A Consortium for Global Engineering Design

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Abstract

How can we understand design in a global economy and prepare engineering students to play creative leadership roles? Further, what can we do through research to re-conceptualize design ideas, methods, and processes in creative ways that raise productivity and improve the lives of people throughout the world? The authors address these questions by discussing the Prestige Consortium that was established to advance global design education through the combined resources of seven universities in four countries.

1. Introduction

Engineering is global, and engineering is done in a holistic business context. The engineer must design under constraints that include global cultural and business contexts—and so must understand them at a deep level. They too are the new ‘fundamentals’.

Dr. William Wulf  
President, National Academy of  
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Engineers can expect to work in multi-cultural teams for multinational organizations in overseas locations and in virtual global teams. In both real and virtual collaborations, engineers are increasingly working with, and in, varied milieux with different technical norms, standards, and procedures, and in different cultures and languages [1].

The changing nature and scope of the global economy is characterized by emerging patterns of corporate structure that are both more diverse and more distributed in order to take advantage of global technological diversity, distributed resources, and global market penetration. Global design and production now uses a 24-hour world clock in performing design and manufacturing tasks in all time zones. The regulatory environment is the complex intersection between local, national, and international practices and standards in engineering. However, along with difficulties associated with mixing many languages and cultures come the benefits of diversity in new ideas, new perspectives, and new needs.

Economic and cultural globalization is an important consideration in the education of engineers. Within twenty years global engineering may well be a defining context for engineering careers. The question is what should global engineering design education look like today? The Prestige Consortium was established not as the answer to this question, but as a forum in which some good answers should emerge.

2. Prestige Origins

PRESTIGE (PREparing Engineering Students for the Global Economy) is a consortium of seven universities in the USA and Europe focused on global product design and development that was formed in 2001 and funded in late 2002. It is supported in the US by FIPSE (Dept. of Educ.) and in Europe by the DAG of the EC. The members in Europe are the University of Leeds (lead, Alan de Pennington), Ecole Centrale de Lyon (Patrick Serrafero), IUT, Bethune of the Université d’Artois (Dominique Sainrve), and the Universidad de Navarra in San Sebastian (Javier Sanchez Sierra). In the United States, the partners are Penn State (lead, Richard Devon), Arizona State University (Mark Henderson), and the University of Washington (Richard Storch) in the USA.

http://Prestige.psu.edu/

Apart from the new consciousness represented by the quote from William Wulf, several factors determined the origins of Prestige. During the period 1997-2001,

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global design teams were established between Penn State and the IUT, Bethune, France, and between the University of Leeds and Arizona State University. An officer in International Programs at Penn State realized this at a 2001 ASEE conference and made the connection. Devon and de Pennington submitted a successful proposal to FIPSE/DAG in 2002 including the original four partners while adding three more.

There were other contextual influences. Engineering education was clearly globalizing and several international engineering education journals (IJEE, JGEE, WTETE) and organizations (UICEE, ICEE, WUN) had appeared in the mid to late 1990s [19]. WUN was created at the same time as Prestige in 2001 and is significant because two of the founding universities were also the University of Leeds and Penn State University. WUN focuses on leveraging (post) graduate level collaborations and is primarily a research alliance. But WUN is similar to Prestige in the intent to use global resources to enhance the academic agenda in research universities. Comparing Prestige and WUN also draws attention to the difficulty of drawing a line between education up to the first degree (undergraduate in the US and graduate in the UK) and education after the first degree (graduate in the US and post-graduate in the UK). In France, Spain, and many European countries the first degree is after five years of higher education. In the US, it takes four years, and in the UK, three years or four years in Engineering. These differences create many constraints in writing agreements.

3. Prestige Programs

Prestige activities include preparing engineering students for work in the global economy through student travel for study abroad and internships in industry and in funded design projects on campus; through bi-lateral and multi-lateral cross-national teams that use information technology, and through a web resource site for design education. These three activities can contribute towards solving the mapping problem between different academic formations. They represent collaborations that minimize the disturbance of existing academic structures. We are going beyond the funders’ requirement of student travel to implement a strong virtual component in the collaborations. Our prior experience in this respect was invaluable.

