INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN
ICED 05 MELBOURNE, AUGUST 15-18, 2005

TEACHING GLOBAL ENGINEERING DESIGN

Richard F. Devon, Sven G. Bilén, Javier Sanchez Sierra, and Peter Olfs

Keywords: Global engineering design, global economy, design education

1 Introduction

In this paper we will draw upon a decade of running programs in global engineering to examine the nature of global design and how to teach it. We have run cross-national, bi-lingual design teams for eight years, industry tours in France for 5 years, established a global internship and cooperative education program, an international engineering certificate program, and established a consortium for teaching global design of seven universities in four countries, Prestige. We have also twice taught a senior global design course, the second time with two industry executives—one of whom, Peter Olfs, was from a German multinational, Siemens, and a co-author, and the other, Audrey Russo, from Alcoa, a US multinational.

Throughout this period we have been vexed by the question: what is global design? We have been looking at the way the practice of design is changing to embrace international and foreign standards, varied design cultures, distributed teams, the 24-hour clock, global markets, global supply chains, and cultural diversity with both its creative and its inhibitive effects. But, because of the rapid and transformative nature of globalization, we believe that we have no choice about including an understanding of these processes in any global design course. Perhaps later, the global socio-technical systems will be better understood and more stable, and we can revert to a focus that is more solely technical.

The question of what is global design raises complex issues, but we think we can show that understanding them is important to engineering education and that design education—particularly innovative design education—may be far more important than is generally understood. We will present our case by first examining the significance of design in the global economy and then discussing the role of the global economy in design.

2 Design in the global economy

2.1 Globalization

There are many different conceptualizations of what is happening in the process of globalization and why. For example, in the forthcoming book, *Global Tectonics*, Ghadar and Peterson identify 12 major changes at work: population, urbanization, disease and globalization, resource management, environmental degradation, economic integration, knowledge dissemination, information technology, biotechnology, nanotechnology, conflict, and governance. [Ghadar 2005] This, in turn, is an expansion of the "Seven Revolutions" named earlier by the Global Strategy Institute of Center for Strategic and International Studies

(CSIS): population, resource management and environmental stewardship, technological innovation and diffusion, the development and dissemination of information of knowledge, economic integration, the nature and mode of conflict, and the challenges of governance. [Peterson 2005]

Engineers might reasonably wish to do their work without becoming too informed about its social and economic context, but the changes are so large and so rapid that they may not have this luxury any more. There are many signs that the engineering education community in the United States is getting alarmed about the growing strengths of the global economy, particularly in Asia. For example, a recent report by the National Academy of Engineering, *The Engineer of 2020,* stresses the impact of globalization on the practice of engineering and the necessity for US engineers to focus on innovative and creative aspects of the profession to be globally competitive. [NAE 2004]

An alternate view of the improvement in some Third World economies is as a long overdue improvement in global equity among nations. Somewhat ironically, it is widely believed that all nations are losing sovereignty to the global economy and the multinationals that drive it, and increasing global equity among nations is paralleled by the decreasing significance of nation states, e.g., the European Union.

Often noted in discussions of engineering education and the global economy is the extraordinary growth of China's economy and of its higher education system. Half the graduates in China are engineers and scientists and they currently produce half the world's engineers, or five times the number produced in the U.S. However, there are some moderating factors. This rapid growth has created at least temporary employment issues for engineering graduates in China, and their population is, after all, about five times that of the U.S. One can also note that US engineers get paid approximately five times as much as engineers in China. Thus, the market value of graduating engineers in the U.S. is similar to that of Chinese engineers—for the time being. However, the per capita rate for the production of engineers in Japan and South Korea is even higher than in either the U.S. or China and there is room to study the relationship between the production of engineers and economic growth. [CASEE Chronicles, 2004]. Finally, it is worth noting that any alarm felt by engineering educators will not resonate with all industry leaders and policy makers in the U.S., since there is a very high level of economic cooperation between the U.S. and China (and Japan and South Korea), both for importing inexpensive manufactured goods that lower inflation and for return flows of dollars that finance the federal deficit.

2.2 Teaching our students

In our global design course, our industry partners Peter Olfs (Siemens) and Audrey Russo (Alcoa) taught our students how the global economy is shaping the context of design in terms of the production of engineers, the human and social capital needs of global corporations, the global flows of work to people and people to work, and foreign investments in the pursuit of comparative advantage. Olfs used case studies and role playing to show that the global economy is a mélange of players: national, regional, and international government agencies, multinational entities such as the World Bank and other multilateral banks, NGOs, and global corporations. After decades of experience in the global economy, he suggests that industrial practice takes place in a continuous web of shifting negotiations as resources, prices, and the economic power of the players change—and these changes are often dramatic, such as the rise of the Asian economies.

