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Internationalization of the Undergraduate Engineering Program, Part 1: The Need*

ABIR ZIYAD QAMHIYAH
Mechanical Engineering Department, Iowa State University, Ames, IA 50011, USA.
E-mail: qamhiyah@iastate.edu

The goal of this paper is to present the evidence for the need for international experience in engineering education. Data on engineering education and the practice of the engineering profession was compiled from multiple sources such as the United Nations Conference on Trade and Development World Investment Reports, the Institute of International Education's Open Doors Reports, and The National Information Center for Higher Education Policymaking and Analysis statistics. Analysis was then performed to present the magnitude of the challenge facing the engineering educational institutions in the United States in their attempt to prepare their undergraduate students for successful careers.

THE NEED FOR INTERNATIONAL EXPERIENCE IN ENGINEERING EDUCATION

A GROUP OF MTS employees volunteered to go to Berlin, Germany, in 1970 to establish a factory and start manufacturing operations [1]:

> *Right at the start, the German engineering culture was found to be very different from the American culture. German industrial codes are very different from ours and require strict interpretation. The German bureaucracies and business climate are also dramatically different than ours. These are issues which young engineers will need to deal with as technical companies face global competition.*

In preparing our undergraduate mechanical engineering students for successful careers it is important to understand the characteristics and trends of their future job market. This work reports on:

1) the rise of transnational corporations (TNCs), and
2) the drastic increase in outsourcing,

as the two trends implying the need for international experience in engineering education.

The economic and technological forces of the past two decades resulted in the rise of TNCs, as indicated by the United Nations Conference on Trade and Development World Investment Report for the year 2002. Such forces include the drop in the cost of cross-border transfer of knowledge, goods, and services, and the advances in the Internet synchronous communication and business management tools. A TNC is a geographically fragmented and highly integrated international production system.

The competitive global marketplace is expected to enhance the forces leading to the formation of TNCs. To gain an insight into a TNCs operation we extracted data from the United Nations Conference on Trade and Development (UNCTAD) World Investment Reports for the years 1990, 1992–2000. The reports provide statistics on the top 100 TNCs worldwide in relation to the foreign and national distribution of their assets, the foreign and national distribution of their sales, and the foreign and national distribution of their employment. The author compiled the data for some of the USA-based TNCs such as the Ford Corporation and General Motors as examples of the automotive industry in the United States of America, General Electric for electronics, IBM as an example of the computer industry, Exxon for the petroleum industry, Du Pont as an example for the chemical industry, and Johnson & Johnson as an example of the pharmaceutical industry. The ratio of the foreign to the total assets, foreign to total sales, and foreign to total employment were then evaluated, Tables 1 to 7.

Table 1 indicates that over the period from 1990 to 2000, the Ford Corporation experienced a drop in the ratio of their foreign to total asset from 30% to 7%, a drop in the ratio of their foreign to total sales from 48.4% to 30.4%, while maintaining a steady ratio of their foreign to total employment at 50%.

Figure 1 is a plot of the employment ratio for Table 1 to Table 7. Figure 1 indicates that across the diverse specialties of the selected TNCs the foreign employment has either increased considerably over the past decade to reach a level close to 40% of the total employment, or the foreign employment remained elevated in a range between 50% and 65% of the total employment.

Figure 2 is a plot of the sales ratio for Table 1 to Table 7. With the exception of GE, Fig. 2 indicates that the size of the foreign market segment in 2000

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Table 1. Ford Corporation ratios of foreign to total assets, sales and employment.

Year	Foreign/total assets	Foreign/total sales	Foreign/total employment
1990	0.310	0.484	0.510
1992	0.155	0.332	0.513
1993	0.155	0.332	0.544
1994	0.276	0.297	0.286
1995	0.290	0.306	0.298
1997	0.263	0.313	0.478
2000	0.070	0.304	0.529

Table 2. General Motors ratios of foreign to total assets, sales and employment.

Year	Foreign/total assets	Foreign/total sales	Foreign/total employment
1990	0.292	0.306	0.327
1992	0.219	0.319	0.363
1993	0.220	0.214	0.357
1995	0.249	0.292	0.339
1996	0.249	0.316	0.342
1999	0.249	0.263	0.408

Table 3. General Electric ratios of foreign to total assets, sales and employment.

