The Global Engineering College: exploring a new model for engineering education in a global economy

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ABSTRACT

The increasing globalization of corporate economies has changed the face of engineering practice. In addition to core engineering skills, modern engineers must possess cross-cultural communication skills, team management skills, and the ability to perform on geographically distributed teams. We describe a novel curricular paradigm called the **Global Engineering College** (GEC) that we are currently exploring under an NSF planning grant. The GEC concept is based on the idea of seamlessly combining the curricula and educational opportunities of several internationally-distributed engineering institutions to create a *virtual engineering college* spanning multiple countries and cultures. We report on the technical, pedagogic, and administrative challenges we have exposed in our exploration of the GEC concept, and on our approach to addressing them.

1.0 INTRODUCTION

For the past several decades, the internationalization of college curricula has been a prominent theme in discussions of curricular reform in higher education (Altbach, 2002; Gray, 2002; Green, 2002; Marginson, 2002; Maxwell, 2002; Miller, 2002; Sjogren, 2002). Few question the necessity of this reform, and the rapid progress of globalization during the last ten years has lent new urgency to this need (Bikson, 1994; Lambert, 1999). A number of institutions have taken concrete steps toward implementing internationalization within individual academic units as well as across the university as a whole. As early as 1993, Oregon State University introduced its "Passport" International Degree Program under which students can supplement a degree in virtually any field with an "international degree" (http://www.orst.edu/Dept/int_degree/). At about the same time, the University of Rhode Island began offering a Bachelor's Degree in International Engineering, a five-year program that graduates students with a traditional engineering degree as well as a B.A. in a language (http://www.uri.edu/iep).

While the initial impetus for internationalization may have come from humanities and the social sciences (the traditional study abroad disciplines), engineering and the natural sciences have realized that their graduates also require strong international skills in order to succeed in the global engineering workplace of the twenty-first century. In April 1995, the cover story of *PRISM*, the journal of the American Society for Engineering Education (ASEE), referred to over 70 engineering programs with international components (Ercolano, 1995). Since then, the rationale for such programs has only grown stronger; the world's economy has become vastly more interdependent, exports account for an increasing percentage of economic activity, and capital, work and jobs move rapidly and frequently from one continent to another. As a result, the trend towards smaller, more independent collaborative development teams over the last two decades of modern engineering practice has rapidly evolved into *international* collaborative teaming. Any recent engineering graduate can expect to work, at some point in his or her career, on teams with members from varied cultural and linguistic backgrounds, geographically distributed across several international locations.

Although international programs for engineering students have had some success, their impact on engineering education as a whole has remained curiously limited and peripheral; the number of student participants remains relatively small. Even the relatively successful International Engineering program at the University of Rhode Island enrolls only about 10% of the over 1000 engineering students at URI[1]. Although the program provides excellent international training, its impact on the majority of the URI engineering graduates remains peripheral; students who do not have the motivation to enter the program at the beginning of their degree program receive little or no international engineering exposure.

The experience at Northern Arizona University has been similar. Following the traditional study-abroad model, the College of Engineering and Technology (CET) at NAU developed an array of opportunities for undergraduate international experience, including student exchanges with a growing number of partner institutions, international internships, lectures by international visitors, and courses taught by international faculty. Student interest in these initiatives has been excellent; more students are now participating in international exchanges (from an average of 1/year in 1990-1994 to an average of 5/year in 1995-2002) and students have formed an International Club that has promoted short familiarization trips to partner institutions in Germany. Additionally, three years ago, the CET developed a Certificate in International Engineering, which indicates that the student has completed - within his or her regular degree program - a 15-credit hour program that includes upper division (300+) language competency, a suite of liberal studies courses that focus upon international issues, and a study abroad experience (http://denali.cse.nau.edu/CETIC/IntnlCertificate.html). Despite these strong efforts, *fewer than 2% of graduating engineers receive significant international training*.