In his presentations, Olfs raised the often neglected issue of technology transfer. Early U.S. policy applications of this idea were efforts to help developing countries such as the "Point Four" program of president Harry Truman in the 1950s and followed by president John Kennedy's "Decade of Development" in the 1960s. Neither had much immediate success, except for the U.S. experts and U.S. companies who received most of the assistance. In the long term, the considerable early educational progress of some developing countries was probably very helpful to their later growth (*cf.*, the "Asian Tigers" and India). Technology transfer next emerged as a domestic policy issue in the 1980s as a U.S. initiative to commercialize ideas from government and university labs in order to be more competitive in the global economy (the Bayh–Dole Act). Now, technology transfer is significant again globally with the establishment of very successful industrial and R&D bases in many countries, even developing countries. For example, manufacturing practices are now remarkably similar in many, if not most, countries and labor costs and other incentives are driving the demographics of manufacturing locations. Olfs, in the global design course described below, noted that China insisted that a substantial portion of the first set of turbine generators for the Three Gorges Hydro Power Plant (won by consortia GE Canada–Siemens–Voith Hydro and GEC–Alsthom) had to be manufactured in China. Similar conditions applied to an order for locomotives (Siemens). In addition, each subsequent tender required a higher Chinese content. By learning to master the technology, China intends to become a competitor first in the Chinese market, then in Asia, and ultimately in the global market. Siemens' answer, observed Olfs, is to be faster than the Chinese with the next steps in innovation, thereby keeping a leading edge. Yet, with most of the direct foreign investment pouring into China, which adds to its huge trade surplus, how successful will this approach be—and for how long—as China build its R&D infrastructure? India also is boosting its R&D expenditures by 24% in 2005 and will triple its number of incubators during 2005–7 inclusive. [Innovation Matters 2005]

Another dimension to the complex issues surrounding the effects of the global economy is that of the "brain drain", i.e., the movement of people to work. The developed nations of North America and Europe have benefited enormously over the last four decades or so by the influx of foreign talent into their graduate schools, and particularly graduate schools in engineering, science, and business. This resource is now in decline because of the growth of Third World economies and the growth of outsourcing: the movement of work to people. In higher education, which has played such a key role in the brain drain, this is causing a new concern: the loss of tuition revenues to global competition and restrictive post 9/11 visa policies in the U.S. (See the congressional testimony of Dan Mote, an engineer and president of University of Maryland. [Mote 2004])

One final comment on the policy context of global design education is the issue of outsourcing. One analyst sees 80% of U.S. workers in the types of jobs that are getting outsourced with a frequency that makes it politically very salient and suffering income declines, while the most highly educated 20% are doing much better and enjoying rising incomes. [Reich] Citing data from the Bureau of Labor Statistics, Forrester Inc. says the architecture and engineering industry will outsource 46,000 jobs in 2005, 70,000 jobs in 2008, and 191,000 jobs in 2015. [Forrester 2005] However, if outsourcing is a factor for engineers, it would presumably show up in a softening of the market demand for engineers in the U.S.

and there is no evidence for this even though the number of graduating engineers is increasing. In this case, too, outsourcing may increasingly affect engineering first in fields where the demand exceeds supply, such as in software engineering. U.S. corporations will continue to hire many U.S. engineers and increasingly we see foreign corporations actively recruiting U.S. engineering graduates, such as Siemens and GKN, in part because of their operations in the U.S. and in part for the perceived skill sets of U.S. engineering graduates.

Thus, we see a global economy affecting the U.S. with outsourcing increasingly penetrating professional and technical work, the brain drain resource decreasing, and the global percentage of engineering graduates in the U.S. falling to around 6% while their quality is still highly prized. Is there something that engineering education in the U.S. should do about this? The numbers enrolling and graduating in engineering are up, and employment prospects are still good. And, in addition to the recruitment by U.S. and foreign multinationals, there will always be a strong demand for engineers in the U.S. for domestic needs from local businesses and industries to public infrastructure works and defense. Nevertheless, as with global warming, it may be prudent to respond now rather than later when we know more but have fallen behind. And we believe there are some obvious strategies that engineering education in the U.S. can pursue.

