The Global Engineering Design Team (GEDT)- Transatlantic Team-based Design for Undergraduates

Mark Henderson, Alan de Pennington, Jim Baxter, Valana Wells
Arizona State University/University of Leeds/University of Leeds/Arizona State University

I. Introduction

Industries are becoming more global in nature, especially in their supply chains. Undergraduate engineering students rarely address this trend nor do they ever get to participate in international or non-collocated teaming. Furthermore, international companies have a desire to explore closer global relationships with their current or prospective supply chain companies. For these reasons, Arizona State University and the University of Leeds have begun a joint academic year course entitled the Global Engineering Design Team (GEDT). The goal was to create a single team of students on a company-sponsored design project that required continual global teamwork, thinking and communication and would prepare the students for Design in a Global Environment.

The first implementation of this course was during the 1998-99 academic year and involved a total of 9 undergraduate engineering students, 4 from ASU (2 industrial engineering, 1 mechanical and 1 aerospace) and 5 from Leeds (4 mechanical and 1 mathematics engineering). The first year was sponsored by Boeing Commercial Airplane Co. in Seattle, WA and Rolls-Royce Engines in Derby, England.

The project proposed by the industry sponsors for this GEDT was to produce 40 spheres, each half produced by superplastically forming either Ti64 or an Aluminum alloy and matching the dissimilar halves into a watertight assembly using a flexible joining method. The resulting spheres would be 4 inches in diameter and would resist rolling on a 10-degree incline. A finished sphere is shown in Figure 1. Note the eccentricity in the top Aluminum portion compared to the spherical bottom Ti64 half. This will be discussed later.

Figure 1: A completed Ti64/Al

This project is different from most student projects for several reasons. Most projects do not require production (other than a prototype) and most projects do not have industry mentors to help with all project aspects including the technical and project management tasks. And, most importantly, student projects typically do not require interfacing with international universities nor international travel.

The project was successful for several reasons. First, the team produced deliverable product and learned about the design and manufacturing challenges to make that happen. Second, the companies became closer together by providing mentors with common, non-competitive goals, all concentrated on a single student team. In fact, the same companies are sponsoring another team this year and are already selecting a project for 2000-01. The universities learned several lessons, covered at the end of this paper and will use them to continuously improve this experience for the students. And, lastly, the faculties at the two universities have become better acquainted both with each other and with the sometimes-diverse cultural issues that help global understanding.

II. Motivation

Academic innovations such as this don't happen overnight nor are they self-starting. Therefore, it makes sense to explain a bit about the environments at both UofL and ASU that generated interest in such a program

The GEDT program had its beginnings during the Conference *"Excellence in Global Manufacturing Education: Defining World Class Models and Transformation Strategies"* at Arizona State University in November 1996. This Conference, a result of a NSF/DARPA-funded technology reinvestment program (TRP) grant entitled "Manufacturing Across the Curriculum", included representatives from 10 countries including the United States with the goal of developing a roadmap to improve global manufacturing education in engineering schools. Among those attending were the authors, Henderson and de Pennington, Steve Coe, Boeing commercial airplane and Dr. Richard Taylor, formerly of Rolls-Royce Aerospace, a member of Royal Academy of Engineers and currently a visiting professor at Leeds. This group discussed at that time the possibility of a joint engineering design team, which would allow Boeing and Rolls-Royce to explore a closer business relationship. Rolls-Royce is a supplier of jet engines to Boeing, both for commercial and military aircraft. The authors had considered the idea of a global engineering design team for several years and this industry interaction provided the doorway to its implementations a pilot program.