Year	Foreign/total assets	Foreign/total sales	Foreign/total employment
1990	0.107	0.144	0.210
1992	0.125	0.147	0.251
1993	0.126	0.185	0.266
1994	0.135	0.201	0.167
1995	0.304	0.244	0.324
1996	0.304	0.266	0.351
1997	0.320	0.270	0.402
1998	0.361	0.286	0.444
1999	0.348	0.293	0.461
2000	0.364	0.381	0.463

Table 4. IBM ratios of foreign to total assets, sales and employment.

Year	Foreign/total assets	Foreign/total sales	Foreign/total employment
1990	0.522	0.607	0.449
1992	0.527	0.619	0.477
1993	0.544	0.577	0.510
1994	0.541	0.622	0.526
1995	0.519	0.627	0.501
1996	0.510	0.614	0.506
1997	0.490	0.623	0.500
1998	0.506	0.568	0.515
1999	0.511	0.575	0.526
2000	0.488	0.579	0.537

Table 5. Exxon ratios of foreign to total assets, sales and employment.

Year	Foreign/total assets	Foreign/total sales	Foreign/total employment
1990	0.588369	0.78152	0.625
1992	0.567059	0.804667	0.621053
1993	0.563615	0.788669	0.626374
1994	0.639363	0.634767	0.639535
1995	0.730559	0.795567	0.536585
1999	0.687889	0.717837	0.635514
2000	0.682738	0.694109	0.653728

Table 6. Du Pont ratios of foreign to total assets, sales and employment.

Year	Foreign/total assets	Foreign/total sales	Foreign/total employment
1990	0.411311	0.462963	0.291433
1992	0.411311	0.462963	0.286713
1993	0.442049	0.45283	0.319298
1995	0.477212	0.488152	0.333333
1998	0.433766	0.471774	0.346535
1999	0.362745	0.494424	0.382979

Table 7. Johnson & Johnson ratios of foreign to total assets, sales and employment

Year	Foreign/total assets	Foreign/total sales	Foreign/total employment
1990	0.463158	0.517857	0.522591
1992	0.436975	0.5	0.522968
1993	0.442623	0.489362	0.524786
1994	0.420382	0.503185	0.51969
1995	0.458101	0.515957	0.538275
1996	0.46	0.49537	0.533035
1999	0.678082	0.44	0.50683
2000	0.421551	0.406721	0.484176

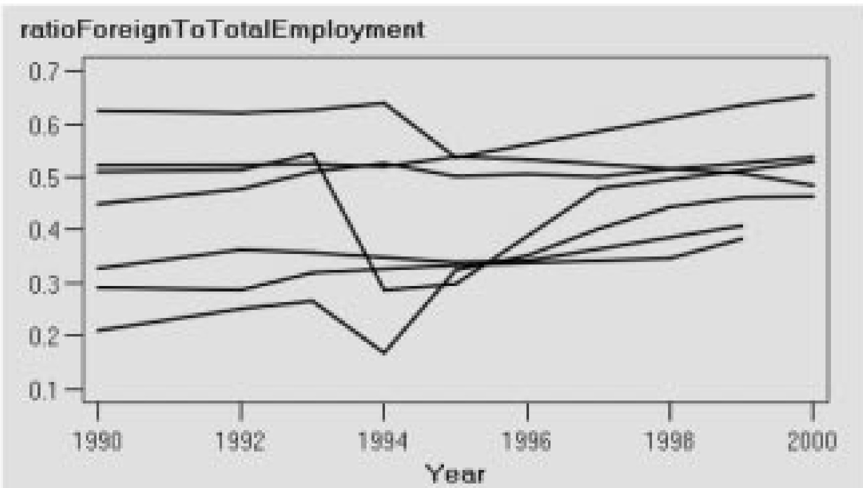

Fig. 1. The employment ratio for Tables 1 to 7.

