A Comparative Analysis and Evaluation of Different Approaches of Globalization of Engineering Curriculum in the USA

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Abstract

To sustain global technological leadership, the need for globalizing U.S. engineering education has been widely recognized by academic institutions, industry, and government for several decades. The world today is much flatter requiring a wider view towards design and development of products due to socio-economic diversities of prospective customers. Engineering, manufacturing and information technology projects require multinational teams of professionals to work together where communication skills, cultural awareness, and interpersonal skills are extremely critical.

Study abroad, student exchange, faculty exchange, foreign language study and international collaborative projects have been used by academic institutions. A study has been conducted by the author that includes the perspectives of students, faculty, and professional engineers employed in the industry from both the US and abroad. The study solicited input from the above group of individuals about their input regarding effective way to globalize US engineering education. In this paper different approaches used for globalization of engineering curriculum will be examined along with the results of the study. This paper will also present the author's evaluation of effective ways of globalization and his recommendation for improvement of engineering curriculum.

Introduction

This paper is the second and final part of a multi-stage research project. In part one, the 'preparedness level' of engineering graduates from US universities was presented concluding the prepared level to be less than adequate [1]. The study was extended in an attempt to provide a solution to the problem identified in the previous paper by organizing responses regarding effective ways for globalizing engineering education.

A comprehensive survey forms the crux of this multi-stage research project. The concluding question of the survey questionnaire was a subjective one soliciting feedback on how to globalize engineering education. A wide array of responses was received from various sects of respondents. In addition, a literature survey showed various approaches employed by educational institutions and industries in an attempt to formulate standards of globalization.

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For decades, approaches used for globalization of academic curriculum and industrial practices can be categorized as student/faculty exchange programs, global study, foreign language study and international studies and global project experience. The aforementioned list is not exhaustive, as there are other possibilities of standalone methods, which may not fit into any one of the above categories. In this paper, an attempt was made to parse and subsequently cluster responses into one of the above categories. Responses were used as an index of quantitative comparison of various methods. This paper is divided into four sections: brief analysis of previous work, survey respondent distribution, statistical analysis of preferred globalization approach, and conclusions with author's recommendations.

Related Studies

Student exchange programs and global study have been one of the most commonly used methods for globalization. In a typical student exchange program, students attend an overseas institution for one to two semesters where they take courses that apply towards their degree program. The Global Engineering Education Exchange Program (Global EEE) was initiated fourteen years ago, focusing on providing undergraduate engineering students international academic experiences and industrial internships. Over the years, the program developed to national stature with over 200 exchanges annually and involving over 80 major engineering schools throughout the world. Gerhardt et al [2], [3] provided the basic concept, philosophy, practice, progress to date, and the remaining challenges associated with the Global EEE Program [2].

The Department of Aerospace and Mechanical Engineering at the University of Notre Dame joined several other engineering departments in offering a foreign study programs for undergraduates. Students have benefited by obtaining critical technical and business knowledge, making valuable contacts, as well as developing understanding of the host country's customs and practices [4]. Worcester Polytechnic Institute (WPI) has incorporated a project-based curriculum that provides opportunities for undergraduate students to complete meaningful off-campus experiences. WPI offers students the flexibility to complete three different degree requirements away from campus under the direct supervision of WPI faculty. WPI has addressed the issues raised by ABET Engineering Criteria 2000. It focuses on aspects of the program that are clearly connected to multi-disciplinary teaming, professional and ethical responsibility, communication competence, a real understanding of the impact of solutions in a global and societal context, knowledge of contemporary issues, and the motivation for life-long learning [5]. Universities in Europe are adopting the bachelor-masters-doctoral (BMD) system as the de facto international standard for engineering education. The driving force for this dramatic change is globalization of the economy, society, industry, and education. Globalization has developed a need for European multinational companies to hire engineers with a more practical education, and for European engineering programs to better compete for graduate students from overseas institutions [6]. Engineering graduates must be competent in teamwork, communication skills, project management and problem solving from a global perspective. The North American Free Trade Agreement (NAFTA) has further intensified the globalization of science and industry to unanticipated levels. Sadat-Hossieny et al. examined methods and practices undertaken by engineering schools across the United States to create curricular paradigms such as the Global Engineering College (GEC) or virtual engineering college [7].

The global engineering education project [8] at North Carolina A&T State University expands the activities of an on-going student exchange program and promotes a wider participation by students and faculty. The overall goal is to develop students' abilities to work effectively in a global environment. The student exchange program allows participating students to spend one semester at the host institution, attend classes, earn credits and transfer them to the home institution. The aluminum-based design of mini Baja project used a multicultural team of student to work on a major meaningful project. A&T students and faculty worked closely with the team members from Ghana to design and develop the vehicle.

