

Framing the Engineering Outsourcing Debate:
Comparing the Quantity and Quality of Engineering
Graduates in the United States, India and China

Gary Gereffi
Director, Center on Globalization, Governance & Competitiveness, Professor
Sociology Department, Box 90088
Duke University
ggere@soc.duke.edu

Vivek Wadhwa
Executive in Residence
Pratt School of Engineering, Box 90271
Duke University
vivek.wadhwa@duke.edu

Ben Rissing
Research Scholar
Pratt School of Engineering, Box 90300
Duke University
ben.rissing@duke.edu

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Abstract

The effect of the dynamics of engineering outsourcing on the global economy is a discussion of keen interest in both business and public circles. Varying, inconsistent reporting of problematic engineering graduation data has been used to fuel fears that America is losing its technological edge. Typical articles have stated that in 2004 the United States graduated roughly 70,000 undergraduate engineers, while China graduated 600,000 and India 350,000. Our study has determined that these are inappropriate comparisons. Here we present comparable engineering graduation statistics for four-year degrees awarded in China, India and the United States. Moreover, these data are presented over a period of five years to show how engineering graduation rates have changed in these countries since 2000. A comparison of like-to-like data suggests that the United States produces a highly significant number of engineers, computer scientists and information technology specialists, and remains competitive as a source of global engineering, computer science and information technology labor.

Introduction: The Engineering Outsourcing Debate

Today, the effect of engineering outsourcing on the global economy is a discussion of keen interest. Over the past two years media outlets, policy makers and industry representatives have painted a grim picture of the future competitiveness of the United States at a global level. Persistent reporting of poorly cited engineering graduation data has been used to fuel fears that America is losing its technological edge. Articles in the popular media, speeches by policy makers and congressional reports have stated that in 2004 the United States graduated roughly 70,000 undergraduate engineers, while China graduated 600,000 and India 350,000. To make matters worse, when cited by the popular media, these numbers were rarely documented or verified (Bialik, 2005a, 2005b). This led to significant debate regarding the validity of these numbers. Exhibit 1 below showcases just a few of the high-level publications and organizations that relied on these figures in the past.

Exhibit 1: Poorly Grounded Engineering Statistics

“Last year more than 600,000 engineers graduated from institutions of higher education in China. In India, the figure was 350,000. In America, it was about 70,000”

- The National Academies, Press Release: “Broad Federal Effort Urgently Needed to Create New, High-Quality Jobs for All Americans in the 21st Century”, 10/12/2005

“Last year China's schools graduated more than 600,000 engineers and India's schools produced 350,000, compared with 70,000 in America”

- The U.S. Department of Education, Press Release: “In Case You Missed It: Let's Get Serious”, 2/7/2006

“In engineering, China's graduates will number over 600,000, India's 350,000, America's only about 70,000”

- *Fortune*, “Can Americans Compete”, 7/25/05

After speaking with students, faculty and colleagues, we found that rising undergraduate engineers had real concerns regarding the possibility of having their engineering jobs outsourced in the future. Engineering students wanted to know what jobs were “outsourcing-proof” and what coursework or practical experiences would better prepare them for a more global working environment. Additionally, some engineering students saw more opportunity and expected better starting salaries in non-engineering fields. These experiences initially took us by surprise, because we had always perceived there to be a relative shortage of engineers in the United States.

To answer these questions and learn more about the current international engineering education environment, we assembled a multidisciplinary team of domestic and international engineering students at Duke University. The goal of this research group was to identify the number of four-year engineering bachelors degrees being awarded in China, India and the United States, in addition to studying how these graduation profiles have changed with time. Our research showed that the commonly cited statistics for these countries were incorrect.

The Chinese Ministry of Education (MoE) and the National Association of Software and Service Companies (NASSCOM) in India are often referenced as sources of engineering graduation data within their respective countries. However, the statistics released by these organizations have included not only four-year degrees, but also three-year degrees and diploma holders. These numbers have been compared against the annual production

of accredited four-year engineering degrees in the United States. Additionally, in some cases these exaggerated numbers included not only individuals in traditional engineering disciplines, but information technology specialists and technicians. Exhibit 2 below concisely displays the different types of degrees that are added together to produce these different graduation statistics for the United States, China and India.

Exhibit 2: Commonly Cited Engineering Graduation Statistics, an Invalid Comparison.

Country	Reported Graduates	What is Included in these Numbers:
The United States	70,000	Four-year engineering bachelors degrees.
China	600,000	Three- and four-year engineering degrees under a broad definition of "engineer". Additionally, computer science and information technology three- and four-year degrees are included.
India	350,000	Three- and four-year engineering, computer science and information technology degrees.

