualization throughout its departments of civil and environmental engineering, electrical and computer engineering, and mechanical engineering. DLR funding was also used to initiate five non-traditional programs, including, microelectronic engineering at Rochester Institute of Technology, bioengineering at Lehigh University, physics and engineering science at Sweet Briar College, multidisciplinary engineering at Purdue University and biological systems/general engineering at Virginia Tech. In terms of traditional programs, the University of North Texas used its DLR funding to develop a new electrical engineering program while the University of Central Florida augmented their industrial engineering program with a new minor in engineering leadership and management.

The distribution shown in Figure 1 was the natural consequence of the community response, the peer review process, and available funding. Given the widely varying contexts and conditions which define engineering schools, the number of departments in a given discipline to be supported was not

Principal Investigator	Title	Institution
Busch-Vishniac, Ilene	Enhancing Diversity in the Undergraduate Mechanical Engineering Population Through Curricular Change	Johns Hopkins University
Chaturvedi, Sushil	Simulation and Visualization Enhanced Engineering Education	Old Dominion University
Cheville, Richard	Collaborative Research: Engineering Students for the 21st Century	Oklahoma State University
Collins, Leslie	Theme-Based Redesign of the ECE Undergraduate Curriculum at Duke University	Duke University
Delale, Feridun	Redefining Mechanical Engineering: Systemic Reform of the Mechanical Engineering Program at City College	CUNY City College
Duffy, John	Service-Learning Integrated throughout a College of Engineering (SLICE)	University of Massachusetts Lowell
El-Aasser, Mohamed	Establishing a Cross-Disciplinary Bioengineering Program with a Technical Entrepreneurship Focus	Lehigh University
Furse, Cynthia	Integrated System-Level Design in Electrical Engineering	University of Utah
Garcia, Oscar	A Project- and Design-Oriented Innovative Electrical Engineering Program	University of North Texas
Glover, Charles	Chemical Engineering Undergraduate Curriculum Reform	Texas A&M University
Gupta, Vinay	Transforming the Educational Experience of Transfer Students in Chemical Engineering using a Multi-Dimensional Spiral Curriculum	University of South Florida
Haghighi, Kamyar	Reforming Engineering Education: Multidisciplinary Engineering	Purdue University
Hayden, Nancy	A Systems Approach to Civil and Environmental Engineering Education: Integrating Systems Thinking, Inquiry-Based Learning and Catamount Community Service-Learning Projects	University of Vermont
Kurinec, Santosh	Leading Microelectronic Engineering Education to New Horizons	Rochester Institute of Tech
Lohani, Vinod	Reformulating General Engineering and Biological Systems Engineering Programs at Virginia Tech	Virginia Polytechnic Institute and State University
McCarthy, Joseph	Pillars of Chemical Engineering: A Block Scheduled Curriculum	University of Pittsburgh
McGourty, Jack	Reforming Undergraduate Education in Environmental Engineering: Urban Studios as Knowledge Delivery Systems and Vehicles for Service Learning	Columbia University
Rabelo, Luis	Reengineering The Undergraduate Industrial Engineering Program	University of Central Florida
Vanasupa, Linda	Triple Bottom Line Awareness in Design (TriAD): Diversifying the Engineering Profession of the 21st Century	California Polytechnic State University
Yochum, Hank	Implementation of a New Engineering Studies Program at Sweet Briar College	Sweet Briar College

Table 1: List of DLR Implementation Projects.

prescribed nor was there an effort to engender a particular number of new programs. Department-wide curricular and pedagogical transformations are defining features of DLR projects. These are summarized in terms of curricula, modalities and themes in Table 2.

Table 2 is not exhaustive, nor is it meant to be an exclusively binary representation of the absence or presence of various attributes. The intent is rather to highlight those aspects which characterize the locus of activity, ascertained on the basis of the original proposal, reports in the open literature,