From Boeing's viewpoint, their goal was three-fold: to explore partnerships with Rolls Royce, provide new graduates with experience they can use and to provide engineering employees at Boeing some mentor training in preparation for technical leadership. As Steve Coe, Director of the Ed Wells Initiative at Boeing, says, "There is a growing trend for design engineers to work in teams that span more than one company and country. This project will provide students with experience of working in such a team environment on a design problem. It is a part of a wider initiative from Boeing and Rolls-Royce, which is directed towards developing qualified engineers into technical leaders. This project will involve qualified engineers from Rolls-Royce (in the UK) and Boeing (in the USA) who will act as mentors to the students, and engineering students from the University of Leeds and Arizona State University who will be working together on a design and manufacture problem. The students will be based in their home universities for the duration of the project and facilities such as video-conferencing will be available to allow team members to communicate with each other across sites." (Steve Coe, Boeing Corp., August 1998)

And, the viewpoint of the University of Leeds: From an educational perspective, the purpose of this project is to give students experience of working on real design projects in a team-based setting that includes a number of distinct cultures and disciplines. Through participation in such projects students will gain both a deeper technical understanding in the area of the project and insights into issues involved with the management and leadership of cross-disciplinary projects. Both of these are distinguishing features of the MEng (as opposed to the BEng & IEng) degree schemes that have been highlighted through the Engineering Council SARTOR initiative in the UK. The establishment of a program to recruit members of the Royal Academy of Engineers to work part-time as advisers at the university provided help in making links with industry. One such RAE member, Dr. Richard Taylor, a retired Rolls-Royce engineer, was available and interested in bringing Rolls-Royce together with Leeds for student projects. Furthermore, the Keyworth Institute for Manufacturing, lead by Prof. De Pennington included this type of activity in its mission.

From ASU's standpoint, interest in Design Teams had evolved on several fronts. Industry partnerships in an Engineering Excellence Program in the early '80s had initiated university/industry conversations and an attempt by ASU to provide students with industry awareness and experience. The NSF TRP grant "Manufacturing Across the Curriculum" included funding for large team-based design experiences including teaching design courses at local industry sites, the Virtual Corporation of a 60-member interdisciplinary design team and exploratory trips overseas to investigate global manufacturing engineering programs. In addition, new team training curriculum materials, developed under an ASU NSF grant had just undergone successful classroom trials. The overseas visits, especially to the University of Leeds, exposed a willingness to explore non-collocated teaming experiences for students. Furthermore, the major enthusiasm for these experiences centered on undergraduate students and international cultural and technical exchange. Other universities were conducting global design teams for graduate students at that time, but undergraduate involvement was minimal[1].

The initial plan for the global engineering design team was for short exchange visits of each group of students to the other school including the industry-created definition of a year-long design project to be conducted by both groups as a single team throughout the coming academic year. During the summer of 1998, four students from ASU and five students from Leeds were selected for this initial implementation. Mentors were selected from Rolls-Royce and Boeing commercial airplane company to guide both students and faculty through his first year's project. We were fortunate during the first year to have five excellent mentors, three from Boeing and two from Rolls-Royce. These mentors communicated with each other and also freely with the students and treated the team members as company employees.

III. Project Deliverables

The project goal was to produce the following

- 40 spheres completed by 30 April 1999
- Ti64-Al hemisphere assemblies
- 4 inch OD
- must stand on a flat surface and not roll on 10 degree incline
- flexible seal to be used to join hemispheres
- meaningful surface graphic features to represent project
- joint tolerance +/-0.75 mm on OD
- watertight with demonstrated internal pressure capacity
- surface finish 63Ra

The first prototype must be demonstrated by 12 January 1999.

The requirements include progress notes every other week. Substantive technical reviews need to be agreed between all parties.