Defining Engineers

To accurately compare the populations of graduating engineers in the United States, China and India, we need to concisely define what degree fields we are counting. For the purposes our analysis, we will be counting four-year bachelors degree recipients from the following disciplines:

- Engineering
- Computer Science (CS)
- Information Technology (IT)

By analyzing these groups, we can fairly compare US engineering and technology outputs with broader international definitions of “engineering.” A plethora of statistical sources exist in the United States, China and India that offer graduation data that meet the above criteria, in full or in part. Tables 1a, 1b and 1c detail the different statistical resources available in the United States, China and India respectively. The explanation that follows gives a brief background on these sources and the viability of their statistics. Highlighted fields indicate the statistical sources we have found most defensible.

Table 1a: US Graduation Statistics

United States

The number of 4-Year Bachelors in Engineering and Technology Fields Awarded during the 2003-4 Academic Year in China	
Source:	Bachelors Awarded:
The US Department of Education's (DoE) National Center for Education Statistics (NCES)	137,437
The American Society for Engineering Education (ASEE)	72,893*
The Engineering Workforce Commission (EWC)	~75,000*

* The data listed above from the ASEE and EWC does not include CS graduates outside of engineering or IT graduates.

The US Department of Education’s NCES publishes comprehensive statistics detailing annual graduation statistics for the United States in the fields of Engineering, CS and IT. As a result, these statistics are the most ideal when comparing the United States to other international graduation profiles with broader definitions of “engineering”.

Table 1b: China Graduation Statistics

China

The number of 4-Year Bachelors in Engineering and Technology Fields Awarded during the 2003-4 Academic Year in China	
Source:	Bachelors Awarded:
Chinese Ministry of Education (MoE) Website and Phone Interviews	351,537
MoE 2005 China Statistical Yearbook	442,463
China Education & Science Research Network (CERN)	376,415

In China, the national government tightly monitors engineering graduation statistics through the Chinese Ministry of Education (MoE). This organization has produced high level engineering graduation statistics, but offers little information on how these data were collected and no breakdown of what fields of engineering have gone into this number. The MoE informed us that their aggregate numbers were obtained by adding the numbers of “engineering” graduates as reported by different provinces. However, no standard definition of engineering exists between the provinces. There were also questions about what qualifies as an engineering program in China. It appeared that any bachelor’s degree with “engineering” in its title was included in MoE statistics regardless of the degree’s field or associated academic rigor. This means that the reported number

of engineers produced may include the equivalent of motor mechanics and industrial technicians.

Recently, the China Education and Science Research Network (CERN) issued a press release containing new information released by the MoE. These new statistics outlined the number of engineering and technology graduates produced by China in 2003 and 2004. Unlike previous MoE web postings and statistical yearbooks, the CERN statistics contain bachelors graduation data sub-divided by major. This has enabled us to feel far more comfortable with these data.

Table 1c: India Graduation Statistics

India

The number of 4-Year Bachelors in Engineering and Technology Fields Awarded during the 2003-4 Academic Year in India	
Source:	Bachelors Awarded:
All India Council for Technical Education (AICTE)	185,758**
NASSCOM 2005 Strategic Review	112,000
NASSCOM 2006 Strategic Review	139,000

** This number represents the government-approved intake of four-year engineering candidates in the year 2000. This number assumes that all seats were filled and that all students graduated

The All India Council for Technical Education (AICTE) releases information on the Indian government’s yearly allocation of engineering bachelors seats. In other words, this refers to the maximum number of engineering graduates permitted to *enroll* in a given year. To achieve estimates of the number of engineering and technology degrees awarded in the year 2004, the National Associate of Software and Service Companies (NASSCOM) scales the intake figures provided by the AICTE for the year 2000.

Engineering and Technology Graduation Profiles

To gain a broader prospective on the engineering graduation trends in the United States, China and India, we approached our sources and worked with lead researchers, directors and statisticians to obtain a five-year window of graduation information for the United States, India and China. These data were collected from the Ministry of Education (MoE) in China, the National Association of Software and Service Companies (NASSCOM) in India, and the US Department of Education’s (DoE) National Center for Educational Statistics (NCES). It is important to note that we were unable to reach a level of comfort with the data provided by the MoE’s Statistical Yearbooks. The graduation statistics published in these yearbooks did not include background information on data collection techniques or explicit definitions of how the “engineering” degree category was structured. Our conversations with MoE representatives and faculty members have led us to believe that the MoE graduation statistics may include additional technology degrees outside the traditional engineering fields. Unfortunately, The MoE’s Statistical Yearbooks are the only current source of five-year trend data for Chinese Engineering bachelors degrees. The results from these research efforts can be found in Table 2 below, and a visual representation is presented in Figure 1.