Faculty exchange programs are another approach for globalizing engineering education. Zia et al. [9] summarizes his experience in organizing a faculty exchange program as one of many elements of international cooperation, as well as the challenges associated with such programs. The objective was to present and promote the faculty exchange program as one of the many components of international cooperation in engineering education.

The Chemical Engineering Department at Iowa State University (ISU) developed several opportunities for students to study in overseas institutions to earn credits towards their degree. Interest among both faculty and students has increased significantly since the inception of the program in the last decade. A number of faculty members have traveled to overseas institutions as well as a number of faculty members from overseas institutions have visited ISU for extended periods [10].

International studies are being used by a number of US institutions as an approach for globalization. Oregon State University's innovative International Degree Program [11] allows students to earn a concurrent bachelor's degree in International Studies associated with an engineering degree. The program requires foreign language proficiency, overseas experience, courses with a cross-cultural focus, and a thesis. The program draws on campus resources such as overseas study programs, international internships, and the honors college, and it enlists engineering faculty members as thesis advisors.

Global collaboration project allows students and professionals to gain meaningful and valuable experience that is one of the most important skills required by employers. Large-scale software development requires communication and coordination among specialists from different fields. To help this generation of software developers understand the distributed, collaborative development process, Favela et al. [12] designed a course entitled the Distributed Software Engineering Laboratory. In this course, pairs of students from different countries work as a virtual organization overseeing the total software development process. In the same context, Xiaoqing [13] elaborates challenges and issues with collaborative global software development and education.

In 1990-91, WPI launched a major initiative, the Global Perspective Program [14], aimed at extending WPI's commitment to global education beyond the off-campus experience of international exchanges and project programs. The Global Perspective Program calls for globalizing all aspects of the WPI educational programs, on campus as well as off campus, by incorporating global perspectives throughout every discipline on campus, as well as within nonacademic programs. Hong Kong University of Science and Technology (HKUST) established a global collaborative educational program [15] at the MS level in electronics packaging to educate skilled engineers, technical managers and visionary leaders who can pull off the transition to the future for the electronics packaging industry. The program is based in the Mechanical Engineering Department (ME) with course contribution from the Electronics and Electrical Engineering Department (EEE), the Chemical Engineering Department, the Industry Engineering Department, and IEEE-CMPT. Curricula of this program include traditional engineering core courses and specialized electronic packaging courses.

Corporations and governments are challenged by a demanding global economy that requires mobility of capital and labor, organizational re-structuring across national boundaries, development and implementation of more efficient production and manufacturing practices. Yet we know very little about how engineers understand and experience globalization, and how globalization affects their education, practices, and collaborations with non-engineers. Lucena et al. [16] collected data through ethnographic fieldwork and interviews, showed how globalization requires non-technical skills to solve complex engineering problems.

The educational experience of future manufacturing engineers should reflect the fact that manufacturing is becoming increasingly a global activity. Stephan et al. [17] showed a complex picture that implies a continuing presence for significant manufacturing in the U.S. as well as substantial growth abroad. A review of most current U.S. manufacturing engineering programs shows that relatively few acknowledge the international nature of manufacturing in their published course requirements. This author recommended including more material on the global aspects of manufacturing in undergraduate engineering curricula.

Survey Respondent Distribution

The survey on globalization of engineering education received 785 responses, which was conducted through the popular online surveying tool Zoomerang. Out of 785 respondents, 67% accounted for student responses, 25% of respondents were faculty members, and professional engineers working in the industry (others) made the remaining 8% responses.

The approximate student to faculty ratio of 3 to 1 is justified with typical student to faculty ratios in U.S. universities, which hovers around 15 to 1. The lower 8% professional engineer (others) respondents can be attributed to the fact that globalization of engineering education and the global work platform are current issues, and a significant part of the existing workforce are unaffected by it. From a futuristic perspective, the upcoming generation of students will be affected by rapidly evolving global engineering work platform. As such, 67% student respondents are justified.