While the initial funding is important seed funding, it is not sufficient to facilitate what we want to do, and even the well intended requirements of that funding have proven restrictive as we develop our ideas. Thus, while the funders want extended student immersion in other cultures, we are implementing a summer nomadic design academy wherein students travel to several universities to study design specializations and visit related industries. This is extremely exciting to us, in that it makes exposure to global issues accessible to larger numbers of students. This compliments the extended internships which small numbers of students participate. We envisage research possibilities, into, for example, studying the dynamics of distributed teams in cross national and multi-national design projects. Finally, through one partner, Mark Henderson at Arizona State University, we are seeing a new professional interest group, GEES (http://cpd.asu.edu/conferences/gees/), emerge in global engineering education with some of the major practitioners of global engineering education in the US. The presentations and working papers of a meeting held in February 2004 will be published in the summer of 2004 in the Journal of Design Research (TU Delft).

In the following pages we will outline some of the activities we have pursued for virtual teams, student travel-based programs, global design teaching resources, and for advancing engineering education. This discussion is supported by a series of papers that have been published before and during Prestige.

4. Virtual Teams

The use of virtual education experiences such as cross-national design teams [20], or lectures and discussions by overseas engineers and faculty, continue to increase, but more slowly than might have been expected a decade ago. As in the corporate and government worlds, the use of information technology can reduce the costs of travel in time and money, and any perceived risks of travel [21]. In education, it allows a scaling up to include far greater numbers of students than will ever engage in real travel. And it promotes interest in real travel. In any given project, both real and virtual activities will be present as they are in the worlds of corporations, not for profit companies, and governments. Virtual work is not as easy as it sounds and the two biggest problems are logistics (finding partners, and mapping educational objectives and calendars) and collaborative technologies that are negatively, and increasingly, affected by firewalls and other security measures. Nevertheless, virtual collaborations are inescapable and the following describes programs that may be co-located, virtual, or mixed.

4.1 Constructing Cross-National Design Teams

While some authors have adopted a typology approach with a few key options for constructing cross-national teams [10], we believe that a parametric approach is more suitable for dealing with the very high number of
options available. To illustrate this approach, seven logistical parameters that characterize the construction of cross-national teams in education are listed below [15].

1. Node frequency
   (a) bi-nodal, (b) tri-nodal, (c) more
2. Relationship type
   (a) collaborative (continuous, inter-dependent, integrated)
   (b) competitive: inter-corporate (multi-national teams) or international (national teams)
   (c) cooperative (occasional sharing): show and tell, or parallel
3. Status relations
   (a) equal partners, (b) “sub-contracting” mode
4. Languages
   (a) mono-lingual, (b) multi-lingual
5. Curricular structure
   (a) in class (multiple teams), (b) out of class (single teams)
6. Duration
   (a) expository, (b) short term, (c) long term, (d) indefinite
7. World Time
   (a) compatible; within ±2 hours,
   (b) manageable: within ±3–6 hrs,
   (c) difficult: within ±7–8 hrs,
   (d) impractical (not impossible) for real time: within ±9–12 hrs

There are certainly many other parameters and the combinatorial possibilities are very large. However, the parametric approach allows you to customize team designs to your needs quickly and effectively. In Prestige, we are trying a variety of design projects using bilateral and multi-lateral teams. These teams may use one, two, or three languages. They take place in-class (many students in multiple teams for fairly short periods) and out of class (a few students in one team for a year or more). Using the subcontract mode, crossover arrangements are possible whereby an ongoing out-of-class project subcontracts to student teams in an in-class situation. The out-of-class projects may also support actual student travel such as in the GEDT [6]. The learning outcomes of the GEDT is being studied and may be reported in the near future. Below we discuss an in-class collaboration that is leading to a publication.

