The Global Engineering College: Lessons Learned in Exploring a New Model for International Engineering Education

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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. In a 2003 ASEE paper⁵, we described a novel curricular paradigm called the **Global Engineering College** (GEC), 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. In this paper, we report on our experiences piloting the key elements of this model under an NSF planning grant, focusing on the obstacles encountered, and solutions developed to address 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, including engineering^{1,8,16,17,20,24}. 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^{3,14}. A number of institutions have taken concrete steps toward implementing internationalization within individual academic units as well as across the university as a whole. For example, the University of Rhode Island began offering a Bachelor's Degree in International Engineering (http://www.uri.edu/iep).

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 components⁷. Since then, the rationale for international training 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. Recent cover stories in ASEE's *PRISM* explore the effect of these trends on modern engineering practice^{12,18,19}; the overall conclusion is unanimous: *all recent engineering graduates can expect to work, at some point their careers, on teams with members from varied cultural and linguistic backgrounds*; these teams may be 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 limited and peripheral; the number of

Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition Copyright © 2004, American Society for Engineering Education participants remains relatively small. Even the relatively successful International Engineering program at the University of Rhode Island (URI) enrolls only about 10% of their over 1000 engineering students^{*}. Thus, its impact on the <u>majority</u> 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 (NAU) has been similar: the College of Engineering and Technology (CET) at NAU has developed student exchanges with international partners, provided lectures by international visitors, and has offered 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. Despite these strong efforts, however, *fewer than 2% of graduating CET engineers receive significant international training*.

A detailed investigation of *why* more students are not participating revealed that student interest in international engineering education is stifled by a number of obstacles, including inflexible curricular structures, language barriers, incompatible semester timing, and a failure to appreciate the implications of a global economic future⁵. Thus, international training remains relegated to the periphery of the curriculum, viewed by most students as an optional add-on to the traditional curricular core; only a few highly-motivated engineering undergraduates take advantage of international training opportunities.

Remedying this condition clearly calls for *comprehensive curricular reform that guarantees that all engineering undergraduates receive basic international engineering exposure*, while making an experience abroad (study or internship) so easy and attractive that *many* students will be motivated to incorporate it into their undergraduate experience.

2.0 THE GLOBAL ENGINEERING COLLEGE

To make international engineering training more relevant and accessible to *all* engineering undergraduates, we have developed a novel curricular model for engineering education called *the Global Engineering College (GEC) that injects international perspectives into every aspect of the curriculum*. In addition to comprehensive internationalization of our engineering curriculum, the GEC concept leverages recent technological developments to create a single "virtual" engineering college that integrates selected NAU courses with parallel courses at our partner institutions abroad. Students at one university will be able to participate via internet in 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 the full array of specialized elective topics, laboratory equipment and practical experiences available at any partner university.

From a practical perspective, the Global Engineering College (GEC) model consists of four key elements that interact in complementary fashion to provide a wide range of international experience and training opportunities:

Curriculum Internationalization. International perspectives can be integrated into existing engineering course curricula by replacing generic, context-free assignments and projects with "scenario-based" challenges, in which the same pedagogic exercises are situated in

^{*} By comparison, an average of 20% of European engineering students study abroad²¹.

international contexts. For example, rather than being asked to "design a bridge to such and such specifications", students would be asked to design a bridge in a specific foreign locale, taking into consideration international issues like materials, measurement differences, currencies, local availability of capital and labor, while still exercising conventional core engineering skills.

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* by leveraging advances in internet technologies. This allows us to "bring the world into our classrooms", ensuring that even students who never go abroad are exposed to international teaming and collaboration; NAU students will gain access to a wide range of curricula offered at participating institutions.

Global Internships. Prerequisites for success in modern international corporate environments include sensitivity and adaptability to differences in work habits, differing legal environments, and respect for local customs and mores. Because these types of experiential knowledge can be best gained in an international workplace, streamlined access to a global internship experience for motivated students is an essential part of the Global Engineering College model.