To understand *why* so few students make an international experience part of their engineering education, we surveyed CET graduates for the past three years. The results indicate that the road to international training is barred by formidable logistical obstacles (real or perceived) that require extraordinary commitment and sacrifice to overcome. These obstacles include:

- Challenging Curriculum. Typical engineering curricula are packed very tightly with required core courses, and have relatively few electives. Integrating study abroad requires extensive effort petitioning for equivalency credits and fitting language learning into a busy course schedule. This often means postponing graduation for a semester or year.
- Language. Like most Americans, engineering undergraduates are usually mono-lingual. Learning a foreign language is perceived as an unnecessary and daunting additional challenge to the heavily-burdened engineering undergraduate.

[1] By comparison, an average of 20% of European engineering students study abroad (Noir sur Blanc, 2000)

- Semester Timing. Many foreign school systems operate on a term schedule that differs significantly from the typical American semester or quarter schedule. In practice, this often means that studying abroad for one term forces the student to miss two terms at the home institution.
- Perceptions and Market. Engineering students tend to be more narrowly task-oriented than students in other disciplines. While personally attracted to international experiences, many students do not yet perceive global competence as a serious requirement in the modern market place. A sweeping change in our approach to international engineering education is required to change these perceptions.

As a result of these obstacles, only a few highly-motivated engineering undergraduates currently take advantage of international training opportunities. Remedying this condition clearly calls for a comprehensive curricular reform that will make international engineering education attractive to all undergraduates.

2.0 THE GLOBAL ENGINEERING COLLEGE

To address the obstacles mentioned above, we are developing a novel curricular model for engineering education called the *Global Engineering College* that injects international perspectives into every aspect of the curriculum, and makes international engineering training more relevant and accessible to *all* engineering undergraduates. Leveraging recent technological developments, our aim is to create, in essence, a single engineering college offering access to the combined courses and resources of NAU and our foreign partner institutions; students at one university will be able to participate - via an appropriate combination of direct (in person) participation and internet technologies (distributed teaming) - in engineering design courses offered at any partner university. An important side benefit in this age of dwindling educational resources is that students will have access to a much wider array of specialized elective topics, laboratory equipment and practical experiences (the totality of courses/facilities available at all partner universities) than would normally be available to them at their home institution. The Global Engineering College thus does not simply enhance the traditional curriculum with valuable exposure to foreign culture and international engineering practice *for a few students*, but increases global awareness and experience *for all students*.

Our efforts towards implementing the Global Engineering College concept center around four key elements:

1. **"Virtual" Student exchange (VSX).** Students at NAU and its partner institutions abroad will be able to participate in each other's design courses *at a distance*, while still enrolled at their home institutions. This capability represents the technological cornerstone of the Global Engineering College, allowing students at NAU and our partner institutions access to the full range of design-oriented curricular elements offered by any participating institution via a mixed remote/in-person participatory model that eliminates difficult geographical, temporal and logistical obstacles.
2. **Global Internships.** Prerequisites for success in a modern internationalized corporate environment include sensitivity and adaptability to differences in corporate work cultures, differing legal environments, and knowledge of and respect for local customs and mores. These types of experiential knowledge can only be earned in the workplace.

Therefore, a global internship experience for interested students is an essential part of the Global Engineering College.

3. **Specialized Accelerated Language Acquisition.** Because culture and language are inextricably intertwined, a working knowledge of a foreign language remains an important aspect of global competence, even in engineering contexts where English is accepted as the *lingua franca*. Because generic university language courses do not take into account the specialized needs of engineering students, we are developing a specialized accelerated language program that will, within a single year of study, provide engineering students with linguistic competence sufficient to attend engineering courses and/or serve an engineering internship in the target language.
4. **Curriculum Modifications.** Not only are many important engineering firms international; many of the problems that these companies work on transcend national borders. Thus, we are working to integrate curricular material on these problems into current courses; we are also creating several new courses that specifically have international engineering as a theme.

In the first phase of the implementation process, we have focused our curriculum development efforts on courses within our award-winning Design4Practice program (Hatfield, 1995; Collier, 1996; Howell, 1996; Larson, 1999). This practice-oriented engineering curriculum, crafted with extensive input from industry, is built around a four-year interdisciplinary sequence of design courses that introduce students to the design process early in their college careers, and then increase the complexity of design challenges throughout the four years of study. Strong emphasis is placed on modeling real-world design scenarios: students work in interdisciplinary teams, interact with a client, and professionally present results. By graduation the students are well versed in the design process and teaming skills, and hence are able to contribute immediately in their first professional employment.