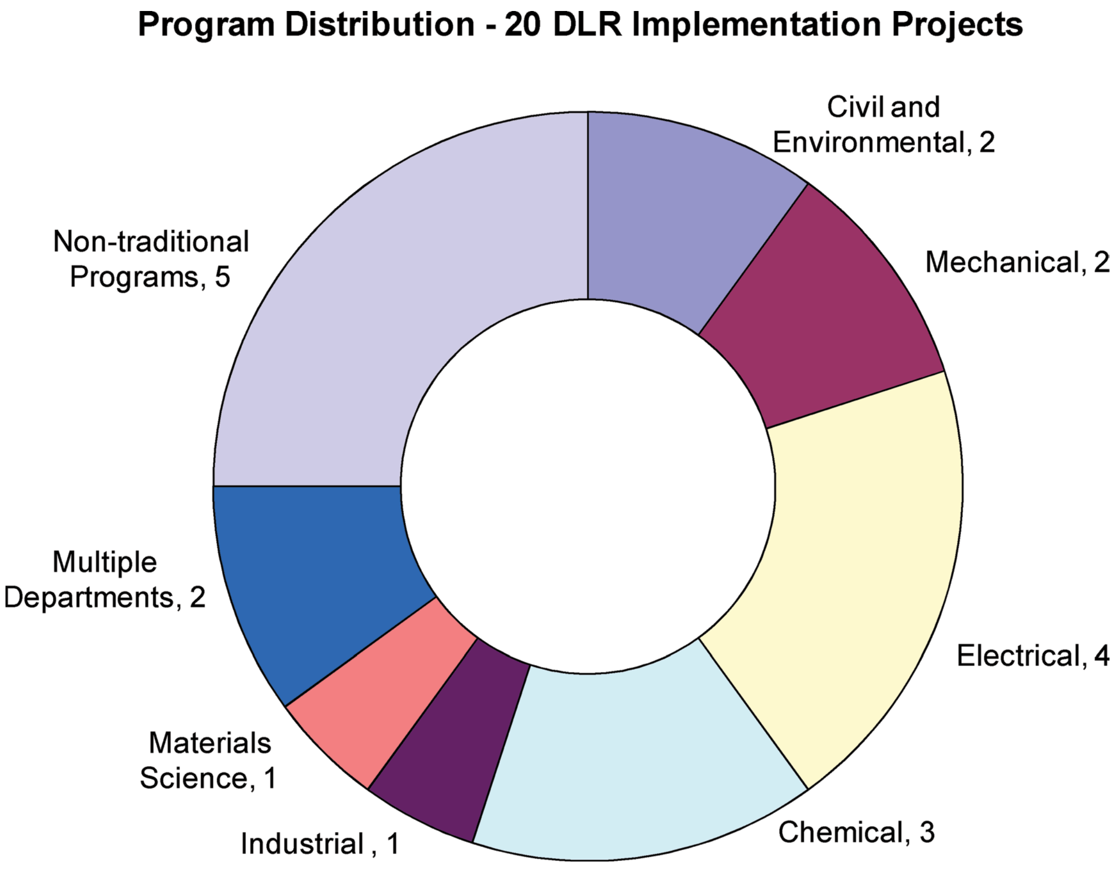

Figure 1. Distribution of DLR implementation grants across disciplines and programs.

grantee meetings and conferences as well as subsequent evaluations (NSF, 2008; STPI 2008a,b). Selected DLR projects are described in the next sections to illustrate the defined categories in Table 2, while greater detail may be found in the articles in this special edition as well as previous publications from DLR awardees. Abstracts of awards and subsequent publications, as reported by principal investigators, are available at: http://www.nsf.gov/awardsearch/.

Curricula

Curricular innovations are generalized in Table 2 according to the development of new academic programs, courses, course format, content and/or the sequence of content. Nearly all of the DLR projects created new courses, new course content, or new sequencing of material throughout the curriculum. In terms of sequencing, many of the DLR projects vertically integrated engineering design experiences throughout the curriculum, ensuring such opportunities occur as early as the

Institution	Curricula					Modalities					Themes					
	Programs	Courses	Course Format	Content	Sequence	Active Learning	Service Learning	Project-based	Visualization	New Technology	Cross-disciplinary	Systems	Leadership/Ethics	Sustainability	International	Entrepreneurship
California Polytechnic		•		•	•	•	•	•			•	•	•	•		
Central Florida	•	•		•	•	•				•			•			
City College NY		•		•	•	•		•	•		•					
Columbia		•	•	•	•	•	•	•		•	•			•	•	
Duke		•			•	•				•	•	•				
Johns Hopkins		•	•	•	•			•					•			
Lehigh	•	•		•	•	•		•			•	•				•
Massachusetts Lowell		•		•	•		•	•						•		
North Texas	•	•		•	•	•		•								•
Oklahoma State		•		•	•	•		•		•						
Old Dominion				•		•			•	•						
Pittsburgh		•	•	•	•	•		•		•						
Purdue	•	•		•	•	•	•	•		•	•		•			
Rochester	•	•		•	•		•	•			•					
South Florida		•		•	•	•										

Table 2: Highlighted transformations in DLR projects in terms of curricula, modalities and themes.