Engineering-specific Language Instruction. Because generic university language courses do not take into account the specialized needs of engineering students, we have developed a model for accelerated, engineering-specific language instruction that will, within a single year of study, provide engineering students with linguistic competence sufficient to attend engineering courses and/or to serve an engineering internship in the target language.

A vital feature of the GEC model is that international engineering exposure is "built-in", providing a core level of international exposure for *all* engineering undergraduates. Although direct experience abroad (e.g., study abroad, international internship) is clearly the most desirable training, there will always be students who lack the required motivation to go abroad, regardless of how easy, streamlined and well-integrated the access to such opportunities. Such students, however, still participate in internationalized courses in our college, and must work on teams with international students via VSX. Thus, the Global Engineering College paradigm does not simply provide streamlined access to foreign culture and international engineering practice *for a few students*, but increases global awareness and experience *for all students*.

Supported by an NSF Department-Level Curricular Reform Planning Grant, we developed and piloted the four key elements of the GEC concept introduced above during the 2003 calendar year, based on our existing partnerships in Germany. Curricular modifications were focused on our award-winning Design4Practice program^{4,10,11,15}, a unique practice-oriented engineering curriculum built around a four-year interdisciplinary sequence of design courses beginning in the freshman year, that incrementally expose students to design and teaming challenges of increasing complexity. The interdisciplinary nature of the Design4Practice program makes it very attractive to foreign students who often come from more rigid educational systems where interdisciplinary experiences are difficult to implement. Thus, Design4Practice courses provide an excellent foundation for the curricular internationalization and "virtual" international teaming elements within our GEC model.

The following sections describe our pilot experience in detail for each of the four elements, describing our development efforts, the obstacles encountered when we deployed them, and discussion of solutions and future directions.

2.1 Course and Curriculum Modifications

As discussed in our introduction, a wide variety of logistical, curricular, social, and financial obstacles exist that collectively discourage most engineering students from interning or studying abroad as part of their undergraduate education. Moreover, a sober analysis of attitudes and motivation among undergraduate engineering students leads to the recognition that many engineering undergraduates will simply not go abroad, no matter how easy, cheap, well-integrated, or streamlined one makes the experience. This reality leads us to shift our primary emphasis away from sending engineers abroad, and towards integrating international exposure into our local curriculum via a comprehensive curricular internationalization effort.

Our approach to curricular internationalization is based on upgrading generic problems and projects currently used in the standard curriculum so that they require students to specifically address international issues and learn about global contexts and cultures in order to develop a solution. Students also gain skill in finding (e.g., on the internet, at the library) the information needed to tackle the enhanced problems. For example, a project in a Sanitary Engineering course can be enhanced to include the complex mixture of technical, social, political, and historical issues that engineers in Arizona (which shares a border with Mexico) must address, ranging from trans-border air quality, water quality and waste management practices to border security and immigration issues.

Focusing on internationalizing the curricula of existing courses has several advantages. First, it minimizes curricular upheaval, political obstacles, and accreditation issues, as the core topics and domain skills taught remain the same. Second, it introduces the realities of modern engineering practice at multiple points throughout the curriculum; solving problems in specific applied (international) contexts is what engineering is all about. In this way, our curricular internationalization initiative complements and enhances our existing and highly-successful Design4Practice curriculum, which also emphasizes applied engineering skills.

2.1.1 Curricular Internationalization: Pilot effort and outcomes

To explore curricular internationalization, we modified our Fall 2003 offering of our freshman level Design4Practice course, entitled "EGR 186 - Introduction to Engineering Design". The main project in this interdisciplinary team design course, involving the design of a simple water filtration system, was embedded in a detailed international scenario: student teams were subcontracted by a German logging company to provide a prototype water filter for communities in the Republic of Congo whose drinking water supplies were affected by the company's logging operations. Successful completion of the project required students to research foreign companies operating in the Republic of Congo, exchange rates, and site-specific data (soils, rainfall, tree species, population, sources of drinking water, economics of the area, etc.); technical design requirements (e.g., flow rate, cost) for the prototypes were also provided. Students were required to build and demonstrate their filter, using only materials available at the international location.