IV. GEDT Schedule

The overall schedule for GEDT was as follows:

August 1998	ASU students traveled for a 10 day visit to U of Leeds and Rolls-Royce for cultural exchange and project definition
September 1998	Leeds students traveled to ASU for a 10 day visit for cultural exchange and team training followed by a 2 day visit to Boeing/Seattle for plant tours and further project definition
October 1998	Project commenced; web site begun
November 1998	Project update meeting in Arizona with one Leeds student chosen to attend; Team behind schedule; Team encouraged to suggest project changes to get back on schedule
December 1998	Project reports from U of Leeds students in the UK for class requirements; Project update from ASU students for ASU course requirements
January 1998	Second phase of project continues with students changing to a second term course
February 1998	Project update at U of Leeds and Rolls-Royce. One ASU student selected to attend; Team seriously behind schedule; Encouraged to redefine deliverables to satisfy customer, yet get back on schedule
April 1998	Project deliverables due, but not ready yet. Manufacturing Process caused delays; Mentors reduce deliverables; Leeds students continue until June and volunteer to finish project
June 1998	12 spheres delivered: 6 to UK sponsors and 6 to US sponsors; Final report written.

V. Link Between GEDT Objectives And ABET And SARTOR

From the start of this program, it has been the plan to use the GEDT as a pilot program to address some of the ABET 2000 curriculum goals for engineering. Below is the Program Assessment table from the ABET website with the left column listing the ABET outcomes. The right column expresses how we feel that the GEDT meets these desired outcomes. Although global issues are not addressed directly, several aspects of the project do fit precisely within this list. For example, (d), (f), (g) and (j) mention teaming, ethics, professional responsibility, communication and contemporary issues, globalization being a dominant issue in this decade.

Table 1: ABET requirements with GEDT Comments[2]

ABET 2000 Audit Form	GEDT
	How GEDT addresses objectives
PROGRAM OUTCOMES AND ASSESSMENT	
Assessment Process with Documented Results to Measure Outcomes	Periodic oral and written progress reports; evaluated by faculty and mentors
Results Applied to Improvement of the Program	Lessons learned used for planning year number 2 and on
Demonstration (incl. Process & Measurements) that Graduates have:	
(a) ability to apply knowledge of math, engineering, and science	Technical project requires modeling and experimentation
(b) ability to design and conduct experiments	SPF manufacturing process designed and prototyped. Products resulted from process knowledge and capabilities as well as customer requirements

(b) ability to analyze and interpret data	Data here involved both scheduling data and technical process and product data. Several project adjustments were necessary to satisfy the customer demands within the time constraints. A design of experiments process helped reach a suitable product result.
(c) ability to design system, component or process to meet needs	Students designed the manufacturing dies as well as the final product. Local vendor helped with die design and SPF process
(d) ability to function on multi-disciplinary teams	This was not only multi-disciplinary teaming, but also global and cross-cultural and cross-time zone teaming. The mentors were part of the team process, also.
(e) ability to identify, formulate, and solve engineering problems	Customer gave product requirements. Students had to design the process to create these products which required modeling and experimentation at two separate sites: USA and UK.
(f) understanding of professional and ethical responsibility	Communication was a key problem and solution. Ethics requires honesty and forthrightness and these two factors were emphasized at each progress meeting.
(g) ability to communicate effectively	GEDT pushed the boundaries of global project communication using video conferencing, online discussions, email, telephone/fax and travel. Monitoring project status involved software project management tools.
(h) broad education	
(i) recognition of need an ability to engage in life-long learning	Cultural and global differences pique curiosity of students to give incentive to life-long learning
(j) knowledge of contemporary issues	Global design is commonplace in industry, but not in the university until this project began
(k) ability to use techniques, skills, and tools in engineering practice	Teamwork, design process, analytical models, CAD/CAM, project management, design of experiments, oral and written communication

VI. Learning Outcomes

The most important aspect of reviewing this GEDT experience is to extract lessons learned to improve future GEDT projects. The following items were major learning outcomes for the sponsors.