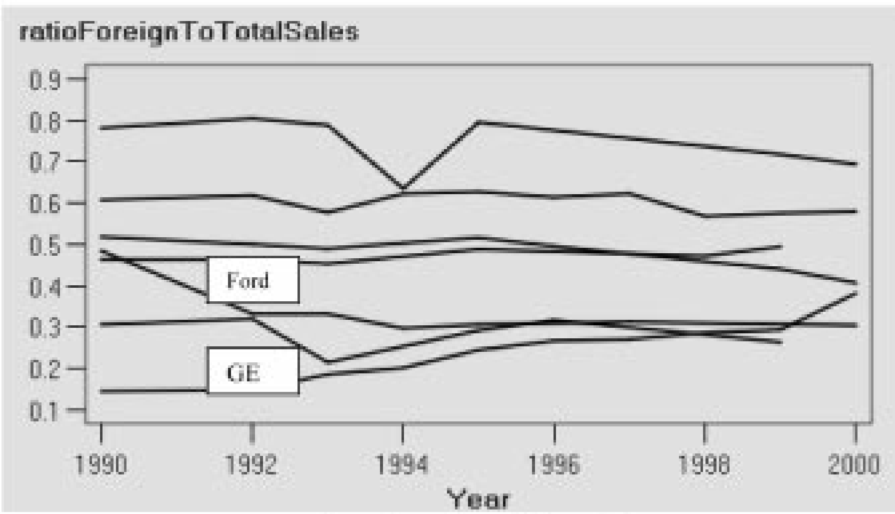

Fig. 2. The sales ratio for Tables 1 to 7.

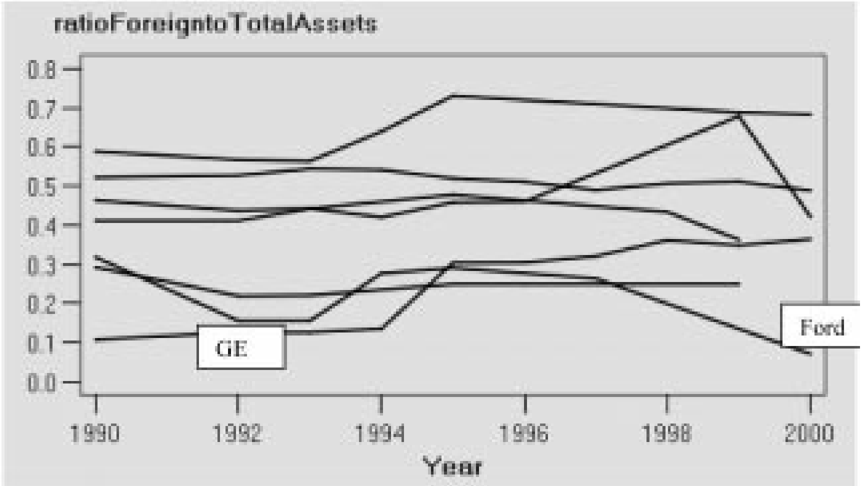

Fig. 3. The assets ratio for Tables1 to 7.

is comparable to that in 1990. In the Ford Corporation case, foreign sales dropped from 50% of the total sales to 30% of the total sales. Such an observation results in the conclusion that employment migration outside the United States for the selected TNCs is not necessarily driven by the lack of the consumer market in the United States. An increase in the foreign employment is therefore driven by other forces such as increasing the corporations overall efficiency through reducing the production cost or reducing the employment cost.

A plot of the foreign to total assets ratio from Table 1 to Table 7 is presented in Fig. 3. With the exception of GE Fig. 3 indicates that the selected TNCs have reached a peak in the ownership of their foreign assets around 1998. The peak was then followed by a noticeable drop in the ownership of foreign assets. The Ford Corporation is an obvious example of the move towards eliminating foreign assets ownership. GE and Ford represent the two ends of the scale with respect to their transnational corporation governance strategy. A detailed explanation of the TNCs governance mechanisms is presented in Chapter V of the 2002 World Investment Report. GE is using an equity strategy to control its extended enterprise. Ford Corporation, on the other hand, is adapting the non-equity governance strategy. In the non-equity approach international outsourcing is used as the option to owning international assets.

The cover story for *BusinessWeek* on February 3, 2003 titled 'The new global job shift' presented examples of the international outsourcing locations. The article explains that China has become a 'key product-development center for GE, Intel, Philips, Microsoft, and other electronics giants.' In the Philippines 'more than 8,000 foreign companies source work in nine different information technology parks with fiber-optic links.' Mexico, on the other hand, is becoming 'a favorite information technology and engineering outsourcing haven for US companies that want to keep work close to home.' The article's list of international outsourcing locations included South Africa, Eastern Europe, Russia, Costa Rica, and India.