Four sections of the modified EGR186 course were offered in Fall 2003. Overall response to the international project was quite promising:

• 82% of students felt that the project had stimulated them to think in new ways about the drinking water treatment challenges specific to the Republic of Congo and site-specific constraints posed by the design.

- 85% of students indicated that they performed research (e.g., via internet) to find information (location, climate, population, industries, etc) on the Republic of Congo.
- 71% indicated that they gained understanding of the operation of global companies through the project (e.g., language, society responsibility, logistics, etc.).

• 75% rated the value of the international experience as either 3, 4, or 5 on a scale of 1-5. Written comments revealed that students would have liked more time and a stronger mandate to research the Republic of Congo, and would have appreciated more guidance in doing such research; several comments indicated that more background on international business and economics would have been helpful.

This feedback shows that, although there is room for improvement, students were led to think indepth on a variety of international issues, extending learning substantially beyond the core technical concepts.

2.2 Virtual Student Exchange

Currently, the only way that a student can gain experience in an international team is by going abroad for a term. Even students who are not motivated to go abroad, however, should have some exposure to international teaming.

Virtual Student Exchange (VSX) was developed as a cornerstone GEC mechanism for ensuring international teaming experience for every engineering undergraduate. The overall idea is straightforward: apply the same groupware[†] technologies increasingly being applied in modern corporate environments to allow students at partner universities to participate remotely in one another's design courses. For example, NAU electrical engineers working to design a novel device might be teamed with counterparts in Dresden, Germany, communicating and coordinating their collaboration using specialized groupware tools. Aside from the international teaming experience, an advantage of this concept is that the resources of all participating institutions become available to the teams, e.g., the class can draw on both the advanced microelectronics lab at NAU, and the CNC prototyping facility in Dresden. As an additional dividend, the experience of using groupware technologies in distributed teams is a valuable educational experience in itself, given the increasing number of major corporations (e.g. Boeing, Ford, Sun Microsystems) now rely on groupware technologies to support design and production teams spread across widely-separated sites.

Specifically, we are leveraging VSX to enhance international exposure within our GEC curriculum in two ways:

- 1. Support virtual international teaming. VSX supports the establishment of "virtual joint courses" centered around internationally distributed design teams. In this way, students who might never choose to go abroad are nonetheless exposed to international teaming.
- 2. Streamline study abroad. VSX eliminates the problems associated with semester asynchrony by allowing a student to participate remotely in a desirable design course at a partner institution, while still completing classes in an ongoing semester at the home

[†] Groupware refers to specialized internet software – e.g., conferencing, shared design and scheduling tools – that allow geographically distributed collaborators to communicate, share data, and organize collective team effort.

institution; optionally, he or she can then travel abroad at semester's end to physically join the semester in progress abroad.

Thus, VSX provides the technological cornerstone for our overall vision of a seamless "global engineering college".

2.2.1 VSX: Analysis of needs and outcome

Our exploration of the VSX concept can be divided into three distinct but overlapping efforts: analysis and planning, infrastructure implementation, and deployment/evaluation in a pilot joint design course with our international partners.

Our analysis effort focused on identifying appropriate groupware functionality to support distributed design teams. A wide variety of groupware tools have been explored over the past 15 years². More recently, an enormous number of commercial groupware solutions have appeared (e.g., Netmeeting, http://www.microsoft.com/windows/netmeeting/, Onevision, http://www.ingenux.com/onevision/; and Intranets, http://www.intranets.com/). Our analysis proceeded in two complementary directions: First, we identified the *functional needs* of student design teams^{22,25}. Drawing on the experience of our Design4Practice program faculty as well as our background in groupware systems, we analyzed the activities and conventional mechanisms (e.g. project management software, intra-team data flow, email, etc.) used by traditional student design teams to organize and coordinate team activities. This provided a set of minimal functionalities that any software solution would have to meet. Second, we examined a wide variety of existing groupware solutions, evaluating each on cost, ease of installation, and functional completeness. The outcome of this analysis yielded the following results, organized by functional category:

<u>Communication tools</u>. Group members need to be able to communicate freely about the evolving design. After examining the needs of design teams, we concluded that email messaging should be sufficient to support intra-team communications. Although we considered real-time communication tools (e.g. text chat, videoconferencing) as well, there did not appear to be any functional justification for real-time communication in our team design context.