Table 1: Respondents' Academic/Employment Status

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Faculty	194.0	24.7	24.9	24.9
	Other (Please specify your title if employed)	61.0	7.8	7.8	32.7
	Student	525.0	66.9	67.3	100.0
	Total	780.0	99.4	100.0	
Missing	1	5.0	0.6		
Total		785.0	100.0		

Statistical Analysis

Defining the Chi-Square Test

A chi-square test is a general technique for the analysis of categorical data used to test the association between two categorical variables (generally a 'group' variable and a 'response' variable) in a given set of data. Specifically, the null hypothesis being tested is that two variables are independent of each other, or that the distribution of categorical responses for one group will be identical to that of all other groups. In the present paper, chi-square tests were used to compare certain groups in terms of their distributions of responses to selected categorical questionnaire items (e.g., comparing respondent groups in terms of endorsement of the Student Exchange Program). For example, a chi-square test was used to test for an association between respondent groups (five levels) and endorsement of the Global Study Program (possible responses parsed into yes and no, i.e., two levels). Tables 3.1 and 3.2 show the cross-tabulation results and Chi-Square test for this example analysis. The chi-square statistic in this case had 4 degrees of freedom (df), and was equal to 5.615 with a p-value of 0.230. This p-value indicates that there was a more than 20% chance of observing an association of this magnitude or larger if these data were collected from a population where there was no association between respondent groups and endorsement of the Faculty Exchange Program (i.e., a population where the null hypothesis was true). As a result, we would accept the null hypothesis and conclude that no significant differences were observed between these five groups in terms of endorsement of global study programs.

Cross-Tabulation and Chi-Square Tests

Given the tabulated data, and the fact that respondents could indicate multiple solutions for globalization, each individual solution for globalization was analyzed separately using chi-square analysis. Specifically, the five groups of respondents were compared in terms of the probability of endorsing a particular solution using chi-square tests.

The five respondent groups were as follows:
1. Faculty-US
2. Faculty Non-US
3. Student-US
4. Student Non-US

5. Others (professional engineers working in the industry)

Of the 785 total survey respondents, 235 respondents provided an open-ended response endorsing one or more approach that can be used for globalizing engineering education. A small number of respondents did not endorse any of the above stating that they did not feel any need for the globalization of engineering education. Their point of view was that US engineering education is one of the best and highly recognized in the world and the graduates can work in a global workplace with some training that is usually provided by the employer.

Table 2: Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
group * endorse	235	100.0%	0	.0%	235	100.0%

A series of six different chi-square tests were performed using the statistical analysis software SPSS (Version 14.0) to assess the bivariate associations between respondent groups and the endorsement of different globalization approaches. The first chi-square test examined the association between respondent group and endorsement of the Global Study Programs. Tables 3.1, 3.2, and Figure 1 illustrate these cross-tabulation results and the corresponding chi-square test results.

Table 3.1: Cross-tabulation of Respondent Group with Global Study Endorsement

			Endorse		
			No	Yes	Total
Group	Faculty-US	Count	56	6	62
		% within group	90.3%	9.7%	100.0%
	Faculty-Non US	Count	34	6	40
		% within group	85.0%	15.0%	100.0%
	Student-US	Count	83	15	98
		% within group	84.7%	15.3%	100.0%
	Student-Non US	Count	10	5	15
		% within group	66.7%	33.3%	100.0%
	Other	Count	16	4	20
		% within group	80.0%	20.0%	100.0%
Total		Count	199	36	235
		% within group	84.7%	15.3%	100.0%

Table 3.2 Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	5.615[a]	4	.230
Likelihood Ratio	5.020	4	.285
Linear-by-Linear Association	3.160	1	.075
N of Valid Cases	235		

[a]2 cells (20.0%) have expected count less than 5. The minimum expected count is 2.30.

The result of respondent's endorsement of different approaches and their corresponding p-values from six different chi-square tests are presented in Table 4.

Table 4: Results of Chi-square Tests (p-value) and Endorsements of Globalization Approaches by Group

Globalization Approaches	**Faculty US**	**Faculty Non US**	**Student US**	**Student Non US**	**Other**	**Chi-Square P-Value**
Global Study	9.70%	15.00%	15.30%	33.30%	20.00%	0.23
Student Exchange	11.30%	25.00%	7.10%	13.30%	0.00%	0.02
Faculty Exchange	6.50%	27.50%	5.10%	13.30%	0.00%	< 0.001
Foreign Language	9.70%	12.50%	28.60%	0.00%	40.00%	0.001
Global Project	30.60%	12.50%	29.60%	40.00%	30.00%	0.181
No need for Globalization	12.90%	2.50%	5.10%	0.00%	0.00%	0.074

Among five different globalization approaches, the chi-square test p-values range from less than 0.001 to 0.230, indicating varying levels of agreement among different respondent groups regarding different approaches. The highest p-value (p=0.23) observed in the global study approach indicates a more universal agreement among the respondents groups in endorsing global study as an effective approach. About 33% non-US students and 20% of engineers working in the industry endorsed global study compared to only 9.7% of the US faculty. The next highest p-value observed (p=0.181) was for the global project experience approach where 30% of the engineers working in the industry and 30% of US faculty endorsed this approach. The lowest p-value ($p < 0.001$) was observed for the Faculty Exchange Program which indicates a significant level of disagreement among respondent groups in terms of endorsement of the Faculty Exchange Program. About 27% of non-US faculty endorsed this approach compared to only 6.5% of US faculty, and no respondents representing engineers working in the industry endorsed this approach. Endorsements of different globalization approaches by different respondents groups are summarized and presented in Figure 2.