An April 2003 article in *Todaysengineer*, [2], explained:

> *During the past half-century, I have observed at least four different engineering career types. Decade by decade, it seems, engineers have been characterized as being corporate engineers; learning engineers; contract engineers; and finally, skilled or global engineers . . . Corporations have also become more global in reach. Some have their headquarters in the United States, but have more employees outside the country than within. At the same time, many Pacific Rim and European corporations now have US-based plants. Although many corporations are managed outside the country, they employ US citizens. In other cases, USA and foreign corporations have merged, making it nearly impossible to determine whether they are domestic or foreign firms. They are both, and they are neither; they are truly global. Why are so many companies going global? They do it to ensure a marketplace for their products—and to find highly skilled labor at the lowest possible cost.*

As the future employees of global corporations operating in a business environment that is heavily dependant on outsourcing, it is essential for engineering students to graduate from the United States engineering educational institutions with the affirmed ability to *design anywhere manufacture anywhere*, and the training necessary to collaborate effectively with their peers from international engineering educational institutions.

Two approaches can be identified in the literature for adding the international component to the undergraduate experience:

1) the student exchange and study abroad programs [3–5], and
2) distributed international teaming approach [6, 7].

The author's experience with both approaches indicated that although exchange programs are more manageable and sustainable, they are limited in impact to a small group of students due to low participation. In comparison, online international teaming projects pose serious management and sustainability challenges but offer a more affordable alternative to study abroad and student exchange programs. Online international teaming projects are the emphasis of Part 2 of this paper.

THE FACTS ABOUT STUDENT EXCHANGE PROGRAMS AND STUDY ABROAD PROGRAMS

Exchange programs are structured around students paying their tuition at their home educational institution while earning credit at a host institution. Students usually absorb the additional cost related to travel and accommodation.

An exchange program is sustainable if a balance exists in the flow of students between the two educational institutions. Such a balance implies that neither of the two educational institutions is suffering financial losses as a result of receiving more students than it is sending. A student exchange program is therefore sustainable with as low as two undergraduate students per year; one per institution.

Table 8 presents the ratio of the number of US students studying abroad to the number of foreign students studying in the USA through an exchange program for the year 2001. Data was compiled from the state statistics sheets provided in the

Table 8. The year 2001 data for engineering USA and foreign exchange programs.

State	Foriegn in USA	US students abroad	Foreign/US students
Alabama	6,040	1,180	5.1
Alaska	479	16	30
Arizona	10,511	3,375	3.1
Arkansas	2,758	601	4.6
California	78,741	12,222	6.4
Colorado	6,692	2,994	2.2
Connecticut	8,050	1,467	5.5
DC	9,241	2,377	3.8
Delaware	1,975	1,064	1.8
Florida	28,303	4,878	5.8
Georgia	11,991	4,379	2.7
Hawaii	5,289	178	29.7
Idaho	1,578	307	5.1
Illinois	25,498	5,864	4.3
Iowa	7,896	3,947	2.0
Kansas	7,240	1,444	5.0
Kentucky	4,789	1,272	3.7
Louisiana	6,312	1,474	4.2
Maine	1,357	1,107	1.2
Maryland	13,947	2,193	6.3
Massachusetts	29,988	7,623	4
Michigan	23,103	5,908	4
Minnesota	8,651	6,495	1.3
Mississippi	2,381	970	2.4
Missouri	10,281	2,721	3.7
Montana	944	380	2.5
Nebraska	3,874	1,035	3.7
Nevada	2,927	345	8.5
New Hampshire	2,436	1,386	1.8
New Jersey	13,516	1,653	8.2
New Mexico	1,893	362	5.2
New York	62,053	13,221	4.7
North Carolina	8,960	5,864	1.5
North Dakota	1,376	158	8.7
Ohio	19,384	7,419	2.6
Oklahoma	8,818	787	11.2
Oregon	6,560	2,507	2.6
Pennsylvania	24,014	8,843	2.7
Rhode Island	3,370	1,372	2.4
South Carolina	3,731	2,007	1.8
South Dakota	770	118	6.5
Tennessee	5,867	1,822	3.2
Texas	44,192	7,188	6.1
Utah	5,950	2,168	2.7
Vermont	908	1,176	0.7
Virginia	12,600	4,823	2.6
Washington	11,624	3,499	3.3
West Virginia	2,108	580	3.6
Wisconsin	7,701	3,508	2.2
Wyoming	448	40	11.2