Sweet Briar	●	●		●	●	●	●	●							●	
Texas A&M				●	●	●	●	●		●				●		
Utah		●		●	●	●	●	●				●				●
Vermont		●		●	●	●	●	●			●	●				
Virginia Tech	●	●		●	●	●		●		●		●	●	●		

Table 2: (Countinued)

freshman year. The chemical engineering program at the University of Central Florida and the biological systems program at Virginia Tech followed a spiral curriculum paradigm, in which students learn and revisit concepts with increasing sophistication and from different perspectives as they progress through the curriculum.

The overall emphasis of the DLR project portfolio on content development may be seen as a natural extension and complement to prior coalition efforts which instead emphasized an improvement in teaching methods and learning assessment, not content creation. A few programs changed typical course format, which is defined herein as an explicit reconfiguration of course duration and faculty contact hours. For example, Columbia University transformed several individual courses into urban studios within their environmental engineering program. The format was designed to foster an intensive environment for collaboration between faculty and students, analogous to pedagogy more commonly found in schools of architecture. Likewise, the University of Pittsburgh implemented a block scheduling approach, as has successfully been used in K-12 systems, to deliver its chemical engineering curriculum. Rather than focusing on compartmentalizing content according to traditional credit hour restrictions (e.g., a three credit hour class), a block scheduling approach employs topically centered "pillar" courses which may range from five to seven credit hours.

Modalities

With measurable learning as the goal, one might argue that the manner in which content is delivered approaches the importance of the content itself. Following and building upon the literature base, DLR projects utilized active learning, service learning, project-based instruction, visualization, as well as new technologies to foster engagement inside and out of the classroom. For example, as described in this special issue, Vanasupa (2010) applied theories of self-determination and self-regulation to the design of courses in the Department of Materials Engineering at California Polytechnic (Cal Poly), San Luis Obispo. The authors identified three key aspects of the learning environment which influence student engagement in learning: freedom of choice, social relatedness support and an explicit connection to broader contexts. The results of the work at Cal Poly suggest that greater learning in the near and long-term is possible when the course climate is holistically designed to address a wide array of antecedent student experiences, while emphasizing student autonomy and content relevance.

Satisfying academic requirements within a degree program by performing service to the community was successfully implemented by several DLR projects. At the University of Massachusetts at Lowell, fifty courses have had service learning integrated into them at a level that exceeds of 15% of the overall content. Through the DLR, forty-eight faculty members have tried service learning in an average of four core courses each. Eight hundred students on average each semester completed service learning projects. The research suggests that such a systemic approach to service learning has resulted in notable increases in student interests, attitude, retention and learning. By definition, all DLR projects which involved service learning were also project-based, although several DLR projects employed projects and case studies that did not involve service to the community yet allowed students to derive the benefits inherent to such inductive methods of instruction.

Integration of technology played an important role in many DLR projects. Old Dominion University used their DLR to explore the use of visualization and allied cyberinfrastructure to improve learning of complex concepts that do not lend themselves to physical modeling. As listed in Table 2, a number of institutions invoked the use of new classroom technologies such as clickers and tablet PCs to respond to real time with fluctuations in student learning and inquiry. For example, researchers at Virginia Tech have documented the improvement in student experience with tablet PC instruction through the use of classroom software that facilitates increased interaction.

