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SPINE – International Benchmarking of Successful Practices in Engineering Education

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Organized by the Board of the Swiss Federal Institutes of Technology, SPINE is a partnership among 10 technical colleges and universities to identify and share educational practices in engineering and computer science; three schools are in the United States (Carnegie Mellon, Georgia Tech and MIT) and seven are in Europe. Five disciplines are chosen for assessment – chemical engineering, computer science and engineering, electrical engineering, materials science and engineering, and mechanical engineering. Assessment of current practices is achieved through quantitative and qualitative questionnaires completed by administrators of each school, questionnaires completed by faculty at the school, and on-site interviews with deans, department heads and senior administration of the school. Additionally, surveys of alumni, human resources managers, and line managers in industry provide external views to support assessment of the schools' educational practices. Practices at a school are compared with the vision, mission and goals developed by the school. The findings and conclusions of the study are shared among all the universities with the goal of identifying what educational practices work best with respect to the goals of the particular school. To our knowledge, this is the first *international* benchmarking study of engineering education, and the study provides a unique networking opportunity among the institutions on an international scale. In this talk we present the most significant results of the SPINE study and contrast educational practices between US and European colleges of engineering.

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OVERVIEW

Engineering is one of the few academic disciplines that continuously engages in introspection of its education practices and benchmarking to provide objective comparisons with other institutions. However, most benchmarking studies are regional or country specific. In 1999 the Board of the Swiss Federal Institutes of Technology and Engineers Shape our Future (INGCH) – a group of leading multinationals - launched an initiative, Successful Practices in International Engineering Education (SPINE), to compare best educational practices among leading engineering colleges in Europe and the United States. The engineering and computer science programs in 10 universities and technical schools participated in this study. The European schools were: Ecole Centrale Paris, Ecole Polytechnique Fédérale de Lausanne (EPFL), Eidgenössische Technische Hochschule Zurich (ETHZ), Imperial College London (ICL), Kungl Tekniska Högskolan Stockholm (KTHS), Rheinisch-Westfälische Technische Hochschule Aachen (RWTH) and Technische Universiteit Delft (TU Delft). The US schools were Carnegie Mellon University (CMU), Georgia Institute of Technology (GIT) and Massachusetts Institute of Technology (MIT). The project was administered and managed by two Swiss organizations, Engineers Shape our Future and the Board of the Swiss Federal Institutes of Technology (ETH-Rat).

The project was managed day to day by the project team of consultants. Overview was achieved through a steering committee composed of representatives of the partner schools and the project team. The project was divided into five stages. (1) Data collection through quantitative questionnaires completed by administrators of each school, qualitative questionnaires completed by faculty at the school as well as questionnaires administered over the internet to professors, alumni practicing engineers and managers (or human resource personnel at the companies). (2) Site visits by the project team were conducted at the 10 partner schools. Interviews were conducted with department heads, deans and their staff, and the provost or rector of the school. (3) 95 'potentially valuable' practices were identified by the project team and distributed to the partner schools for the setting of priorities. (4) Three 'successful' practices were determined for each school through voting by *all* the partner schools. (5) The description of the three successful practices for each school were verified by telephone interview between the school and the project team.

The primary objective of the project was to identify *successful practices* in the education of engineering students at the undergraduate and masters level. Successful practices are defined as concepts, methodologies and tools that have proven successful at a school in relation to the school's strategic objectives; this input was achieved through stage (3) above. Furthermore, the other partner schools must find a particular practice important and interesting; this verification was achieved through stage (4) described above. It was important to learn about the administrative structure of each school, its quantitative dimensions and governance, and its vision and goals. Much of this information was obtained through the site visits by the project management team. Assessment was also critical, so emphasis was placed on obtaining completed questionnaires by the faculty, alumni and employers. Through written questionnaires, internet questionnaires and oral interviews, input was obtained from 543 faculty, 1372 engineering alumni now in the workforce, 145 human relations personnel and managers in companies employing these alumni, and 66 administrative leaders of the schools including department heads, deans and provosts.

Each of the three successful practices identified for each school were classified in terms of their relation to four basic topical areas: (i) structure and organization of the school; (ii) quality of education, teaching methods, and internationality; (iii) cooperation with other universities and industry; (iv) performance and competence of the graduated engineers.

In order to focus the study and keep it manageable, only five engineering sub-disciplines were included in the study: chemical engineering, computer science and engineering, electrical engineering, materials science and engineering, and mechanical engineering. At some schools the administrative boundaries for these disciplines are not clear. For example, at CMU computer science is a department outside the engineering college, and computer engineering is housed in both the electrical engineering and computer science departments; in RWTH chemical engineering is found within the mechanical engineering school. However, these clerical details were overcome through carefully worded and administered questionnaires and interviews.

The final report of the SPINE project was made public on May 25, 2002. In this paper we highlight some of the significant findings. One important feature of this study is its networking value. To maintain this network, the 10 SPINE partner schools plan to keep the coalition, albeit in a less formal structure, over the next two years.

IMPORTANT FINDINGS

The criteria for ‘successful’ in successful practices are school specific in that the yardstick for measurement depends on the mission and goals of the school. However, some consensus was sought by having the 10 partner schools vote on the ‘most interesting’ educational practices of each other. The initial list of 95 potentially valuable practices (about 9-10 per school), which were identified by each school itself, was prioritized by having the *other* nine partner schools vote on the potentially valuable practices for the particular school. The top 3 vote-getters from a particular school are listed as the *most successful* practices for the school, giving the final list of 30 successful practices. The result is the list of 30 successful practices; however, the list of 95 potentially successful practices is also found in the final report.