Institute of *International Education's Open Doors Report 2002*. The ratios indicate that most of our exchange programs are out of balance with more foreign students coming for study in the USA than US students traveling to study abroad. An exchange program that is out of balance runs the risk of being phased out due to financial losses incurred by the US institution.

Table 9 presents the data for student exchange programs in the USA and the total enrollment numbers of undergraduate students for the year 2003. The data is compiled from the state statistics sheets provided in the *Institute of International Education's Open Doors Report 2004*, and The National Information Center for Higher Education Policymaking and Analysis. The author then evaluated the percentage of undergraduate students in the USA participating in exchange programs to the total number of undergraduate enrollment per state, Table 9.

Statistical analysis of the percentage of undergraduate students in the United States participating in exchange programs to the total number of undergraduate enrollment per state resulted in a mean of 38.2%, a standard deviation of 20.14, a maximum of 84.4%, and a minimum of 6.12%.

A histogram of the percentage of undergraduate students in the United States participating in exchange programs to the total number of undergraduate enrollment per state is presented in Fig. 4. The figure indicates that across 27 states in the USA undergraduate student participation in exchange programs is less than or equal to 37% of the total undergraduate students population.

Table 9. Exchange programs and undergraduate enrollment statistics in the USA, 2003.

State	US students abroad	US total enrollment	Ratio
Alabama	1,004	8,046	12.478250062
Arkansas	787	2,261	34.807607253
Arizona	3186	8,489	37.53092237
California	14,224	47,189	30.142617983
Colorado	3,162	8,642	36.588752604
Connecticut	1,572	2,938	53.505786249
Delaware	926	1,096	84.489051095
Florida	4,836	19,136	25.27173913
Georgia	4,716	6,770	69.660265879
Hawaii	331	634	52.208201893
Iowa	3,570	6,122	58.31427638
Idaho	340	2,595	13.102119461
Illinois	5,947	12,854	46.265753851
Indiana	5,586	10,684	52.283788843
Kansas	1,533	5,334	28.74015748
Kentucky	1,622	3,375	48.059259259
Louisiana	1,532	8,383	18.27508052
Massachusetts	8,184	10,281	79.603151444
Maryland	2,107	9,534	22.099853157
Michigan	5,966	22,865	26.092280778
Minnesota	6,198	4,256	46.304885591
Missouri	2,995	6,468	29.58490566
Mississippi	784	2,650	20.939147101
Montana	437	2,087	61.41834743
North Carolina	5,664	9,222	9.796437659
North Dakota	231	2,358	63.680518079
Nebraska	1,180	1,853	33.452338451
New Jersey	1,874	5,602	12.976827094
New Mexico	364	2,805	15.562913907
Nevada	376	2,416	55.380630539
New York	13,684	24,709	43.846432015
Ohio	7,275	16,592	12.478250062
Oklahoma	933	4,993	18.686160625
Oregon	2,659	4,960	53.608870968
Pennsylvania	9,897	18,754	52.772741815
Rhode Island	1,630	1,543	41.435490973
South Carolina	1,882	4,542	6.1269146608
South Dakota	140	2,285	30.186300602
Tennessee	2,155	7,139	23.640242902
Texas	7,202	30,465	31.879504713
Utah	1,725	5,411	56.560685107
Virginia	5,746	10,159	73.34220448
Washington	3,307	4,509	43.75
Wisconsin	4,151	9,488	22.232223222
West Virginia	494	2,222	18.686160625
Wyoming	79	1,194	6.616