2.3 How higher education can respond

A study by the Design Council in the UK found that companies good at design outperformed the average company listed on the FTSE by 200% over a 10-year period, 1994–2003. [Design Council 2003] A recent study in the U.S. by CHI research found that the "top twenty-five S&P companies with patents that are most highly cited by papers and other patents" far outperformed the S&P 500 over 1990–2003. [Schwartz 2004] In addition, cross-national studies show a very high correlation between patents per million and a nation's standard of living. [Schwartz 2004a]

If one accepts the significance of design as an economic driver, then one can infer that we must train our engineers to be prepared to succeed in the global economy, and one way to do this is by teaching global design. Another is by teaching innovative design, although there is some overlap between the two. What is most serious about the situation for the otherwise superior quality of engineering education in the U.S. is that both global design and innovative design are more absent than present at the moment, although there are positive signs of change. The main reason for their absence is the low status accorded design in the engineering curriculum. U.S. schools of engineering (particularly large engineering schools) too often teach one design course in the first two years to help students feel good about engineering and one capstone design course in the last year—unrelated to the first design course—to prepare the students for professional work. Both are typically based on experience with a single project absorbing much of the curricular time available. In total, this means only 5–7% of curricular time in a U.S. engineering degree is devoted to design and even specializing in design is not usually an option that is easy to pursue. [Devon et al 2004] This situation is unfortunate since the practice of design has a direct and critical impact on the economy and at least 50% (a rising trend) of the engineering graduates of Penn State report it as a characteristic activity of their first job. [Internal unpublished data]

Thus, engineering education in the US can best respond to the globalization of industry by teaching more design, and more innovative and global design in particular. As mentioned, these two areas overlap since global diversity can play a very creative role in the design process.

3 The Global Economy in Design

3.1 Shaping Factors

There are several ways in which the global economy affects design. They include:

1. The need to access markets in other countries;
2. The need to run globally distributed teams;
3. The need to reduce time to market by using the 24-hour clock;
4. The need to benchmark globally and understand the emergence of global practices;
5. The need to understand industrial practices and standards thatvary from country to country, despite ISO and increasing global conformity;
6. The need to harness the benefit of using cultural diversity in idea generation and knowledge development.

Example 1: Illustration of how #1 above might change the design process.

> "An American company has identified an overseas acquisition candidate with a great compatible product that could be brought across the Atlantic to expand its market reach in the U.S. Extremely popular in Europe, the product is of very high quality, promises great margins, and is nothing like anything available domestically. The price seems good and the company's financials appear in order. …
>
> "When U.S. sales of the product proved disappointing, a closer look at the market turned up some jarring revelations... Installation of the product, a vandal-proof floor-to-ceiling bathroom partition system, hampered sanitation procedures by making it more difficult to mop floors. In the U.S., the common maintenance practices of daily mopping and navigating in and out of many tiny rooms added significantly to maintenance costs.
>
> "The product's vandal-resistance features were important in Europe, less so in the U.S. In American schools, a major potential market for the partition, the vandalism problem is attacked by unionized janitors who are employed on an annual basis and are kept busy during summer months repairing and repainting damaged stalls." [Price et al, 1998]

Example 2: Illustration of how #2 above might change the design process.

> "In 1993, a group of nine architectural and engineering firms joined forces to see whether they could help each other expand into new markets without the risks associated with mergers, acquisitions, or opening new offices.

"The plan was relatively simple. Firms would retain their autonomy, yet collectively bring the strength and reach of a mega-firm to clients through joint ventures and similar associations. What followed was the birth of STAR (Strategic Team of Allied Resources), a corporate alliance with a combined total of 47 offices and more than 2,000 employees.

"Five years and scores of projects later, the alliance is still looking for that big, splashy commission that will raise its profile in the industry. But in the meantime, it has grown larger, more diverse, and more ambitious. Its ranks have swelled to 15 members, which include environmental and acoustical consultants. And in December, STAR hired its first CEO, who immediately changed its name to Global Design Alliance (GDA).

"McCracken also indicated that GDA will continue placing most of its emphasis on domestic work. Thus far, the ability to combine the geographic diversity of large corporations with the personal service of a smaller, local firm has been GDA's chief calling card in the U.S. (The alliance has 70 member firm offices in 22 states.) But that very strength also causes confusion among potential clients, who don't always understand who—or where—the project coordinator is, or that GDA is a group of firms rather than a single entity. [anonymous, 1998]

Example 4: Illustration of how #4 above might change the design process.