<u>Access to designed artifacts</u>. In general, providing high-quality access to the artifact (e.g., a small robotic toy) being designed to all (distributed) team members is extremely challenging, since the artifact being produced typically exists physically at only one "production" site. To limit this challenge, we focused our pilot effort on supporting VSX for computer science teams. Being essentially text, software can be easily shared in a distributed context, although version control becomes an important issue (as discussed below).

<u>Coordination and project management tools</u>. This area proved to be extremely challenging due to the diversity of coordination and project management mechanisms revealed by our analysis. Most conventional student design teams maintained, in electronic (e.g. project management software, electronic document) form or on paper in their project notebooks, an evolving schedule for the project, with major tasks timelines somehow denoted. Some mechanism for documenting evolving "to-do lists" for each team member was also common, ranging from a document on the team website to scribbled notes from team meetings. Finally, team members frequently archived (at various levels of completeness), emails from teammates and notes from team meetings.

Under the assumption that coordinating team activities and keeping members on-task would be even more difficult in a distributed teaming context, we emphasized sophisticated calendaring, flexible task lists, and work status monitoring mechanisms in our survey of existing groupware applications. After extensive evaluation, we determined that no existing commercial solution met our criteria. Although some products did provide calendaring functionality of some sort, no existing groupware solutions supported team task management: assignment of tasks to individuals, shared monitoring of task completion status, and capture of design notes/rationale. In addition, many commercial groupware offerings are based on "subscriber model", in which the host company maintains control and ownership of the group site, charging groups a perminute fee to use the groupware feature. This model is (a) not economically feasible for relatively low-budget educational contexts and (b) does not provide groups with the flexibility to custom configure their group space to the group's specific needs. For products based on the conventional "purchase and install locally" model, we found that (a) the installation process was generally quite complex, requiring a trained systems administrator to create and configure groups and (b) the group environments provided were monolithic and inflexible, often overloaded with features irrelevant to team design contexts.

Based on this analysis, we elected to draw on our expertise in groupware design to create a custom groupware tool specifically designed to support small, distributed design teams. In addition to the functional requirements noted earlier, we set ease-of-use as a central design constraint, meaning that all components must be cheap, small, and easy to install. 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.

The MOGWI System

Our software development effort resulted in an elegant groupware prototype called the Modular Groupware Infrastructure (MOGWI; http://denali.cse.nau.edu/Groupware/mogwi/) system that explores a novel ultra-lightweight, highly-modular groupware architecture. Key features of the system include:

- <u>"Thin client" architecture</u>. MOGWI does not require users to install any client software on their desktop machines. Rather, the MOGWI client consists of an applet-based core infrastructure that automatically downloads to the user's machine when the MOGWI website is accessed. This maximizes ease of use, while providing for easy universal access: group members may access the group site anytime, anywhere, from any machine with a web browser.
- <u>Flexible, Customizable, Extensible</u>. MOGWI is based on an innovative *nested applet* design, in which the initially downloaded applet establishes a framework that hosts and provides core networking services to an extensible set of functional modules; these functional modules implement various groupware tools, e.g., project scheduler, virtual shared disk, team newsgroup, and so on. Because the architecture is completely modular, individual teams may select and install only those modules that they feel they need to support their team activities on a specific project. New modules can be implemented and added to the running system at any time, becoming immediately available for teams to use.

• <u>Easy site maintenance</u>. Installing the MOGWI server software and creating managing groups in MOGWI is extremely simple as well. An install script allows a system administrator to install and configure the MOGWI server and database in about 30 minutes. After that, group management is trivial: to support a new design team, a MOGWI administrator creates a new MOGWI group and defines one team member to be the group administrator. This team member then adds all of his or her teammates, and configures the tools (modules) that the group should have access too. In short, a design team can create and configure a collaborative work environment in less than 20 minutes.