Themes

In addition to the various changes in curricula and the modes in which learning was augmented in DLR projects, a number of projects were characterized by an overall theme. As shown in Table 2, these are categorized according to whether a project emphasized cross-disciplinary activities, a systems orientation, leadership and ethics, sustainability, international awareness or entrepreneurship. In general, the leitmotif of a given DLR serves as a framework of broader context with which various research experiences, projects and course material are connected. Some projects have multiple themes. For example, Columbia University was thematically characterized by cross disciplinary activities as fostered by collaboration with the Departments of Earth and Environmental Engineering (EEE), Civil Engineering and Engineering Mechanics (CEEM) and Mechanical Engineering (ME) as well as the Graduate School of Architecture, Planning, and Preservation. Sustainability concepts were incorporated into the community service projects, and the hands-on laboratory modules. A departure point for inculcating global awareness was provided by having New York City as the focal point of activities at a time when an increasing fraction of the world's population is located in mega-cities (i.e., cities with a population in excess of 10 million), as noted in the Grand Challenges articulated by the National Academy of Engineering.

As another example, Lehigh University emphasized entrepreneurship as part of its DLR project to create a cross-disciplinary bioengineering program. All students in the program participated in integrated product development projects which benefited from industry partnerships and start up companies. Students from this program graduate with the understanding that while they are eligible for many job opportunities they also have the ability to create jobs, thereby contributing to economic prosperity and national security.

Assessment

While many institutions have used DLR projects to establish new programs that continue beyond NSF funding, at this point, all DLR projects have completed the scope of work funded by the NSF. As such, it is appropriate to consider what has been accomplished and how that might inform future initiatives. To that end, a workshop focused on the DLR program was held (NSF 2008) and a review of the outcomes and impacts of the DLR program was conducted by the Science and Technology Policy Institute of the Institute for Defense Analyses (STPI/IDA 2008a,b).

The purpose of the workshop, held on May 15, 2008 in Arlington, Virginia, was to solicit general comments on trends in engineering education as well as DLR-specific feedback. The meeting was also an opportunity to collect input as to what sort of programs and investments ought to be pursued in the context of the American Competitiveness Initiative, the America Competes Act and general federal policy. With respect to DLR, the consensus of the workshop was that an implementation effort over three to four years was too short of a time frame to fully gauge longitudinal performance and impact. Meaningful department level change is an inherently ambitious task, analogous to the effort required to achieve a research vision over ten years, as with the Engineering Research Center program. To leverage existing investments, it was recommended that regional workshops should be funded by NSF and offered as a way to disseminate DLR best practices, with involvement as appropriate by technical and professional societies.

The evaluation by STPI/IDA was intended to (1) evaluate the extent to which the DLR program met its goals, (2) determine how effective the DLR program was for catalyzing useful changes in engineering departments and (3) define the indicators of success for individual DLR projects or the entire portfolio. The DLR program was evaluated, in part, through ex ante and ex post analyses with the National Academy of Engineering recommendations in the report *Educating the Engineer of 2020* (NAE 2005) as well as with the ABET Inc. criteria, commonly referred to as "a-k" (ABET 2007). In terms of key findings of this evaluation, the comparison between DLR project goals and NAE recommendations were considered to mesh well as did the DLR criteria and implementation relative to ABET criteria. However, too little longitudinal data was available to comment on the permanence of DLR-initiated changes, as measured in terms of specific outputs and outcomes. As with the workshop (NSF 2008), one of the recommendations was to increase the duration of projects and augment resources for assessment.

FUTURE DIRECTIONS

How can the program improvements, advances in understanding, and achievements from DLR projects attain wider visibility for the benefit of other departments and programs? As a field, engineering education has continued to mature. There is now a recognizable framework of understanding that includes theoretical and practical elements. The framework is erected on foundational literature and has mechanisms in place to ensure continued growth. For example, a diversity of research funding streams are regularly available, articles from journals and conference proceedings are more widely referenced and academic departments and programs have been developed, all in support of engineering education. Yet there remains a nontrivial communication gap between those engaged in engineering education research and those who would benefit from such efforts. This topic is very aptly described in the June 2009 report of the American Society of Engineering Education which is entitled "Creating a Culture for Scholarly and Systematic Innovation in Engineering Education". The overall goal is to establish an innovation cycle of engineering educational practice and research. See http://www.asee.org/about-us/the-organization/advisory-committees/CCSSIE/CCSSIEE_Phase1Report_June2009.pdf for the complete report.