"Fritz Mayhew, chief of North American design for Ford Motor, is among many designers applauding the direction their discipline is heading. 'Ten to 15 years ago there used to be marked differences between public design tastes in Europe, the United States, and the Asia Pacific markets,' he says. 'Europeans typically liked their products much more functional, straight-forward, kind of pure design, while we in America were still doing wood-grained toasters, for example. The same thing was happening in auto design. In the U.S. we were still using a lot of fake wood grain and living room-type front seats. All that has changed. Now design has become much more international.'" [Braham, 1993]

Example 5: Illustration of how #5 above might change the design process.

"Scientific Technologies Incorporated (STI) might be the U.S. leader in safety light curtains, but it isn't resting on its laurels. Company officials have their sights set on being a major player in the world market as well. And as the world's most compact safety light curtain, STI's MicroSafe^{TM} line is intended to help take them there.

"The path to developing the MicroSafe, however, was an interesting one. Engineers had to contend with the vagaries of European standards, which were being written and modified even as the product was being developed. Meeting these standards wasn't a simple formality, either. Europe requires safety light curtains on certain types of manufacturing machines. UL is currently composing a standard for the United States, but it will probably be written around the European one, titled IEC 61496.

…

> "The existence of the European IEC standard is a blessing wrapped in a curse. On the plus side, its existence makes for a mandated market for the devices. On the minus side, it spells out specific and critical performance requirements that STI officials say often favor technology from several European manufacturers, may restrict innovation, and placed constraints on MicroSafe's design. [Gottschalk et al, 1997]

4 Teaching Global Design

If teaching global design is important, we still need to discuss what to teach and how to teach it. We have answered "how" by using global resources such as:

1. Globalizing the instruction, e.g., co-author and co-teacher, Peter Olfs
2. Cross-national design teams using information technology with five countries
3. Direct experiential programs
    - Global internships and coops in 8–10 countries
    - Focused academic programs such as
        - A 10-day industry tour
        - A 4-week, 3-country, Nomadic Design Academy.

The content of teaching global design has settled on teaching about globalization, the demographics of the global flows of work and people, case studies of global engineering projects (usually large scale), the emergence of common practices such as in manufacturing, the adoption of ISO, global supply chains, and the use of distributed teams. Then, we study the role of diversity in national practices, in global markets, in cross-cultural communications, and in idea generation for new approaches to policies and in the design process.

4.1 Examples of Global Design Education

Our strategy for teaching global design has evolved over the last eight years and now includes two courses. Study abroad and global internship programs are not discussed here.

Honors Section of the Introductory Engineering Design Course

- A two-hour discussion and debate on the global economy featuring large scale global projects such as the Three Gorges Dam, the Millau Bridge, or the Tapei Towers.
- A two-hour discussion and role playing experience on cross-cultural communications
- A cross-national design project with students at a French university. The design problems come from both French and US industries. The project lasts 8 weeks and the final documentation is in both languages. (This project, Alliance by Design, received a national award. AT&T 2003)
- Ten U.S. students selected by performance on this design project then go the next summer on a one week tour of French industries followed by a cultural weekend. This is largely financed by the Schreyer's Honor's College at Penn State and there is no

reverse program. (This type of program is often disparaged for its brevity, but we routinely get high praise for it from our students. The impact as measured by qualitative assessments is very high and we have seen student social groups form during the experience that last until graduation. It is cost effective and, in particular, does not impact summer earnings since it takes place in mid-to-late May.)

- Those who go on the 7–10 days tour also take a 1-credit cross-cultural orientation course before traveling.

Nomadic Design Academy

The Engineering Design Program at Penn State helped set up the Prestige Consortium, which consists of seven universities in four countries. It is dedicated to design education and preparing students for the global economy. http://prestige.psu.edu/ It features student travel for internships, distributed design teams and a web resource site for design.

In the summer of 2004, Prestige began offering the Nomadic Design Academy and sent students from Arizona State University Industrial Engineering Department (who organized the Academy), the University of Washington, and Penn State to four sites in Europe: University of Leeds (UK), IUT Bethune and École Centrale de Lyon (France), and Tecnun, the engineering school of the Universidad de Navarra in San Sebastian (Spain). The students spent a week at each site where they studied manufacturing and design topics and visited major engineering sites such as Rolls Royce in the UK and Mercedes in Spain. A student website for this may be seen at, http://prestige.psu.edu/Nomads2004/

The NDA will run again in 2005 and a reverse program for EC students will be hosted by the University of Washington Industrial Engineering Department for eight weeks of classes and industry projects and site visits. The content of the NDA is currently rather more manufacturing than design. This is much easier to do, but more design will be added as the program matures.