The Design4Practice program is also the single most important reason that international students have historically selected NAU-CET as a study-abroad location, primarily because the interdisciplinary nature of the program is impossible to achieve under the more rigid disciplinary separation common in engineering education in many other countries. This makes it a natural focus for international collaboration. In addition, our previous efforts towards internationalizing Design4Practice (Doerry, 2000) make it an excellent cornerstone for development of our Global Engineering College.

The following sections describe the four central efforts we are pursuing in implementing the Global Engineering College concept is more detail.

2.1 Virtual Student Exchange (VSX)

Currently, the only way that a student can gain experience in an international team is by going abroad for a term. As discussed earlier, semester timing and curricular inflexibility make such exchanges unattractive; a study-abroad experience that delays graduation by two or more semesters is simply not practical in the eyes of many students. Moreover, even students who are not motivated to go abroad under any circumstances should have some exposure to international teaming.

The key to including international teaming experience in the undergraduate education of *every* engineer lies in minimizing the curricular disruption with respect to the student's degree program and assuring that he/she can study abroad without missing key courses at home. Over the last five years, sophisticated internet technologies have become available that provide an answer to this requirement. The goal of these technologies, collectively known as *groupware systems*, is to allow geographically distributed groups of collaborators to communicate, share data, and organize their collective team effort so effectively that the geographical separation of the team becomes irrelevant. Although it appears unlikely that distributed collaboration will ever match the full efficacy of traditional (co-present) teaming (Doerry, 1995), groupware technology has proven to be quite useful; an increasing number of major corporations (e.g. Boeing, Ford, Sun Microsystems) now rely on groupware technologies to support design and development teams spread across widely-separated sites. Given this trend towards groupware and distributed teaming in corporate America, applying groupware technology to facilitate international educational experiences for engineers pays a double dividend: not only can we address the curricular obstacles mentioned earlier, but the experience of using groupware technologies to support distributed teaming is in itself a valuable educational experience for modern engineers.

As a model for applying groupware technologies to address logistical challenges, we have developed the concept of Virtual Student Exchange (VSX) as a cornerstone of our Global Engineering College. The overall idea is straightforward: apply the same groupware technologies currently being used extensively in modern corporate environments to allow students at partner universities to participate remotely in one another's design courses. Specifically, we are leveraging VSX to enhance international exposure within our GEC curriculum in two ways.

First, VSX will eliminate the sacrifices associated with study-abroad in the past. A student will be able to participate remotely in a desirable design course at a partner institution, while still completing classes in an ongoing semester at the home institution; conversely, a student that is abroad at a partner institution may rely on distance participation to avoid missing the beginning weeks of the next semester at home.

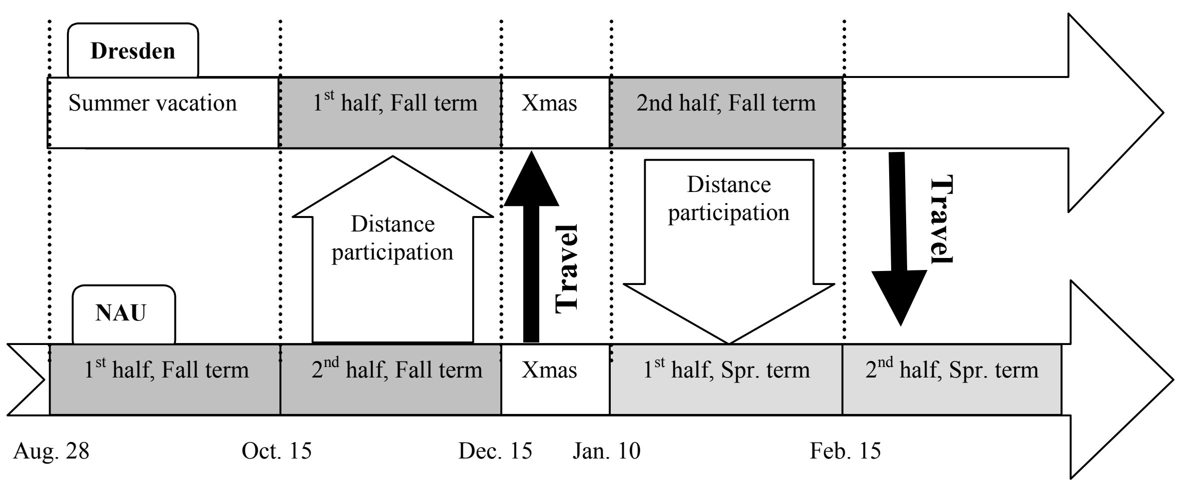

Figure 1: Use of distance participation to allow an NAU student to participate in a course offered in Dresden via Virtual Student Exchange with minimal curricular disruption.