Also, the imperative to better prepare engineering students for their role in society is eloquently articulated in the National Academy of Engineering report entitled Grand Challenges for Engineering. See http://www.engineeringchallenges.org/?ID=11574. There are fourteen grand challenges which describe how engineering provides crucial contributions to societal needs. These grand challenges all require the next class of engineers to be able to deal with complexity, systems thinking and systems engineering. The grand challenges also require that the next class of engineers be able to communicate effectively with policy makers and the general public throughout the world. And finally, the grand challenges will require engineers who are continuously updating their technical and professional skills to match societal needs and/or emerging opportunities. Indeed one of the grand challenges, "personalized learning" addresses this very issue by calling for research and development to invent new processes and tools to achieve life-long continuous learning for all people.

The future requires a societal, institutional and personal commitment to learning. Hopefully we have arrived at the phase in which the infrastructure and understanding of engineering learning developed by these DLR efforts can be applied to institutional and individual learning contexts and needs. Ultimately, engineering education is about building capacity to solve the increasing flux of grand challenges posed by sustainably living in the 21st century. The papers in this special issue provide insight on how such capacity can be developed in a variety of institutional profiles across multiple disciplines. We invite you to explore and use them.

REFERENCES

ABET. "Engineering Education Answers the Challenges of the Future," Proceedings of the National Congress on Engineering Education, Accreditation Board for Engineering and Technology, Inc., November 1986.

ABET. 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, 2007.

ASEE. "Quality of Engineering Education," Final Report of the Quality of Engineering Education Project, American Society for Engineering Education, September 1986.

ASEE. "A National Action Agenda for Engineering Education," Report of an ASEE Task Force (E. E. David, Jr., Chair), American Society for Engineering Education, 1987.

Borrego. M. "Development of engineering education as a rigorous discipline: A study of the publication patterns of four coalitions." *Journal of Engineering Education*, 96 (1):5-18, 2007.

Coward, H.R., Ailes C.P. and Bardon R.. *Progress of the engineering education coalitions*. Final Report prepared for the Engineering Education and Centers Division of the National Science Foundation, SRI International: Arlington, VA, 2000.

Jesiek, B.K., Newswander L.K. and Borrego M.. "Engineering education research: Discipline, Community or Field?" *Journal of Engineering Education*, 98 (1):39–52, 2009.

NAE. *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*, National Academy of Engineering, 2005.

NRC. *Engineering Education and Practice in the United States*, National Academy Press, Washington, DC, 1985.

NSB. *Undergraduate Science, Mathematics, and Engineering Education*, National Science Board, NSB 86-100, Arlington, VA, 1986.

NSF. Engineering Education Coalitions: Program Solicitation, NSF 89-107, Directorate for Engineering and Directorate for Science and Engineering Education. Washington, DC: National Science Foundation, 1989.

NSF. Planning Grants for the Department-Level Reform of Undergraduate Engineering Education, NSF 02-091. Program solicitation Arlington, VA: National Science Foundation, 2002.

NSF. Grants for the Department-Level Reform of Undergraduate Engineering Education Education, NSF 05-531. Program solicitation Arlington, VA: National Science Foundation, 2005.

NSF. *Department Level Reform, Proceedings of the Path Forward Workshop* Directorate for Engineering, Division of Engineering Education and Centers, August 2008 Arlington, VA: U.S. National Science Foundation, 2008.

Seely, B. E. "Patterns in the history of engineering education reform: A brief essay." In: *Educating the Engineer of 2020, Adapting Engineering Education to the New Century*, National Academies Press, Washington DC, 2005.

STPI/IDA. *Evaluation of the National Science Foundation (NSF) Engineering Education Program: Grants for the Department-Level Reform (DLR) of Undergraduate Engineering Education. Part I: Synthesis Evaluation*. OIA-040860, Task OSTP 20-0002.37, 2008a.

STPI/IDA. *Evaluation of the National Science Foundation (NSF) Engineering Education Program: Grants for the Department-Level Reform (DLR) of Undergraduate Engineering Education. Part II: Case Studies and Dissemination Outputs*. OIA-040860, Task OSTP 20-0002.37, 2008b.

Vanasupa, Linda. 2010. The Process of Systemic Department-Level Change: A view from the inside. *Advances in Engineering Education* in review, submitted 7/31/09 (Special Issue on Department Level Reform).

Willenbrock, F. K. *Imperatives in Undergraduate Engineering Education: Issues and Actions*. Report of an NSF Ad Hoc Task Force , "the Belmont Conference" August. Washington, DC: National Science Foundation, 1989.

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