Abstract — The "Gateway" Engineering Education Coalition is a collaborative of 7 academic institutions, supported by the Engineering Directorate of the National Science Foundation. Headquartered at Drexel University and representing diverse institutional structures and cultures, the Coalition has opened new "gateways" for learning by altering engineering education from a singular focus on course content to one inclusive of the development of human resources and the broader experience founded on a multidisciplinary, integrated curriculum. As intellectual threads, the introduction of engineering and its functional core "up-front", the integrative aspects of the engineering process, the development of professional competencies, multidisciplinary emphasis, assessment and continuous improvement, and instructional technologies are woven together into a seamless educational fabric. This paper describes the interactive processes among and within institutions and the resulting sustainable systemic changes to the engineering education programs of both the Coalition institutions and well as many schools outside of the Coalition.

Index Terms — assessment, curriculum integration, engineering education, human resource development, learning, multidiscipline.

COALITION VISION

The Gateway Coalition, centered at Drexel University, is a partnership of seven institutions. These partners include the Colleges of Engineering of Columbia University, Cooper Union, Drexel University, New Jersey Institute of Technology, Ohio State University, Polytechnic University of Brooklyn, and the University of South Carolina. The Coalition's broadest goal is to change the way we conduct the engineering educational process; to change the process of engineering education reflected not only in innovative curriculum development but also in how faculty interact with students, how students learn, and how emerging technologies are imbedded into the educational environment. Thus making it more exciting and more effective in learning.

As we alter the educational landscape, we address how we teach as well as what we teach, informed by a continuous quality improvement process with the discipline of asking ourselves who our audience is, what our objectives are, how we will know when we have achieved those objectives, and what tools are necessary to make those assessments.

We strive to develop an emerging engineering professional who possesses a broad set of competencies by instilling in him or her, from the very first day on campus, an understanding of the context as well as the content of their academic program and their professional objectives. This is further achieved by making the student a collaborative contributor to the learning process through an integrated curriculum and program where the faculty and institutional leaders help the students make the connections; synthesize as well as analyze; develop a sense of open ended inquiry, and do so through a learning environment that fuses experiential learning with the fundamental scientific and technical principles, all within an engineering context.

The specific goals and expected outcomes of the Coalition are derived from the common interests, vision, and expectations of the collective body of individual institutions and supported by the facilitating role and influence of the cross-coalition support functions. The Coalition (i.e. the collective body of institutions) has defined six major functions and related objectives that address those common interests, goals, and vision. While the emphases have shifted over time, the six major objectives remain as follows:

- Implement and continuously improve innovative and adaptable curricula, driven by the work of the coalition and others, recognizing the needs of students, industry and society.
- Imbed a culture in the learning environment for Professional Development of faculty and students.
- Broaden Diversity of race, gender and socio-economic status to enlarge the opportunities for development of our human capital and to enhance the respect for, and benefits of, diverse cultures.
- Broaden the use of Information Technology to further the learning and educational objectives.
- Imbed Assessment and Evaluation, as well as continuous improvement, as a fundamental ingredient of the educational process.
- Routinely link and share with others, through web sites, publications, conferences, and product realization, to transcend individual, disciplinary, and intra-institutional and inter-institutional boundaries.

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Curriculum Development and Implementation

A primary objective of the coalition has been to take a leadership role in generating new curricular innovations to provide 21st century engineers with the knowledge and skills that will be required. The changes are in the fundamental structure of the educational program as well as in program content. Starting with an emphasis on engineering design as both a driver and motivator, all of the Gateway schools have implemented comprehensive design experiences into the freshman year, allowing first year students to gain true insight into their field of choice and to grasp the foundational mathematics and sciences in an engineering context. These freshman experiences have served as a catalyst for further curricular and cultural changes throughout each institution.

The majority of first year students, enrolled in Gateway institutions, participate in freshman design experience. Over 3000 freshmen were directly impacted during this academic year as illustrated in figure above. The focus on design in the first year is completely institutionalized at all partner schools. Also of importance in this curricular and cultural change is the number of senior faculty now involved in teaching lower division courses. The number has quadrupled since the beginning of the Coalition. Senior as well as Junior faculty are participating and this participation in lower division courses is beginning to be noted as part of the institutional faculty reviews and rewards. The Coalition has recently released a textbook titled "Tools and Tactics of Design" which embodies the interaction of the technical with the interpersonal, organizational, and communication skills as embodied in the Coalition's curricular strategies. The text may be obtained through John Wiley & Sons, publisher.