1. Communication is the key to success of this project and the experience, in general. Because of great distances and times and also because of large schedule differences between the US and UK academic calendars, the teams lost track of some of the project milestones and subtasks. As can be seen from the abbreviated schedule above, each project update reflected that the team was behind its original design and manufacturing plan. The reasons were many, but the overall problem was communication. When the schedule began to slip, at one location, that part of the team was hesitant to admit it and increased their efforts to catch up. The schedule slippage, though, is sometimes due not to amount of work, but amount of coordination. For example, the two halves of the team decided to use different tactics to make their individual hemispheres: the Leeds students found a manufacturer in London who would charge for manufacturing the parts, but would take the order and agree on a delivery date while the ASU students found a local vendor who agreed to do the job for free, but had never used superplastic forming as a manufacturing method before. The difference in risk between these two methods was higher than it should have been. These approaches are vastly different. In the UK case, the project was dependent totally upon the vendor to meet his delivery dates. In the AZ case, the students helped the vendor learn the process and could affect the delivery, yet were not confident of the part quality. The differences in the two halves can be seen in Figure 1. The aluminum top half is eccentric because of improper processing parameters while the bottom Ti64 half looks hemispherical primarily because the UK vendor had processing experience. Toward the end, it was evident that the delivery dates

of the two halves would be different by 2 months. Communication between team members and a risk-management program may have helped avoid this problem.

2. Communication on another front was important, as well. Video conferencing was tried twice with mixed results. The students liked the fact that they could see each other and detect opinions and feelings not obvious using telephone or email. However, the videoconferences exceeded the communications budget and had to be stopped halfway through the year. The result was that email and telephone were the primary communication media. Email became frustrating if no answer was received in a reasonable amount of time. Phone calls were awkward because of the time difference. However, there were times when the time difference was an advantage. At one point, when the customer demanded an updated presentation within 12 hours, the task was started in Arizona and passed off to Leeds. The updated presentation arrived by email by the time the ASU students got to school the next morning.
3. The third communication factor was regular contact with mentors who acted as the customer. The team found that their tendency when falling behind was to be mute and not initiate customer contact. They found that this was a mistake and they paid for it during the progress reports when the mentors expressed pointed concern and each time required the team to redo its project update with a plan for getting back on schedule. They did give the team the option of changing the deliverables, but had to keep the customer somewhat satisfied.
4. Project selection is a key ingredient to making the GEDT a success. Initially, the team members were chagrined with the project assignment. They originally had wanted to do aircraft or engine design and to be assigned manufacture of a simple sphere (albeit superplastically formed) was a disappointment. However, after becoming involved with the project, they realized that it contained more challenges than they originally thought. And it resulted in a healthy respect for technical complexity, project management and communication, the three major objectives of this GEDT experience. The result here shows that the industry mentors can be extremely helpful in choosing a suitable project and the students in the team should be made aware that the goals of the GEDT are not only technical. In fact, the technical portion turned out to be manageable, yet not easy. It was the management and communication that caused most of the problems throughout the year.
5. Cultural issues, even without language barriers, can become issues. One reason for the two universities to select each other for this project was the absence of a language barrier. And, it was assumed that other cultural barriers would be minimal. There were no problems with collegiality or understanding each other, yet the differences in other aspects of the culture did cause some problems. Each of the schools has a different class schedule and different set of requirements for classes. The difference in schedules caused a period of discontinuity from early December until February, almost a 2-month period. The UK academic calendar requires intense exams during some of this period while the US universities spread exams throughout the semester and break for a month of vacation. Also, ASU students continued with the same course format for the spring as a capstone course, while Leeds students were required to switch to an *individualized* course in design rather than one that emphasized teaming. In addition, the Leeds students were provided with an office setting including a computer workstation where they could gather everyday to discuss the project while ASU students, most of whom commuted to campus, had disparate class schedules and no meeting place provided so their meetings were less frequent, but by necessity more structured. On another note, however, cultural issues can be an advantage. The students enjoyed talking and

became very good friends partly by many conversations comparing their lifestyles even including the pizza topping preferences between the two countries.