Table 1 provides a list of the three successful practices identified for each of the 10 partner schools. Also noted is the relationship between each practice and the four basic topical areas. There is considerable overlap among the successful practices between schools. From this list and the interviews and questionnaires completed by faculty, alumni and human resource personnel at companies, the following summary is drawn:

1. In both the US and Europe, there is increased emphasis on *non-core* competencies – writing, oral communication, teamwork, multidisciplinary projects, business and entrepreneurship. The partner schools feel that standards of learning in the core competencies (i.e., technically relevant subjects of the sub-discipline) have remained high; thus, the introduction of non-core subjects has probably been achieved by making the curriculum more flexible for the student and removing some constraints of elective slots.
2. The emphasis on international experiences for students and faculty is greater in Europe than in the US.

3. There is a significantly greater emphasis on industrial residence for students in Europe compared to the US. The percentage of undergraduates completing a practicum training in industry during the school year is significantly higher in Europe; however, when summer internships in industry within the US are counted, the difference between European and US schools in this regards might be less.
4. Cooperation with industry and practical relevance of education is regarded by engineers and managers to be more important than by professors.
5. Professors generally assess the quality of education at their own university higher than engineers do (difference between inside and outside view).
6. The trends for women are different in the US compared to Europe. The percentage of women in undergraduate studies is higher in the US, but the retention through the PhD is less. For example the ratio of percent PhD/percent undergraduate of women is lower in the US than in Europe, even though the denominator is larger in the US.
7. Three engineering programs with strong reputations in engineering (ETHZ, MIT and TU Delft) emphasize a rigorous and formal external and internal evaluation process.

There also are some noticeable cultural differences between the US and Europe. All seven of the partner schools in Europe are public institutions that are highly dependent on government funding. On the other hand, two of the US partners (CMU, MIT) are private and even the one public institution, GIT, derives a minority of its revenue from the state government (as is the case with many research-oriented private colleges and universities in the US). The greater reliance on government funds make the political climate of education in Europe more sensitive. For example, public rankings of engineering and computer science programs in the US are common and accepted, with little turmoil within the individual schools; however, such rankings are not common in Europe. A second difference is the administrative structure within the schools. In Europe the departments (sub-disciplines) are essentially independent units and report directly to the rector (provost) or associate rector. The dean of the collection of departments has no significant budget authority and hence lacks administrative control. While this situation is changing (at least two of the European partner schools are changing to a department – dean – provost reporting arrangement), the absence of a strong dean's position presents a different landscape for introducing educational reform in engineering.

There are some other interesting findings. Most of the 10 partner schools noted more interdisciplinary research and education now than in the past. Distance education, a topic of current discussion at most schools, is generally absent from the successful practices list; only Georgia Tech has distance education as one of the three practices.

POTENTIAL FUTURE USE OF THE NETWORK

The first question to be addressed is what is the impact of the study on the educational practices of the partner schools? The answer(s) will require follow-up on the report. The second question is how can the network established by the SPINE project be continued and used? As participants in the project, we have gained an appreciation of the similarities and differences in the culture of education and university administration. The fact that non-core competencies (communication, business, etc.) are being emphasized more on both sides of the Atlantic came somewhat as a surprise. The issue of a four-year bachelor's degree versus a five-year diploma is still there and debated on both sides. Finally, this project demonstrated to value of getting input from all points of the educational triangle: faculty, former students and employers. The evaluations by the managers and HR personnel at companies employing our graduates will surely be useful.

The intention is to hold the partner schools together for two more years to see what further benefits can be obtained by such an international consortium focused on education and university administration. Whether this partnership grows even stronger and larger, or withers in the face of more pressing demands on time and money, is uncertain but definitely an experiment worth conducting.

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Table 1. Successful practices. The list of three for each school was determined by voting by the other nine schools on the initial list of 7-12 potentially valuable practices put forth by the particular school. The assignment of topical area was made by the project management team.

	University Structure	Education and Internationality	Cooperation with universities and industry	Performance of engineers
CMU				
Introduction to engineering courses in parallel with mathematics and engineering		X		X
Broad undergraduate studies with high flexibility for students		X		X
Cross-disciplinary approach and team projects		X	X	X
ECP				
Restructuring of final: combination of professional and scientific approach		X		X
Implementation of long-term strategy for internationality	X	X	X	
Strong links with industry in funding, teaching, and research			X	
Integration of non-core competences and human sciences		X		X

EPFL				
Internationalization in research and education			X	
Focus on basic sciences in combination with strong links to industry		X	X	X
Integration of new, important topic areas in engineering curricula	X			
ETHZ				
Cosmopolitan and very international composition of faculty	X	X		
Well defined internal and external evaluation system	X			
Mechanical Engineering: strong focus on project orientation		X	X	X
GIT				
Interdisciplinary research centers	X	X		
Strong entrepreneurial program	X		X	
Excellent Distance Learning/Distance Education Program	X	X		
ICL				
Integration of project and teamwork into curriculum		X		X
WISE(Women in Science and Engineering) program to attract female students	X			
“Mastery” to provide engineers with a more holistic education		X		X
KTHS				
Integration of lectures, exercises, and teaching of non-core competences		X		X
Creation of international master programs		X		
High level of interdisciplinarity		X		X
MIT				
Successful quality assurance by external Visiting Committees (VC)	X			
Innovative way of creating new units	X			
Education: Broad, fundamental, yet practical		X		X
RWTH				
High number of interdisciplinary activities and research areas	X	X		
High involvement of students in research		X		X
Students with broad view and deep fundamental knowledge		X		X
TUD				
International MSc Program		X		
Elaborate external and internal quality management	X			
Highly innovative program in Electrical Engineering		X		X