The curricular innovations span the full matriculation period of freshmen to seniors; many with a multidisciplinary emphasis. Examples of course developments and modules beyond the freshman experiences include such areas as systems and control across multiple disciplines, materials engineering, environmental engineering, engineering biotechnology, concurrent engineering and manufacturing, as well as embedding the issues of ethics and communications within the engineering program. In addition, modules on such emerging fields as wireless communications, medical robotics, waste containment, nanotechnology, network security, genomic engineering, internet technologies, and network security are being added to the portfolio of available resources. Our website contains examples of syllabi and course materials, some complete downloadable programs, and samples of others that are available in full through traditional publishers.

Our institutions have individually and collectively worked on the development and implementation of innovative upper division multidisciplinary programs. The role of such upper division interdisciplinary courses in the curriculum is to broaden the technical background of every undergraduate engineering student and is achieved through two approaches. One approach provides fundamental in-depth knowledge in an area bridging several more traditional disciplines while the other presents new and exciting discoveries and developments at the forefront thus eliciting the excitement of engineering horizons. The purpose of these new programs is to expose the students to technologies that are yet to mature. The former generally includes significant problem solving and design issues while the latter is more conceptually based serving as a motivator and more general broadening experience solving design issues from any disciplinary major. The latter brings a sense of excitement in new and evolving engineering disciplines; many of which can be seen to improve the human condition or serving as a driving force for economic vitality. These initiatives often encompass topics of the “Nano”, “Info” and “Bio” technologies, manufacturing, materials, and others.

Professional Development

Changes in the Gateway engineering educational process have led faculty and students to participate in professional development with a broader set of educational competencies. For faculty these changes involve the use of new educational support tools, an increase in understanding how students learn, and how faculty can help students increase their ability to apply new information, new tools, new skills, and new approaches. For students there are new programs that integrate communications skills, teaming and interpersonal skills, and the ethical dilemmas faced by engineers. In keeping with Gateway’s fundamental premise, these skill-based activities are imbedded within the student’s educational program to bring the issues to life in real context rather than as separate programs to be provided outside of the College of Engineering. A series of monographs on student oral and written communication as well as course modules emphasizing ethics can also be found on the Coalition’s web site. Additionally, information and downloadable sample of the Team Developer, a
Faculty incorporate cooperative learning techniques in the classroom. These techniques promote interdependence amongst students, encourage interaction, require information sharing and typically include the use of team-based projects as cornerstones of the learning process. One of the keys to making cooperative learning successful lies in shifting the student’s role from that of a passive receiver of information into an active participant in both his/her own and his/her peers’ learning. Across many of partner’s initiatives there is a growing movement to involve the student more in the learning process. This is a major change in the educational environment and various activities to increase student involvement have been supported.

**Underrepresented Populations**

Evaluation of project institutionalization and related activities includes measures of women and minorities’ participation in an effort to mainstream these underrepresented groups throughout all Gateway initiatives. A principal outcome is to establish a foundation that is inclusive and beneficial to these groups. This concept is in keeping with the view that the Gateway programs themselves, as they are institutionalized, should be able to provide improvement in the many factors that lead to better attraction and retention of underrepresented groups in engineering education as well as serve the broader general institution’s engineering student population.

The Coalition has focused on strategies that improve the enrollment and retention of women and minorities in engineering undergraduate education. As a Coalition, we have encouraged extension of traditional institutional supported programs and supported several selected programs dedicated to serving the needs of women and minority students. All of our partner institutions have programs in place and are continuously looking to improve these. In addition to supporting existing programs, we have been instrumental in initiating some innovative approaches for enhancing our students’ skills. Many of our institutions have embraced mentoring as an effective approach to supporting women and minorities as they enter the early stages of their engineering education. Learning from each other, our schools have continued to enhance these formal mentoring mechanisms. We are pleased that these programs have helped lead to significant increases in retention in engineering from first to second year and second to third year for our women and African American populations as well as the general engineering student body. The percentage of the engineering undergraduate degrees that have been awarded to women in the Coalition schools has increased by about fifty percent and the percent of degrees that have been awarded to African Americans has more than doubled since the beginning of the Coalition.