VII. Approach To Assessment

Assessing the two groups of students comprising the team proved a bit difficult, especially when considering the differences in evaluation schemes between the two universities. In order for the team members to consider themselves part of one team, it was preferred to align the assessment methods between Leeds and ASU. Universities in England do most of the assessment at the end of the term unlike American universities. Design teams at ASU are evaluated collectively and the members' grades differ only in extreme situations, while at Leeds, individuals are assessed on their individual work. In addition, the course requirements for ASU are for teaming during the complete yearlong project while Leeds students switch from team to individual projects at the middle of the year. Coordination of the assessment proved difficult. Because of these differences, students at Leeds and ASU were evaluated according to their own faculty and tradition, however during this second year with a new team, we have exchanged our grading requirements with each other and are in the process of developing a common assessment tool for all participants.

VIII. Project Schedule

The following table is included to show some of the tasks and proposed due dates at the beginning of the project. Some items to note are the differences in school start dates, final exam dates, vacation periods including winter and spring breaks. These differences were key times when the communication lagged and tasks became tardy. Because the communication methods disappeared during these times, the natural discoordination that would have happened was multiplied.

Task	Due Date
Americans travel to Leeds - participate in team-building activities	Thu 8/20/98
Team building exercises	Wed 8/19/98
Define tentative project plan	Thu 8/20/98
School starts at ASU	Mon 8/24/98
ASU England trip report due	Fri 8/28/98
First semester- project work	Fri 12/11/98
Prepare for English team members to ASU	Tue 9/8/98
English travel to ASU	Fri 9/18/98
receive design spec from customer	Fri 9/4/98
Participate in team training	Thu 9/10/98
Prepare for presentation to Boeing	Tue 9/15/98
Travel to Seattle	Fri 9/18/98
School starts at Leeds	Mon 9/21/98
Scheduled video conference (bi weekly)	Wed 12/9/98
Seattle trip report due	Mon 10/5/98
ASU - project proposal due	Tue 9/22/98
tool design 50% review video conf.	Thu 10/15/98
ASU - oral report due	Tue 10/27/98
tool design 75% review video conf.	Thu 10/29/98
Finite element model of design	Fri 11/20/98
Technical review at ASU	Mon 11/16/98
request for materials	Mon 11/16/98
first rapid prototype hemisphere manufactured	Thu 12/10/98
ASU- semester project report due	Thu 12/10/98
Leeds- semester project report due	Fri 12/11/98
ASU- final exams	Fri 12/18/98
Leeds- winter break (no work)	Mon 1/11/99
ASU-winter break (no work)	Sun 1/17/99
Leeds- final exams	Mon 1/25/99
Second semester- project work	Thu 4/29/99
Scheduled video conference	Wed 4/28/99
Begin manufacture of Al & Ti64 hemisphere	Mon 1/18/99
Link call with prototype (POT)	Mon 1/25/99
Progress review at Uof L	Fri 2/26/99
ASU- spring break	Mon 3/22/99
Leeds- spring break	Mon 4/19/99
Project Conclusion- final report due	Thu 4/29/99

IX. Results

In short, the first GEDT was successful. Products were produced; the students learned about design, manufacturing process, teamwork, communication and global collaboration. The students wrote a complete report outlining where they think the team could have improved. Communication was the major area of first priority. Below is a list of other benefits to the various partners.

Benefits To Students

- The students worked on a technically demanding project which was conducted in a realistic setting
- In this context they demonstrated an ability to initiate and then develop innovative ideas to solve problems and, in parallel, they learned about cost effectiveness, working within budgets and timescales and when to drop apparently good ideas for non-technical reasons
- They took the opportunity to use new technology to facilitate communication within a collocated team and across sites and continents and learned first-hand the benefits and limitations of a number of communication methods
- In the environment that the project created, the students acquired a number of skills that will give them a grounding for a professional career. These skills included appreciation of the need for a single point of contact to a given group of people and discipline in communications, and the importance of agendas and strategies for meetings and other interactions with people.
- The project enabled them to experience the management of change. In addition, they have had to realize that attention to detail and the need to liaise with others (including customers and suppliers) is important - input from industrialists raised the tenor of the project and made it possible for the students to work in a rich environment
- As a learning experience, working in a team of mixed ability with demands meant that non-collaborative activities became infeasible
- Industrial mentors played the role of both coach and customer for the students, a role that academic staff alone cannot provide
- The students personal development as team players grew in terms of each individuals- self-awareness and appreciation of the potential of others in the team. This was underpinned by an initial introduction to theory of teams which was consolidated with real practice and opportunities to reflect upon this experience.
- The students gained skills in communication, levels of sharing information and knowledge, risk management, how to take and seek advice, and program management where dependence on customers. suppliers and partners is important.