For example, Figure 1 illustrates the use of VSX to allow an NAU student to participate in a design course offered in Dresden, Germany during the (German) fall semester. The student initially registers for fall courses at NAU, which begin in late August. In mid-October, when the

German falls semester starts, she participates via groupware technology, communicating with her design team members in Dresden, and submitting her contributions electronically. Over Christmas, she then flies to Dresden to participate in her team project in-person during the critical second half of the term, when the design effort becomes more focused and intensive. To avoid missing a critical core class for her NAU degree offered in the spring semester, she registers for the course, and participates via internet during the first two months of the (N AU) spring semester. Upon finishing with the German design course in mid-February, she returns to Arizona for the last half of the NAU spring semester.

As this example illustrates, leveraging groupware technology makes it possible for the student to *virtually* participate in courses at both institutions in parallel[2]. Indeed, it essentially erases the logistical boundaries between study at the two institutions, realizing our goal of a seamless "global engineering college".

Of course, there are many students who, for various reasons, will not wish to travel abroad for exchange study, regardless of how painless one makes it. This brings us to the second way in which we plan to leverage VSX to internationalize our curriculum, namely, through participation in design teams in which one or more team members are participating remotely, via VSX. Although the NAU student in the above example is the only person who actually travels, all of her teammates in Dresden gain valuable international, distributed teaming experience during the time the first half of their course, when the NAU student is contributing remotely to team activities.

The technical challenges associated with implementing VSX center around identifying and providing appropriate groupware tools to support distributed design teams. A wide variety of groupware tools have been explored over the past 15 years (Baeker, 1992). More recently, a number of commercial groupware products have appeared (e.g., Proshare, http://www.tribecaexpress.com/proshare.htm; Netmeeting, http://www.microsoft.com/windows/netmeeting/, and TeamWave, http://www.markroseman.com/teamwave/). Our initial analysis of team design activities suggests that VSX teams will require groupware support in three key areas:

- <u>Communication tools</u>. Group members need to be able to communicate freely about the evolving design; both asynchronous (e.g. e-mail, newsgroup) and synchronous (e.g. text chat, videoconferencing) mechanisms should be available.
- <u>Coordination and project management tools</u>. Coordinating team activities and keeping all members on-task is much more difficult in distributed contexts. An effective system must provide sophisticated calendaring, task lists, and work status monitoring mechanisms.
- <u>Access to design artifacts</u>. Team design is task-oriented; the goal of team collaboration is to actually *produce* some designed artifact. Providing access to an evolving design to distributed team members presents perhaps the most difficult challenge, particularly where the designed artifact is physical in nature (e.g., an impellor blade) rather than electronic (e.g., a computer program).

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[2] The above example also emphasizes that physical, on-site participation remains a crucial element of the VSX paradigm. In-person participation is vital to team morale and efficacy, particularly during the latter, more intensive stages of the design process. More importantly, the experience of actually living abroad is, of course, a central learning experience that distance participation simply can not provide.

To meet these goals, we are creating a cohesive suite of groupware tools composed of both commercial products (for common tasks like email, chat, etc.) and custom designed software to support the more specialized communication and organizational needs of distributed design teams. Specifically, we are proceeding along two complementary tracks.

First, we are surveying and testing existing groupware products to determine which of these, if any, are suitable for deployment in this particular distributed design context. A major constraint we have set for the design of the groupware infrastructure for VSX is that any deployed system must be relatively "lightweight", meaning simply that all components must be cheap, small, and easy to install on systems used by participating students. This constraint is dictated by both practical and financial realities: student design teams work together for relatively short periods (i.e., several months), so a lengthy, complex setup is not justifiable. We also expect little funding for dedicated systems or support personnel, so students teams should ideally be able to do most of the configuration on their own.