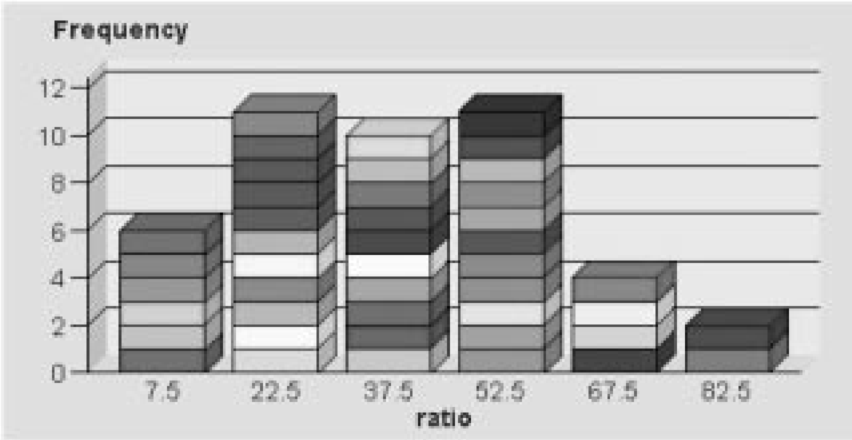

Fig. 4. A histogram of the percentage of undergraduate students in the USA participating in exchange programs to the total number of undergraduate enrollment per state for the year 2003.

THE GAP BETWEEN THE EDUCATORS' EXPECTATIONS AND THE REALITY OF THE UNDERGRADUATE STUDENT SITUATION

Success of an exchange program or a study abroad program requires popularity and large participation. Most undergraduate engineering students are known to avoid participation in activities that are costly or would delay their anticipated date of graduation. The cost factor is paramount especially during the summer term where undergraduate students need to work, or participate in internships. Therefore, unless the cost of a student exchange program is drastically reduced by financial assistance from the home institution, local businesses, or the availability of internships in the host institution country, a noticeable increase in participation in student exchange programs or study abroad programs cannot be anticipated.

Some of the educators' misconceptions in relation to international education include the following:

1. The student would spend a term abroad if the host institution provides instruction in English,
2. The student would spend a summer abroad if supported by an assistantship.
3. International internships will increase student participation.

However, undergraduate students would not participate in a program that would delay their graduation especially with the continuing increase in tuition fees. Therefore, few undergraduate students would be willing to spend a term abroad independent of the instruction language. In addition, summer is usually the time for internship experience and for gaining an income that the student could use towards their education. As a result, undergraduate students would be reluctant to spend a summer abroad even if supported by an assistantship. Finally, foreign language skills are not a graduation requirement in US universities. Therefore, the possibility of securing an internship in the host country is almost non-existing if the host country language of business is not English, since an internship provider expects the student to communicate effectively and to successfully carry the responsibilities of their position.

A PROPOSAL FOR BRIDGING THE GAP

The responsibility of bridging the gap needs to be shared equally between the undergraduate engineering students and their educators. Foreign language skills must become a graduation requirement for engineering colleges in the United States. The educators, on the other hand, need to shift the focus from sending more students abroad to bringing the international experience to the United States engineering campuses through distance education techniques.

Participation in a visible international education institution such as the Institute for International Education and its Global E3 initiative will reduce the need for the development of student exchange agreements on a university by university basis while freeing up some of the resources required for the engineering departments to integrate the international educational experience into the undergraduate curriculum. An independent survey of international education institution initiatives such as the GE3 is required to guide the educators in their selection process.

SUMMARY

It is essential for engineering students to graduate from the United States engineering educational institutions with the affirmed ability to *design anywhere, manufacture anywhere*, and the training necessary to collaborate effectively with their peers from international engineering educational institutions. Statistics indicate that our current efforts have not come close to meeting the target of providing the undergraduate engineering student with the skills necessary for a global practice of their profession.

Web-based technologies and distance education techniques have matured enough to allow US engineering colleges to bring the international educational experience home to our students through direct integration into the engineering curriculum. International distance education has the potential of becoming an affordable and more accessible alternative to a full immersion study abroad programs or student exchange programs.

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Abir Qamhiyah is an assistant professor of mechanical engineering at Iowa State University, and the founder and president of CMNET Incorporated a software developer for contract manufacturing network technology. Her research areas are collaborative engineering education, geometric reasoning for CAD applications, Integrated system and product design, and design methodology. Qamhiyah was awarded her Ph.D. in mechanical and Industrial engineering in 1996 from the University of Toronto, Canada.