Benefits to Staff

- The project provided a basis for starting to understand how to share knowledge and information and how to communicate in a global context

- Starting to understand what it means to be globally aware - realized some of the implications-
- Helped to understand how to develop projects based on the team but allowing individuals to be recognised
- This year's project will provide useful case study material for projects in future years.
- Development of relationships between staff at the universities and companies.

Benefits To School

- Publicity material for the School, for example, the GEDT Web pages will be used at Leeds in open days for sixth formers considering an engineering degree scheme.
- At Leeds, the GEDT project is located in an identifiable area in the Mechanical Engineering Design Office. This provides opportunities for ad hoc publicity.

X. Applying The Lessons Learned

The second version of the GEDT has begun this 1999-2000 academic year and builds on the experience from last year. Several changes have been made.

1. Students have been required to develop a Gantt chart showing all differences in ASU and Leeds class schedules, exams, vacations and assessments. This chart will help assure that the work does not become uncoordinated during these differences in schedules.
2. An improved team training session has been added
3. The students were chosen much earlier than before so that they could get a running start as the term began.
4. An internship program has been added. Two Leeds students performed a 10 week internship at Boeing Helicopter in Mesa, AZ during the summer and 2 ASU students spent 10 weeks interning at Rolls-Royce in Bristol, UK. It is hoped that this internship will enhance their cultural exchange and allow them to return to their home institution and company with a better view of how design and life are done on the other side. The ASU students are continuing their internship during the school year, but at Boeing in Mesa, AZ. The Leeds students are not able with their class schedules to do an internship during the academic year.
5. One student from Leeds will spend the entire calendar year at ASU as an exchange student. This will balance the teams this year with 2 ASU and 1 Leeds student in the US and 3 Leeds students in the UK.
6. The project is more related to aircraft and engine design. It involves re-design of the jet engine exhaust system for a Boeing military helicopter being fitted with a Rolls-Royce engine for sale in the UK. This level of technical complication is possible primarily because the students spend much time at their internship during this academic year. The major mentor from Boeing is also the students' supervisor on the job and intimately involved with the design project. Sophisticated technical modeling and analysis require the use of company-specific software, so the presence of the students at Boeing seems to be a requirement for this type of project.
7. Assessment is being adjusted to be consistent between the two universities. Faculty members from each university are designing an assessment tool together, which will be a compromise between the 2 schools' requirements.
8. Communication is done this year with sparing use of video conferencing. Telephone conference calls are scheduled regularly with email being sent daily. Each team now has a central office on campus with a dedicated computer using Microsoft Net Meeting as a new communication tool. Net Meeting allows video (as yet untried) and audio communication with white board and chat available. Other software solutions are being investigated, as well.
9. More faculty have been added to the support staff at both universities. A communication mentor is also available. Support at Leeds is through the Keyworth Institute and at ASU through the Center for Research in Education for Science, Math, Engineering and Technology (CRESMET). Company sponsors are also providing financial as well as mentor support.

Future implementations of the GEDT will build upon each preceding year and the experiences in talking with other schools who have similar programs.

XI. Bibliography

1. Nosenchuck, Daniel, Global Engineering Design, Proceedings of ASEE 1998 Annual Meeting, Seattle, WA, June 1998, Session 2202.
2. Engineering Criteria 2000, Manual of Evaluation Process 1999-00 Visits, Engineering Accreditation Commission of The Accreditation Board for Engineering and Technology, 1999.