There is a great deal of research activity that takes place on distributed teams across several different disciplines such as engineering, business, social and organizational psychology and information systems [8, 9], and Prestige programs offer a valuable environment for data collection. Several research initiatives have already begun with different groups of partners within Prestige and 2004-5 should see these efforts increase with the first publications emerging in late 2004. One of these initiatives is a study of the effect of global diversity on creativity in design teams. While the research literature often documents the U-shaped distribution of the effect of diversity on team performance [14, 16], it works for you or against you, we are seeing very big positive effects of global diversity on idea generation.

In one example, a new course on global design established at Penn State, in part through Prestige, ran for the first time in the Fall of 2003. In this course four teams were established between the Penn State students and students at the engineering school of the Universidad de Navarra, Tecnun, in San Sebastian. The students decided to establish a set of design objectives for the dashboard of a car. The data generated are being written up for an article but are summarized here. The method is similar to a customer needs assessment approach but collects unique ideas (innovative design) rather than repeat ideas (market share).

At first the bi-national teams were split nationally and a graph of data were generated for the number of unique ideas provided first by one student, then by the national sub-team, then by those sub-teams extended by each member asking three other people, and then by the four national sub-teams combined. At this point, coincidentally, about 80 ideas were generated by both the Tecnun students and by the Penn State students. A fifth point on the graph of the number of unique ideas vs the number of people asked combined for both countries may then be generated. One may predict roughly where this point should be by extrapolating the Tecnun and Penn State curves from the first four points. If the new point is above the predicted values, it is reasonable to consider that this is due to the diversity introduced by merging data from two different countries. Preliminary data for design objectives for a second project, a travel clock show this effect in Figure 1.

![Figure 1](image-url)

**Global diversity in idea generation**

In fact, when combining all the teams’ data for the dashboard, we found only 10% of the ideas in
common. We have studied the idea lists and have not yet determined what cultural content was at work since both lists look what plausible. We then did a repeat study for a travel clock (Figure 1) that was being designed by students at the University of Leeds and we ran a 3-multi point video conference using NetMeeting. The data were not as systematically collected but we can again see a very large diversity effect. We could not use data from the University of Leeds this time since the students there were actually required to build a prototype alarm clock and the brief required the students to use ‘a standard part’. They were also focusing on analysis of requirements rather than generating new ideas. Design for manufacturing was a severe constraint there! Next time we expect to be combining three sets of data, however. This method is a very interesting way to generate a valuable metric for the diversity effect in enhancing team performance. The metric may facilitate research examining what factors help and what hurt team performance, although care is necessary as the people are student designers.

4.2 Global Engineering Design Team (GEDT)

The genesis of this collaboration was a workshop held in 1996 at ASU entitled “Excellence in Global Manufacturing Education”. Industry representatives present included Steve Coe from Boeing and Richard Taylor from Rolls Royce. Building upon studies reported by SME (Society for Manufacturing Engineers), on the gaps in UG education perceived by employers they committed to defining a team project involving students from ASU and Leeds. All stakeholders needed to derive first benefit and a report on the first project team was presented at ASEE 2000 [6].

Having industrial mentors in conjunction with Faculty added significantly to the students’ experience. The GEDT was regarded as a pilot programme to address ABET requirements and SARTOR [2, 3]

The modus operandi of the GEDT activity has developed over the past 6 years including exchanging students and time in companies during the summer. Such collaborations require dialogue between faculty from well before the project begins until after final assessments have been completed.

4.3 Design Projects

The approach to design projects varies at the different universities. In mechanical engineering at the University of Leeds for example, following Pahl and Beitz [13], they have developed a creative use for the Design for X method(s). First the students in a class split into teams that each use a different X (manufacturing, environment, ...) for the same problem. The results are then presented so each student should learn one method well and become aware of several others. New teams are then formed from members of different methodology groups [11]. Of interest here is the Design for X approach, which has many uses, but which rarely appears in design texts in the US (design for manufacturing and assembly is very common, however [17]). Further, the final configuration of the teams at the University of Leeds is considered multi-disciplinary and thus meeting the SARTOR requirements for mechanical engineering education in the UK. In the US, it is ABET standards that are the driver, although they are similar for this criterion.