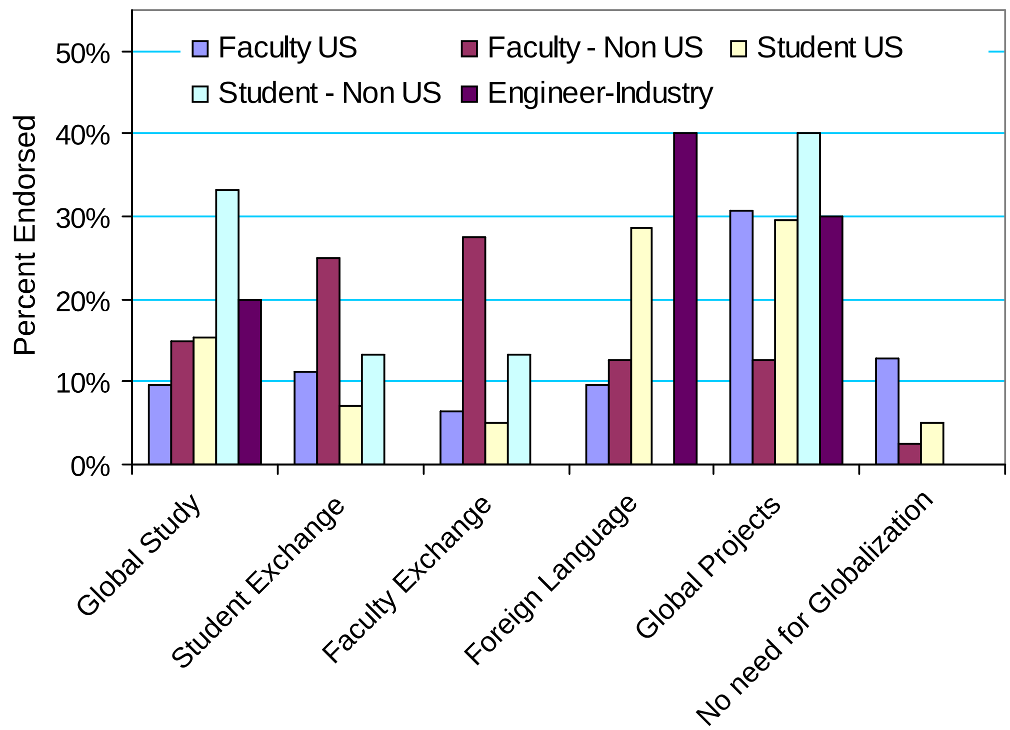

Figure 1: Endorsement of Global Study by Different Group of Respondents

Summary and Conclusion

Table 5 shows the overall summary of endorsement of different approaches by all groups indicating global projects with approximately 28% or highest level of endorsement followed by incorporating foreign language in US engineering curriculum with 20% endorsement. One important parameter worth mentioning regarding foreign language is that the respondents emphasized a foreign language from a country with an emerging economy. Lowest number of endorsement was observed for faculty exchange programs without considering a small segment of the respondents who did not feel any need for globalization at all. It was interesting to observe that most of the respondents who did not feel any need for globalization are engineering faculty from US institution. This interesting phenomenon clearly shows a difference in perception regarding globalization between US engineering students and engineers working in the industry who strongly felt the need for globalization.

Table 5: Overall Summary of Endorsement of Different Approaches

Name of Program	% Endorsing
Global Study	15.30
Student Exchange	11.10
Faculty Exchange	9.40
Foreign Language	20.00
No Need for Globalization	6.00
Global Project	27.70

Although this group of respondents preferred global projects and foreign language study to be the two most effective ways for globalization of US engineering education, the appropriate globalization method may depend upon the program requirements. Realizing the constraints associated with the number of credit hours and total time required for a Bachelors degree in engineering along with institutional and accreditation (ABET) criteria, requiring foreign language study may pose a challenge to curriculum redesign. This study was performed to improve our understanding of the higher education stakeholder's perspective about which approaches are most effective to further globalize US engineering education.

The author recommends incorporating one or more of the above approaches in the current engineering curriculum to improve the global awareness and skill of US engineering students. This may seem to be burdensome to the program and institution in the short term, but will provide meaningful and valuable experiences to prepare our students to address future global
challenges.

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Biography

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