After exploring a number of module concepts, we settled on four core MOGWI modules to implement for our pilot effort: an Awareness module, a NewsPost Module, a Task and Workflow module, and a Filebrowser module.

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Figure 1: The MOGWI workspace showing the four key modules.

Figure 1 provides a snapshot of the MOGWI workspace with the four modules open; individual users can organize the MOGWI workspace as they see fit.

The Task and Workflow (TAW) module provides the core project management functions for the distributed team, by laying out project tasks on a Gantt chart timeline. Tasks may be created by any group member; responsibility for each task is assigned (by percentage) to some combination of group members; task completion status is maintained by the assignee. The TAW also supports task dependencies and thus can display tasks in a dependency graph, as an alternative to the Gantt view. In this way, all group members can easily determine what tasks remain to be done, who has been assigned to do them, how each task is progressing, and how their assigned tasks influence other tasks remaining to be done.

The NewsPost module implements a secure, flexible archive for group communications. Group members can initiate new topics (threads) of discussion, post new messages, and reply to existing postings. A sophisticated permissions mechanism allows users to specify whether threads and messages can be read by others, replied to by others, or deleted by others, supporting a wide

range of configurations. Another important feature of NewsPost is that it can be configured to serve as an automatic archive for emails sent to the group mail alias (which MOGWI also provides).

The FileBrowser module is essentially a shared virtual hard drive, a place where group members can store and make available arbitrary electronic files. Although the primary purpose of the Filebrowser module with respect to our pilot effort is to support sharing of software code being developed by our teams, it can also be used for picture files, design documents, and so on. To help manage coding projects, the FileBrowser supports a rudimentary version control system, allowing group members to check-out/check-in stored files.

The Awareness module represents our nascent attempt to support some "peripheral sense" of how hard (or whether) teammates are working, what they are working on, and some sense of "working together", which has been shown to be a critical factor in bonding a set of individuals together into a robust team^{6,9}. The Awareness module provides real-time feedback about which teammates are currently online, as well as a historical record of when and for how long they logged into the group workspace.

2.2.2 VSX: Pilot deployment and outcomes

To evaluate the VSX concept and MOGWI, we modified our sophomore level Design4Practice course, labeled EGR 286, to incorporate team members from our international partner institutions in Dresden, Germany, and Wroclaw, Poland. EGR286 is team-taught by faculty from all engineering disciplines and focuses on interdisciplinary design to meet a complex robotics challenge. For the Fall 2003 VSX pilot, the challenge was to design a "rescue robot" to explore a rubble-strewn building, mapping out obstacles and delivering aid packets to trapped victims. Students were grouped into four "corporations"; disciplinary sub-teams within each corporation collaborated to create a coherent design, e.g., the MEs designed the chassis and drive system, the EEs designed the sensor package, and the computer scientists developed control software and interfaces. The four corporations designed solutions in parallel, with a competition at the end.

Our pilot VSX effort was limited to the Computer Science teams. Coordinating with our international partners, we established two remote teams in Dresden and Wroclaw that acted as "outsourcing consultants" to NAU teams. The local NAU CS teams were tasked with the control interface for the robots; each team then "outsourced" the design of a sophisticated "smart" module that would allow robots to map obstacles. This meant that each remote team had to develop the requisite software, with interfaces to integrate equally well with *either* of the implementations developed by the NAU-CS teams they were consulting for. Collaboratively specifying, testing, and integrating this outsourced module represented the main challenge for students in the VSX pilot.

Although the EGR286 course ran successfully, an overall problem was that the structure of the pilot course did not adequately motivate more intensive international collaboration, allowing the local teams to successfully complete the project without interacting intensively with their international cohorts. Specific problem areas included:

• Weak NAU-international interactions. Although there was considerable initial interaction between teams, it was not well-organized, i.e., individual team members emailed back and

forth a number of times, relaying vague requests for information. Interaction tapered off over time, however, particularly once the international teams felt they had enough information to proceed towards *some* solution on their own. In short, we found that, students were not able to construct a truly effective collaboration when merely presented with a collaborative challenge and given communication channels.