Conversely, design education in the US is very focused on customer needs and product realization. So the collaboration immediately brings diverse perspectives and methods into play. Even pedagogy can be enriched by a global collaboration. At the University of Leeds, the popular experiential learning cycle of Kolb is taken as the underpinning for learning in design projects. Both the experiential learning theory of Kolb and his theory of learning styles may well yield new data when studied in global design teams with students from disparate backgrounds [12].

5. Student Travel: Tours, Internships, Study Abroad, and Global Design Academies

While the use of information technology can seem attractive the acquisition costs and operational costs may be significant. Most still believe in the value of real foreign experiences. We have found that virtual experiences raise the interest of students in real travel. Penn State has used a one week industry tour in France that follows in the summer for students in an introductory design class featuring cross national teams. Many of the students are traveling abroad for the first time. Anecdotally, and we have a lot of anecdotes and reports, this seems to have an extraordinary impact on the students who go considering how short it is. However, an advantage of short activities is they require fewer resources, less cost and less time. Short programs have effects that are less than most longer programs but probably far more than virtual experiences, particularly for first time travelers. Under Prestige, we have assumed that semester abroad programs were already a possibility and we have been exploring the task of creating internships for students. Some of these are in industries (IUT placements), some
in research institutes attached to universities (such as CEIT, [http://www.ceit.es/](http://www.ceit.es/) at the Universidad de Navarra in San Sebastian) and some in funded research and development design projects on campus that may be embedded in longer virtual experiences (such as the GEDT). Many of the assignments are in foreign language environments for the students, and some students have done this even after only one year at university. We find this is a good place for the development of foreign language skills that is less exacting than taking classes. We hope that students who do these internships may feel able to study abroad in that foreign language later. Originally, we had thought that we could continue the practice of short industry placements in the summer as a viable alternative to study abroad. However for US bound students, new post 9/11 restrictions have made that impossible for the case where students will stay less than 6 months. And for 6-12 months, it requires a J-1 Trainee visa that is not easy to acquire. For EC bound students the summer internship is still possible and we are using it. Thus, US bound students must settle for an internship in an on-campus design project. At a large research university in the US these projects are not hard to find and have the added appeal of being amenable to pre- and post- internship collaboration using information technology. Further, the EC students get a close look at engineering education in the US.

The aftermath of 9/11 has had other impacts on student travel to the US, but not as much as might have been expected, and student travel from the US continues to grow [7]. Despite sharp drops in students from the Middle East and Muslim countries, the total number of international students attending colleges and universities in the U.S. in 2002–3 still showed a slight increase (less than 1%) over the prior year, bringing the total to 866,323 [7]. However, this story has not yet played itself out, and real delays due to increases in visa constraints and other bureaucratic requirements mean that planning and applications must begin much earlier than usual.

5.1 Global Student Tracking System

One of the tools we are developing to assess our programs is a web-based Global Student Tracking System (GSTS, see Figure 2). It also serves to provide contact information for the students. This system is password-accessible via the web and provides different levels of access for facilitators, students, industry mentors, etc. The system collects information on

- contact information for student for all locations plus application material and details of placement
- assessment log entries
  - at initial application
  - prior to departure
  - two weeks after arrival
  - 6 weeks after arrival
  - at departure
- final student report on programme experience
- assessment entries that focus on objectives, problems, successes, and satisfaction (numerical)

Figure 2: Assessment data collection screen in the web-based Student Global Tracking System

The GSTS also allows us to collect data using new assessment tools developed and/or obtained. With the data collected via the system, we are using qualitative research methods such as content analysis on student reports with the coding frame based on the specified set of student outcomes [1].