Senior Global Design Course

This course has been run twice at Penn State. The new Engineering Design Program (EDP) is focused on integrated design, the cross-cutting areas of design that apply to most fields of engineering. In practice, it is focused on integrated design methods, design projects, innovative design, and global design. It is beginning a graduate program with such courses as innovative engineering design (TRIZ), design cognition, and the design of integrated systems.

The course had several resources of great value. The corporate executives, Peter Olfs from Siemens and Audrey Russo from Alcoa, were highly rated by the students. Olfs gave 2-hour classes with presentations and discussions, including role playing examples and case study presentations to involve the students. His topics included case studies of global engineering projects, cross-cultural communications, and a review of the major players in the global economy. Russo focused on the rising significance of the human and social capital needs and costs of corporations, which are now sometimes the featured sections of annual corporate reports.

A second major resource came with the 11 students who were attracted to this optional global design course. Many already had experience of and in the global economy. The students began with a study of engineering design methods and gave presentations on global engineering topics. Two students presented their experience with the first NDA and showed convincingly the similarity of manufacturing methods in the three countries. Another student had worked for Bosch in Germany for two years and confirmed this finding while presenting his experiences an American working overseas. A fourth student, a graduate in architectural engineering, described his experience building a hospital in Bosnia that was prefabricated in Germany. Prefabricated buildings obviously present a case where industrial engineering methods can apply in a different field of engineering. Finally, another graduate student presented his survey research on the increasing role of distributed teams and low cost engineering centers (LCECs) in global architectural engineering companies. The few "novice" students chose topics like the ISO and case studies of major engineering projects overseas.

Collaborative Design

The third resource was a partner in the Prestige Consortium. Javier Sanchez Sierra of Tecnun (Universidad de Navarra), who collaborated on design projects for consumer products in the first offering of the global design course in the fall of 2003. This collaboration found a marked added value effect of global diversity through more idea generation [Devon, et al, 2004]*. In the fall of 2004, he brought 16 of his third-year engineering students to another collaborative design project in which four teams of Tecnun and Penn State students tackled the same design problem. The problem, provided by the Penn State administration, was to redesign one of the few classrooms not recently remodeled.

* Devon, Richard, Alan de Pennington, and Alison McKay. "A Consortium for Global Engineering Design." *Canadian Design Engineering Network (CDEN) Inaugural Conference Proceedings*, Montreal 2004.

The classroom redesign problem was also given to a class studying innovative engineering design methods. We thought we could compare innovation through learned methods with that inspired by global diversity. In the end the students did remarkably similar things, most notably switch the "portrait" orientation to a "landscape" orientation. The Penn State architect who handled the commission had originally downplayed this idea as impractical because of line-of-sight problems. The next semester, a team of students presented a design solution using the best ideas from both classes. The orientation solution was very well received and so were other changes that offer a great improvement for students and faculty with physical disabilities or who were too short to function effectively in the classroom.

The line-of-sight problem was solved by using two screens and a study of usage that suggested that the problem may occur only in 10% of the classes. For 90% of the classes they would be able to use the two screens for different displays, if they wished. The delivery area and first level of seating was kept at the same level as the corridor thus eliminating any need for ramps. The back two levels of seating were raised to allow visibility. Compared to the original, students would be closer to the instructor and the displays, and the floor being raised now allows much better visibility. This project is still active and it seems likely the student user-centered design will shape the remodeling.

5 Conclusion

Global design is design where the global context is salient. The degree of salience varies. At some point, the level of salience is high enough to characterize it as global design and at this point in history we think a lot of things are brought into the design process that will not be there unless we call it global design. Teaching it means including an understanding of globalization, of who the players are in the global economy, of global practices in design, of distributed teamwork and the role of cross-cultural differences in creativity and communications. And, just as we stress the value of project-based experience when teaching design, so we think the value of virtual and real experiences in global design are essential.

The outcome of courses and programs in global design should be students prepared to work in the global economy. Finding metrics that measure our success in doing this is not easy. We have previously proposed using a stakeholder assessment model, but that is only a partial solution—although useful in the short term for program development. [Bilén, et al., 2004] Two other methodologies would be an *a priori* model whereby we designed the education on knowledge gained from researching global design practices, and a performance model whereby we track the consequent professional performance of the students. Of all these methods, we think that the *a priori* research-based approach is most needed in the long run.