Of course, the most "lightweight" installation is no installation at all. To this end, our second VSX development thrust is to develop a sophisticated tool suite, called the Modular Groupware Infrastructure (MOGWI; http://denali.cse.nau.edu/Groupware/mogwi/) system, that supports key team organization and communication functions within a simple browser-based interface. Using MOGWI, students forming a collaborative design team will be able to create and configure a collaborative work environment for the team in less than 20 minutes. Only a web browser will be required to access the system.

We have also identified a wide variety of administrative challenges raised by VSX. The most obvious of these is the need to synchronize design curricula between partnering institutions, so that students participating in cross-institutional courses can receive appropriate credit at their home institutions. We are currently working to identify design courses at NAU and partner institutions that are strong candidates for the VSX model, i.e., that are similar enough in content to satisfy the curricular requirements of both institutions and involve team design projects. Another key feature of the VSX model is that students should be able to participate for the first months at a distance in other (non-Design4Practice) critical upper-division courses at their home institutions in order to avoid falling behind in their studies. Thus, we are also identifying key non-design, upper-division courses that must be enhanced to allow distance participation.

Long-standing university policies geared towards strictly on-campus educational models present further obstacles that must be addressed to implement the VSX paradigm. For example, we are working to reconcile INS and financial aid definitions of "full-time study", the management of tuition waivers, exchange quotas, credit transfer and accreditation with the new opportunities created through VSX.

2.2 International Internships

As at most American universities, internship experience (international or otherwise) at NAU falls outside of the core curriculum: internships are encouraged but not required for graduation with a B.S. in Engineering. Approximately half of all students complete at least one internship, usually with a local or regional company, prior to graduation.

Although NAU has recently opened its internship network to international students, the lack of contacts with overseas corporations has severely limited international internship opportunities for NAU students; the few students that have found international internships have done so on their own initiative. Because the number of international interns has always been small, it has been possible to administer them on a case-by-case basis. Requiring an internship as a part of our Global Engineering College curriculum will require both a significant expansion of such opportunities and the necessary planning to articulate their relationship to the rest of the curriculum.

To expand our pool of international internship possibilities, we are leveraging our existing network of industrial partners on the CET Industrial Advisory Council (CEIC) – including Boeing, Raytheon, IBM, and Motorola - to create new international internships opportunities at companies operating internationally. Because many of our partner institutions require an industrial internship in their curriculums, they have an extensive network of industrial contacts able to provide international internships. We are also developing contacts to national organizations such as the Global Engineering Exchange (http://www.iie.org/pgms/ge3.htm) and the Association for International Practical Training (AIPT) (http://www.aipt.org) to create new internship opportunities.

Of course, having a pool of internship opportunities is not enough; internships must be integrated into the core curricular structure of various programs of study at CET to motivate students to pursue these opportunities. This is particularly important in light of the fact that internships in most foreign countries are not nearly as lucrative as those offered in the United States – most offer interns only a sparse stipend to cover room and board. To further promote international internship, we are working to identify public and corporate funding sources for supporting international internships, and minimizing logistic obstacles (e.g. visa issues) raised by paid internships.

Because internships currently fall outside the regular curriculum, our initial analytic efforts have also revealed a lack of mechanisms for evaluating the educational contribution of an internship experience. Thus, we are delineating and testing procedures for monitoring progress, performance and well-being of international interns, and are developing safety and risk management guidelines.

Collectively, these efforts will replace past tentative and isolated steps with a robust global internship program as an integral part of the Global Engineering College.

2.3 Accelerated Specialized Language Programs

Over the past 30 years, the percentage of students exposed to foreign language instruction during their undergraduate years has dropped from over 16% to less than 8 % (Lambert, 1999); the percentages are even lower among engineering students. Fewer and fewer students believe traditional language instruction to be a worthwhile investment of their time. Because progress toward communicative competence in a typical college language course is slow and diffuse and topical content provides little or no coverage of the technical language that pervades an engineer's world, engineering students find themselves still tongue-tied in the target language, even after four semesters of traditional instruction. With this low benefit/cost ratio, it is no surprise that foreign language instruction often has low priority for engineers; it is simply not valuable enough to squeeze into an already challenging curriculum.