- Poor use of software tools. The MOGWI system was under-utilized. Several teams made use of the group mail alias, the Filebrowser (for sharing design documents), and the NewsPost module (to post design discussions). The Task and Workflow module received little usage, reflecting the poor coordination between local and remote team elements. MOGWI usage was highest at first, then tapered off as design and testing became more intense. Although this reflects a general tendency in student design teams to ignore "non-productive" (e.g. documentation, communication) tasks when time pressures grow, such lack of communication is particularly damaging when remote collaborators are depending on it to make progress themselves. An exacerbating factor here may have been frustrations caused by inefficiencies and bugs exposed in the MOGWI prototype (although these were generally fixed in short order).
- Lack of Synchronous Interaction. Our initial requirements analysis placed a low *functional* value on synchronous communication, especially video-conferencing. It soon became clear, however, that we had greatly under-valued the *social* value of such interactions in generating trust, commitment, and team cohesiveness. In the latter half of the term, we arranged for a video connection so that remote teammates could watch the testing and final competition of the robot prototypes. Simply seeing a remote teammate and chatting real-time appeared to greatly increase the excitement, commitment, and level of satisfaction of participants.

These observations indicate that the success of international teaming experiences is quite sensitive to details in design; even small weaknesses can lead to a deterioration of productive interaction. We are currently engaged in a follow-up VSX pilot (Spring 2004), that imposes stronger structure on the international collaboration. Specific improvements include: new deliverables (e.g. communication logs, status reporting requirements, etc.) to enforce core communication; a restructured project that places the foreign sub-team contribution in a critical central role; and provision of robust video-conferencing support to build stronger social relationships within the distributed teams.

As a learning experience, the pilot VSX effort provided many insights – both expected and surprising – on the implementation of international teaming in design courses. With the revisions and enhancements outlined above, we expect the Spring 2004 follow-up pilot to yield tighter collaboration and a solid basis for expanding VSX-support to other courses in the future.

2.3 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. Lack of contacts with overseas corporations and high logistical barriers (e.g., visas, housing, financing) have limited international internship opportunities for NAU students. Streamlining access to international internships in the GEC will require significant expansion of such opportunities, strong support

for finding internships and managing logistical hurdles, and a framework for integrating internships into programs of study.

Our goals during the pilot phase of the GEC initiative were to articulate a vision for streamlining the process of finding internship opportunities, leverage our relationships with international partners to establish new international internship providers, and finally, to validate our understanding of the process by placing at least one student in an international internship.

2.3.1 International Internships: Progress and Outcomes

We began our efforts with an informal survey of students in our CET International Club, to get a better sense of why students have not historically pursued international internships. The overwhelming response was that the logistical effort of locating a suitable opportunity was simply too daunting, particularly given the relatively easy access to stateside internship opportunities. Specific obstacles included:

- **Finding internships.** The first obstacle is even knowing what companies offer internships in their discipline. While company websites and services like Praktikum.de (http://www.praktikum.de) generically invite applications for internships, they leave most students overwhelmed at the prospect of placing an application (as foreigners, to boot) into an anonymous pool with hundreds of other applications. What is needed is a comprehensive, searchable database of internship opportunities.
- Finding Community. Going to work in a foreign country is a novel and intimidating concept to most American engineering students. As the international internship program gains momentum, however, a growing number of students will have faced this challenge and will have brought home a wide variety of experiences. What potential interns need is access to these students and their experiences to draw on for advice and encouragement.
- **Finding Answers.** There is an endless series of questions that students must find answers to in pursuing an international internship, e.g., where and how do I find an apartment from abroad, what is the visa application process and where do I find the proper forms? Collectively, this flood of uncertainties represents a significant obstacle that drains away student initiative and, simply put, makes it easier to stay at home. What students need, therefore, is a comprehensive, "one-stop-shopping" resource for answering questions related to the internship experience.
- Fitting internships into undergraduate study. Many foreign companies require a three-month minimum stay for interns; many American students, however, are unable to invest more than 8-10 weeks of time. What is therefore needed is a technology solution that allows internships to be extended *virtually* beyond the timeframe that students are physically at the company.