**Instructional Technologies**

Gateway has been innovative and aggressive in anticipating the potential of new modes of interaction and communication and its impact on the educational landscape. We have created a Gateway communication infrastructure that is already enabling and encouraging the Coalition schools to share, on-line, a variety of distributed resources such as faculty, laboratories and learning/teaching tools. The focus has been on expanding the boundaries of instruction beyond the classroom and beyond each institution. This includes electronic sharing of courseware, remote access and control to laboratory and other unique facilities, remote control of student experiments, video conferencing among institutions connecting Gateway colleagues and students, bringing experts into the classroom in real time, sharing images and programs as well as textual material in real time, conducting electronic collaboration on course design and instruction.

The Coalition's efforts have resulted in significant gains in incorporating new media technologies into the classroom and beyond. For example, our collective faculty are now using new media technologies in over 370 courses throughout the seven schools. There are several reasons for this increased usage in new media technologies. First, a large percentage of professional faculty development activities have focused on the integration and application of digital technologies in the classroom. Another factor that has enhanced the use of instructional technologies is that each of our schools has learned how to capitalize on their strengths in the technology area by forging new interdisciplinary relationships within their institution thus driving and taking advantage of the information technology infrastructure of the institution. A third practice supporting faculty use of technology is the emerging trend to capitalize on student technical expertise with web and multimedia applications.
Assessment

One of the Coalition’s objectives is to embed and institutionalize outcome-based assessment and continuous improvement processes within engineering educational programs, departments, and colleges. Our assessment program is structured to instill the discipline of asking ourselves who our audience is, what our objectives are, how we will know when we have achieved those objectives, what the necessary tools are to generate those assessments and, finally, to establish a feedback process that enables the faculty and leadership to make valuable use of the information obtained.

All the Coalition schools have focused on expanding their assessment programs so that one hundred percent of students participated in these evaluation and feedback processes. Much of the activity to accomplish this objective involves the integration of technology to support assessment processes. The majority of our schools have expanded their web-based assessment programs beyond the pilot test phase and into full implementation. Fully functional systems allow all students and faculty to participate. Systems applications developed include course evaluation, longitudinal tracking, student, faculty, alumni, and employer surveys. Several schools have made great strides in implementing an electronic course evaluation system. The course evaluation applications include such features as basic survey development, data collection and database management capabilities, and multi-level report generation.

Another product that has recently become fully available is the Team Developer™. The Team Developer is a computer-based approach to the assessment and feedback process used to solicit student self and peer feedback learning outcomes linked to engineering curricula. The computer application enables students to evaluate both themselves and other members in their project team on skills required to successfully complete projects and the class, in general. Individual feedback reports are processed and distributed back to the students providing them information to support their future development of these competencies. Faculty members receive aggregated results to support both student growth and course improvement. Over 2000 students both in and outside the coalition have used the product in its beta test phase. This product can be obtained from John Wiley & Sons, publishers. A sample is available on the Gateway web site.

The technology based assessment tools, such as the complete turnkey web-based assessment program with the UNIX based executable program and operational instructions, as well as tools and other aids to assist in identifying objectives, establishing outcomes, and creating survey instruments are available via the Coalition’s web site. Also available are quantitative graphical illustrations of the changes in some of the forty parameters that have been monitored among the partner institutions since the Coalition’s inception.

Linking and Sharing

The Gateway Coalition has developed many new materials relating to the curriculum, explored new teaching methodology, used the newest technologies for undergraduate education, instituted professional development activities, and institutionalized assessment and continuous improvement in all partner schools. These developments are the elements around which systemic change at individual institutions are being implemented. The NSF Coalitions provide a wealth of examples and pilot programs that can be used for full-scale adoption. The key is to get the information to the planners and potential users. With this objective in mind, the Coalition has pursued an aggressive dissemination program that includes product realization and distribution via the Web, numerous professional workshops, and published papers, monographs, and conference presentations. Many collaborative associations with other institutions at the four-year college, community college, and some pre-college levels have been established to share information, experiences and results. The Coalition's web site is regularly updated with new materials. The reader is reminded of the URL address as <http://www.gatewaycoalition.org>.

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