At the same time, there is clearly a demand for intensive, focused language training. The Institute of International Education (IIE), in its annual volume *Open Doors*, notes that participation by U.S. students in immersion-style language acquisition programs has soared in the last decade. This trend is evident at NAU as well; the 2000 edition of *Open Doors* cited NAU as among the top twenty institutions in its peer group in terms of students studying abroad, with the largest segment participating in language acquisition programs in Mexico, Spain, France, Germany, China, Germany, China and Japan. Clearly, more and more students, including engineering students, are highly motivated to participate in focused language acquisition, programs that bring them to linguistic and cultural competence quickly, efficiently, and early in their undergraduate program.

Responding to this need, a few universities have established progressive on-campus language instruction initiatives to introduce "Language across the Curriculum" (Shoenberg, 1998; Knecht, 1999). Building on these efforts, we are developing a two-semester sequence of specialized language sections that bring engineering students, within one calendar year, to a level of linguistic competence sufficient to allow participation in engineering courses taught in the target language or success at an internship abroad. These sections will be accelerated, progressing faster than the normal sections, meeting for five hours weekly and making extensive use of the NAU Language Learning Lab, and will focus on the technical vocabulary of engineering from the beginning. Although several institutions (e.g. the University of Rhode Island) have developed specialized language courses for engineers, there is as yet no consensus on teaching methodologies and materials best suited for engineering-oriented language instruction; or on minimum, maximum, and optimal class sizes of accelerated language sections. Exploring and addressing these pedagogical issues is a major goal of our development effort.

Simply providing language instruction is not enough; in order to be successful, the language initiative must be packaged within a supportive and an attractive infrastructure. To provide a capstone to our language training initiative, we are developing a network of specialized, in-country eight- to ten-week immersion programs, which students will enroll in during the summer following the two on-campus semesters of instruction.

Choosing a single language to focus our initial development efforts on presented a difficult decision. Although Spanish is by far the most popular foreign language at NAU, long-term support by the German Academic Exchange Service (DAAD) and other German government sources has resulted in a rich variety of in-country language programs, extensive financial aid opportunities, and a dense network of engineering-specific partnerships in Germany. For these pragmatic reasons, we selected German as the target language to focus on in our first phase of development.

2.4 Complementary Course and Curriculum Modifications

Previous sections have focused on planning curricular modifications and enhancements within the NAU Design4Practice course sequence. In order to fully achieve our vision of a Global Engineering College, however, the entire engineering curriculum must be examined for opportunities to inject international engineering themes into the course material. For example, environmental engineering courses could be enhanced to include the complex mixture of technical, social, political, and historical issues that Arizona, which shares a border with Mexico, must address on topics such as trans-border air and water quality and waste management practices.

Our approach to this curricular restructuring involves both modification of existing courses, and creation of new, specialized courses in international engineering. Modifications of existing courses under exploration include injecting new curricular material, or modifying existing curricula to highlight international issues. For example, our CENE 440/540 "Environmental Protection: Today and Tomorrow" course examines and compares environmental policies in the U.S. and other countries. It has often attracted international students whose perspective has always enriched the course for all participants. We are also developing specialized courses for each of CET's engineering disciplines devoted exclusively to placing engineering in its global context under the general title of "[Civil, Mechanical, Environmental, etc.] Engineering in an International Context." Each of these courses will focus on presenting international issues important to the specific discipline. As international developments occur, we expect these issues to change, giving the curriculum the flexibility to respond to a rapidly changing global environment. Clearly, these courses will benefit greatly from participation by international students via the Virtual Student Exchange element described in Section 2.1.