To address the obstacles revealed by our planning effort, we propose to develop a



Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition Copyright © 2004, American Society for Engineering Education sophisticated GEC *Internship Portal*. As shown in Figure 2, the GEC Internship Portal (GEC-IP) will effectively establish an *online community*, in which students interested in internships can inform themselves about internship logistics, interact with each other and with internship providers. Briefly, the **Community Module** establishes an interactive online forum in which past, present, and future interns can share information; the **Provider Module** contains searchable background information on each internship provider; the **Resource Module** is a constantly growing searchable archive of logistic and administrative information; and the **VISTA module** draws on the same technology used for the VSX effort to allow interns to *virtually* extend their internship to satisfy the needs of an employer. All modules are fully inter-linked, so that the GEC-IP establishes a cohesive, vibrant internship community that effectively archives "institutional memory" related to internships.

To validate our understanding of the logistics of international interning, we placed two interns in Germany with BMW and Daimler-Chrysler, respectively, in the Summer of 2003.

2.4 Engineering-Specific 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%¹⁴; the percentages are even lower among engineering students. Fewer and fewer students believe traditional language instruction to be a worthwhile investment of their time, mainly because progress toward communicative competence in a typical college language course is slow and diffuse, with little coverage of the technical language of engineering. With this low benefit/cost ratio, it is no surprise that foreign language instruction often has low priority for engineers.

During our planning effort, we built on progressive language initiatives developed on other campuses^{13,23} to pilot an engineering-specific German language training sequence (2 semesters + 8-weeks summer immersion) designed to bring engineering students to a level of linguistic competence sufficient for successful participation in a foreign language engineering course or an internship abroad *within one calendar year*. As a pedagogical framework, we started with a popular German instructional text, but then developed a companion lab manual[‡] that provided a comprehensive set of engineering-oriented language exercises (i.e. focused on measurement, engineering processes, technical vocabulary) to go with the text.

The first semester of the sequence was offered in Fall 2003; the second semester is currently underway. The course was offered by the Modern Languages Department, but taught in the engineering building. Enrollment was limited to 15 students to provide the individual focus necessary to make rapid progress. The follow-up immersion course was developed by our German partners in Zittau, Germany, and will involve seven weeks of intensive language study, followed by a two-week "mini-internship" at a local company in Summer 2004.

The response to our offering was extremely encouraging: eight engineering majors immediately enrolled. Student satisfaction ratings were uniformly high, and nearly all of the students from the first semester segment also signed up for the second semester offering. Six course graduates will be participating in the Summer 2004 immersion follow-up in Germany, and then continue their stays for further internships and/or study abroad.

[‡] The complete lab manual is available on our GEC website at http://denali.cet.nau.edu/GEC .

3.0 CURRENT STATUS OF THE GEC PROJECT

The GEC project is currently in a secondary evaluation phase as we plan for full implementation, with internationalization and VSX-supported international teaming across of a wide range of courses spanning all disciplines and programs within our college. To support this full implementation of GEC, we have applied for substantial NSF support under the same program for Dept. Level Curricular Reform that supported our planning effort. Further details on the GEC project and current status can be found at http://denali.cet.nau.edu/GEC .

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, cultural mediator) 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 motivation for our GEC initiative – 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 proposed here 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 in the hallways and classrooms, *routinely* work in teams with international students, 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.

The pilot efforts described in this paper were aimed at developing key elements of the overall vision. Our experiences have been very promising overall: while not without disappointments or open challenges, our results show that the key elements of the Global Engineering College concept are both feasible and worthy of further development. Just as importantly, our experiences indicate that students respond positively to a more central focus on international issues, recognizing the importance of such training to their future careers.

In sum, our pilot efforts give every reason to anticipate a successful implementation of the Global Engineering College paradigm at NAU, and that our work will serve as a model for other engineering schools nationwide. In short, we view the Global Engineering College as an exciting model for bringing engineering education into the 21st century.

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