References

[1] Ghadar, F. and Peterson, E.R., *Global Tectonics: Underlying Trends Shaping the Future of Business*, release date June 2005.

[2] Peterson, E.R., "Seven Futures", available at http://216.12.139.57/gsi/index.cfm.

[3] *The Engineer of 2020: Visions of Engineering in the New Century*, The National Academies Press, 2004.

[4] CASEE Chronicles, 2004; National Science Board. 2004; Companion to Science and Engineering Indicators 2004, available at http://www.nsf.gov/sbe/srs/nsb0407/start.htm.

[5] Innovation Matters, 3/5, 2005 (International News page)

[6] Mote, D., http://www.president.umd.edu/ForeignRelationsTestimony/

[7] Forrester, Inc., http://www.nspe.org/etweb/10704outsourcing.asp

[8] The study may be downloaded from http://www.designcouncil.org.uk/webdav/servlet/XRM?Page/@id=6007&Session/@id=D_5AFlTvf705tL9HUtNzYb&Document/@id=6942

[9] Also go to http://www.designcouncil.org.uk/ and see their report on 1500 companies in Design In Britain 2004-5.

[10] The quote is from Schwartz, Evan I. (2004) Juice: The Creative Fuel that Drives World-Class Inventors, Boston: Harvard Business School Press, p.213. His source was "Investing in Invention pays off" Technology Review May 2004, 38.

[11] Schwartz, 2004a "Global Invention Map" Technology Review May 2004, 76-77. Source: Schwartz, op. cit.

[12] Global Designs: Tough Challenges for Acquirers, Allan Price, Jacqueline Sloane. Mergers and Acquisitions. Philadelphia: May/Jun 1998. Vol. 32, Iss. 6; pg. 50, 5 pgs.

[13] Design alliance goes global, Anonymous. Building Design & Construction. Chicago: May 1998. Vol. 39, Iss. 5; pg. 16, 1 pgs

[14] Engineers strive for world-class design, Mark A Gottschalk, John Lewis, Rick DeMeis. Design News. Boston: Nov 17, 1997. Vol. 52, Iss. 22; pg. 75, 12 pgs

[15] Global design is here, but ... Braham, James. Machine Design. Cleveland: Mar 26, 1993. Vol. 65, Iss. 6; pg. 32, 7 pgs

[16] Bilén, Sven G., Richard F. Devon, Mark R. Henderson, & Hien Nguyen. "Global Approaches to Teaching Global Design: Stakeholders, Programmes, and Assessments." World Transactions on Engineering and Technology Education, vol. 3, no. 1, pp. 29–34, 2004.

[17] National Academy of Engineering (2004). The Engineer of 2020: Visions of Engineering in the New Century. Washington, DC, National Academies Press.

[18] CASEE Chronicles, National Academy of Engineering (2004). Progress and Accomplishments: Engineering Education Research and Development 2002-2004. Washington, DC, Center for the Advancement of Scholarship on Engineering Education (CASEE).

[19] Devon, R., S. G. Bilén, A. de Pennington, A. McKay, P.Serrafero, and J. Sanchez Sierra, "Integrated design: What knowledge is of most worth in engineering design education?" International Journal of Engineering Education, 20, 3, 2004.

[20] National Science Board. 2004. The Science and Engineering Workforce: Realizing America's Potential

Corresponding authors name: Javier Sánchez Sierra
Institution/University: Tecnun. University of Navarra.
Department: Mechanical Engineering
Address: Manuel de Lardizabal 13
Country: Spain
Phone: +34 943 219877
Fax: +34 943 311442
E-mail: jsanchez@tecnun.es

Name:	**Sánchez Sierra, Javier**
Biographical Notes:	J. Sanchez is Assistant Professor of Engineering Design at Tecnun (University of Navarra) Engineering School. He received his MS degree in Mechanical Engineering from the University of Navarra in 1995. He was working at Widia Valenite in Germany and Spain., in the cutting tools industry. His research interests include mechanical design, CAD/industrial design, NURBS representation and construction, tensile structures, membranes and rapid prototyping.
Address:	Tecnun (University of Navarra) Manuel de Lardizábal 13, 20018 San Sebastián, Spain
Phone Number:	(34) 943 219877
Fax Number:	(34) 943 311442
E-mail:	jsanchez@tecnun.es
Website	www.tecnun.es/labcad/jsanchez