3.0 CURRENT STATUS OF THE GEC PROJECT

Although the Global Engineering College concept represents a compelling vision for the future of engineering education, implementation will require careful planning and an enormous investment of effort to meet the technical, administrative, and organizational challenges outlined in previous sections. As the first step of a five year implementation effort, we are currently completing an initial "proof of concept" phase, during which we have worked to refine our understanding of the issues and develop the tentative solutions presented in this paper. To validate these solutions and expose unforeseen obstacles, we are now implementing pilot versions of all four key elements of the Global Engineering College within the limited scope of a single discipline, namely, computer science. The fact that the designed artifact in this discipline is computer code makes providing shared access to the evolving design to distributed design team members relatively simple. Specifically we are:

- Developing a trial VSX course. We are actively developing groupware infrastructure and are collaborating with colleagues in Dresden, Germany, and Wroclaw, Poland to allow a small number of select students from those institutions to participate in one of our design courses using the VSX paradigm. This pilot offering is scheduled for Fall 2003.
- Creating international internships: Using the mechanisms outlined earlier, we have successfully developed a growing pool of internship opportunities for computer science undergraduates. Our goal is to place at least two NAU undergraduates in global internships for Summer 2003, and use this experience to validate our internship monitoring and evaluation protocols.
- Developing an accelerated language course. In collaboration with German faculty from the NAU Modern Languages department, we are developing prototype course modules for two accelerated language courses in German; the beginning course will be offered to engineering student in Fall 2003.
- Developing a specialized international perspectives course. We are developing course outlines and course materials for a "Computer Science in an International Context" course. We plan to offer the course as an experimental elective in Fall 2003.

We expect that these pilot efforts will reveal problematic issues within each element, provide us with a comprehensive assessment of the synergistic interplay of these four elements as a coherent, integrated program, and provide a good indication of the feasibility of the Global

Engineering College concept as a whole. These insights will be crucial in shaping our detailed plans for implementing the full-scale GEC vision starting in Spring 2004.

4.0 CONCLUSION

The past two decades of increasing corporate globalization - accompanied and facilitated by the rapid development of the internet – have heralded a revolutionary change in the face of future engineering practice. The engineer of the 21st century will, in addition to traditional technical skills, be asked to play multiple roles (e.g., worker, project manager, secretary) on small independent design teams; will need excellent communication and teaming skills; and must be prepared to work efficiently with team members from other cultural and linguistic backgrounds, either in-person or in a distributed teaming context.

To prepare young engineers for this future, engineering education must adapt to incorporate training specifically aimed at honing the design, teaming, and global engineering skills that modern engineers will need. Although some institutions (including our own) have made efforts to provide appropriate training opportunities, these efforts have all been essentially "add-on" approaches, in which opportunities for global engineering experience are made available to students as optional extras, peripheral to the conventional curriculum.

Our observation – and the motivating point of departure for this project – is that this is simply not working; the stubbornly low percentage of engineers participating in existing global engineering programs makes it clear that a comprehensive curricular reorganization is called for.

The concept of the Global Engineering College we are developing represents a novel educational model that essentially *inverts* the traditional approach, making global engineering education a central, ubiquitous curricular element, rather than a peripheral add-on. By eliminating the logistical, curricular, and geographical barriers between collaborating international partner institutions, we propose to create a truly progressive educational environment in which engineering undergraduates *continually* encounter international peers on-line, in the hallways, and in the classrooms; *routinely* work in teams with international students, both in-person and remotely via groupware technologies; and *seamlessly* take advantage of courses and facilities available at various partner institutions. In effect, we aim to create a single global engineering college that virtually encompasses NAU and all of its partners – a novel educational model that directly reflects the real-world global workplaces that students will encounter when they graduate.

We do not expect our vision of a Global Engineering College to be accepted immediately in all quarters; many traditionalists will initially have difficulty accepting a model that does not maintain absolute local control over undergraduate education. We believe, however, that the increasing trend towards globalization and international industrial partnership requires a corresponding shift in engineering education, away from isolated, one-campus experiences, and towards a more distributed, multi-institutional and cross-cultural model. In short, we view the Global Engineering College as an exciting model for bringing engineering education into the 21st century.

Looking further into the future, we anticipate that a successful implementation of the Global Engineering College paradigm at NAU will serve as a model for other engineering schools nationwide and, indeed, represents just the first step in an evolution towards even more global, distributed paradigms for engineering education.

Bibliography

---- (2000). "2000 Open Doors: Report on International Educational Exchanges," Institute of International Education. New York.

Altbach, P. (2002). "Perspectives on International Higher Education," (Resource Review column), *Change*, 34:3, p. 29.