6. Global Resources for Teaching Design

At each partner university the Faculty are teaching design and have developed local resources that can be placed on the web if not already there. We are developing a website that will collect such resources and organize them to be of use for teaching design. It is expected that they will be translated into French and Spanish at the Prestige partners in those countries. At present, we expect to organize many of the resources around the stages of the design process, despite the variability with which this process is conceived and presented. Even such ubiquitous topics as design ethics and project management may be more or less organized in this way. Nevertheless, some topics such as design theory, links for societies and conferences, and design practices in various organizational settings and countries may need special treatment.

By offering global approaches to design in a format that can be continuously updated, such a web based
resource could be an attractive complement to the many good design texts currently available. None of even the best texts yet tackle global design issues, although one global industrial ecology text is beginning to include design topics. At present it seems likely that the web site will be password controlled but the plans are ambitious and even the first appearance of pilot site will not take place until the end of the summer of 2004.

6.1 Global Product Development Body of Knowledge

Behind the development of the website a process must take place within Prestige whereby a body of knowledge about global product development is created. The web resource site will just be an educational resource derived from the general knowledge acquired. There are some recent industry websites that are already useful, educationally since they seem to reflect the provision of training services[18]. The categories in which we have initiated working groups include:

- the human aspects of product design and development: teamwork and Integrated Project Teams, collaboration, communication, project management, product and process design ethics;
- Processes: stage gate processes such as design reviews, project risk management (only a few texts cover this [17]), and resource planning;
- Strategic aspects: supply chains have become both more critical and more complex in the global economy and Prestige will address these issues, since the faculty at the University of Leeds have relevant expertise;
- Technology issues: data representation and exchange (eg STEP), collaborative tools, and uses of CAD, CAE, FEA, time to market issues such as rapid prototyping and rapid manufacturing;
- Design methods: decision making models, abstraction and modeling, robust design;
- Innovative design: Around the world industrialists know that those who do innovative design well now, will do well in the future battle for market share. Prestige faculty at Penn State, for example, have expertise in innovative design and entrepreneurship and expect to contribute.

7. Advancing Engineering Education through Global Collaboration

At Arizona State University in March 2004, Mark Henderson held a two-day workshop on global design education that brought together many experienced practitioners. They concluded that the future of engineering education was global engineering education and plan to continue to operate as a practitioner group to share ideas and experiences. That workshop has influenced one publication already that presents an assessment model for global programs [1], and several participants stated that they had immediate venues for presentations based on the workshop findings. The workshop papers are being published. We are aware that long term trends are showing ever greater integration of capital, resources, and people across national boundaries. Not the least of these processes is that of outsourcing which has already started migrating from manufacturing to service to professional work. We have to consider not only what will be taught and to whom, but by whom and where. And the implications are far greater than, say, finding cost effective grader in Bangalore or South Korea. In general, we think that research intensive universities will tend to have strong anchors if they adapt to changing global realities. Strong research universities will be found in most regions of the world. Assuming the future of engineering design education is global engineering design education (GEDE), we have provided some possible futures by disaggregating engineering education in Table 1. We welcome suggestions.
8. Conclusions

In summary, with Prestige we have created an entity that can adapt creatively to the changing needs of design in the global economy. We will be able to respond to change even while we cannot yet see what such changes will be or how such adaptations will occur. This, in turn, means that Prestige must be developed as an institution that is connected globally to the right nerve centers: the progressive centers of design and design education. Pursuant to this goal, we are very interested in developing a relationship with CDEN.

9. References


[18] Websites with good educational resources for product design an development topics:
http://innovation.im-boot.org/index.php
http://www.npd-solutions.com/bok.html

[19] Selected international engineering journals:
http://www.ijeem.htm

Selected international engineering organizations:
http://www.ineer.org/Welcome.htm
http://www.wun.ac.uk/


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