Baecker, R. (Ed.) (1992). *Readings in Groupware and Computer-Supported Cooperative Work: Assisting Human-Human Collaboration*, Morgan Kaufmann Publishers.

Bikson, T. and S.A. Law (1994). "Global Preparedness and Human Resources: College and Corporate Perspective," Rand Corp.

Collier, K., J. Hatfield, S. Howell and D. Larson (1996). A Multi-disciplinary Model for Teaching the Engineering Product Realization Process. *1996 Frontiers in Education Conference*, Salt Lake City, UT.

Doerry, E., B. Bero, D. Larson, and J. Hatfield. (2000). "Northern Arizona University's 'Design4Practice Sequence': Interdisciplinary Training in Engineering Design for the Global Era", *Proc., 3rd Workshop on Global Engineering Education (GEE3)*, Aachen, Germany.

Doerry, E. (1995). "An Empirical Comparison of Communicative Efficacy in Technologically-mediated Environments". Dissertation. University of Oregon.

Dourish, P. and V. Bellotti (1992). Awareness and Coordination in Shared Workspaces. *Proceedings of ACM CSCW'92 Conference on Computer-Supported Cooperative Work*, Toronto, Canada.

Ercolano, V. (1995). "Globalizing Engineering Education", ASEE PRISM, April, 21-25.

Gray, K., G. Murdock and C. Stebbins (2002). "Assessing Study Abroad's Effect on an International Mission," *Change*, 34:3, p 44.

Green, M.F. (2002). "Joining the World: the Challenge of Internationalizing Undergraduate Education", *Change*, 34:3, p 12.

Grueber, S., D. Larson, M. Neville and D. Scott (1999). "Writing 4 Practice in Engineering Courses: Implementation and Assessment approaches." *Technical Communications Quarterly*, 4th Quarter.

Hatfield, J., K. Collier, S. Howell, D. Larson and G. Thomas (1995). Corporate Structure in the Classroom: A Model for Teaching Engineering Design. *Proceedings of 1995 Frontiers in Education Conference*, Atlanta, GA.

Howell, S., T. Harrington, D. Larson, K. Collier and J. Hatfield (1996). A Virtual Corporation: An Interdisciplinary and Collaborative Undergraduate Design Experience. *1996 Design for Manufacturability Conference*, Irvine, CA, ASME

Knecht, M.. (1999). "Integrated Learning and Internationalized Education through Languages Across the Curriculum." ADFL Bulletin 30.3, 17-22.

Lambert, D. (1999). "The Winds of Change in Modern language Instruction," *International Educator*, 31-35, 57.

Larson, D. (1999). A New Role for Engineering Educators: Managing for Team Success. *MRS Spring 2000 Conference Proceedings*, San Francisco, CA.

Larson, D., D. Scott, M. Neville and B. Knodel (1998). Measuring Student's Confidence with Engineering Problem Solving. *1998 ASEE Conference Proceedings*, Seattle, WA.

Marginson, S. (2002). "The Phenomenal Rise of International Degrees Down Under," *Change*, 34:3, p. 34.

Maxwell, D. and N. Garrett (2002). "Meeting National Needs: The Challenge to Language Learning in Higher Education", *Change*, 34:3, p 22.

Miller, M. (2002). "American Higher Education Goes Global" (editorial), *Change*, 34:3, p. 4.

Noir sur Blanc (2000), Report: "A Survey of Engineering Studies Worldwide," Paris, France.

Rogers, Y. (1993). "Coordinating Computer-mediated Work," *Computer Supported Cooperative Work: The Journal of Collaborative Computing*, 1(4):295-315.

Shoenberg, R. and B. Turlington (1998). "Next Steps for Languages Across the Curriculum: Prospects, Problems, and Promises." Report, American Council on Education, 1998.

Sjogren, J. and J. Fay (2002). "Cost Issues in Online Learning: Using 'Co-opetition' to Advantage," *Change*, 34:3, p. 52.

Ulrich, K. T. and S. D. Eppinger (2000). Product Design and Development. Boston, Irwin/McGraw-Hill.

Vick, R. (1998). "Perspectives on and Problems with Computer-Mediated Teamwork: Current Groupware Issues and Assumptions." ACM SIGDOC Journal of Computer Documentation 22(2): 3-22.

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