Table 2: Four-Year Bachelors in Engineering, Computer Science and Information Technology Awarded from 1999-2004 in the United States, China and India

	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04
United States ¹	101,249	108,750	114,241	121,263	134,406	137,437
India ²			82,107	109,376	129,000	139,000
China (MoE CERN) ³					293,125	376,415
China (MoE Yearbook) ^{4 *}	195,354	212,905	219,563	252,024	351,537	442,463

Note: Gray highlighted data may constitute an overestimate

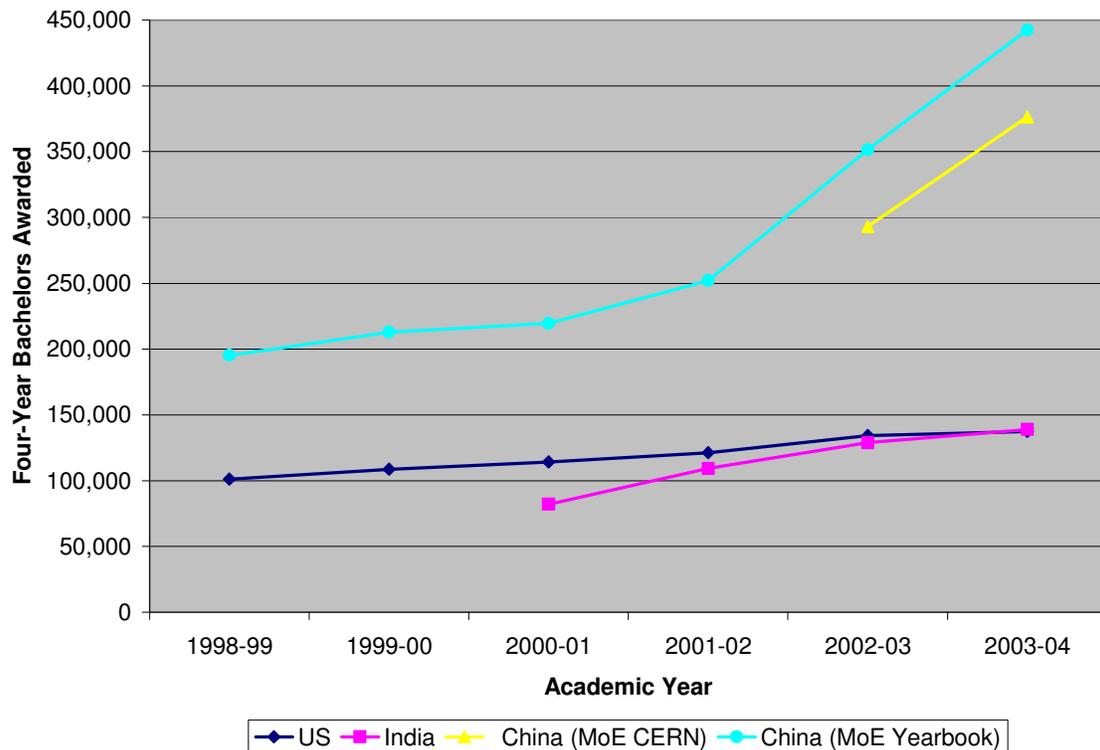
* This data provided by the Chinese Ministry of Education may include additional engineering and technology degrees outside traditional engineering fields, CS majors and IT specializations (example: auto mechanics)

Note: The National Center for Education Statistics reports the total US engineering bachelors degrees granted in 2004 to be 63,558. This number differs from the American Society of Engineering Education's (ASEE) 2004 statistic of 72,893. This variation is due to the way each of these organizations classifies and categorizes engineering graduates.

Sources:

1. United States Department of Education (DoE) National Center for Educational Statistics (NCES), (Assorted years). Current Tables 249 and 253.
2. National Association of Software and Service Companies (NASSCOM), (Assorted years). NASSCOM Strategic Review: The IT Industry in India.
3. China Education and Research Network (April 2005). The Ministry of Education announced in the last two years of ordinary professional enrollment data. <http://www.edu.cn/20050430/3136324.shtml>
4. Chinese Ministry of Education (MoE) (Assorted years). Chinese Statistical Yearbook. Number of Students in Regular HEIs by Field of Study.

Figure 1: Four-Year Bachelors in Engineering, Computer Science and Information Technology Awarded from 1999-2004 in the United States, China and India



The numbers presented in Table 2 strictly report four-year engineering degrees without considering accreditation or quality. In 2004, the United States awarded 137,437 bachelors degrees in engineering, computer science and information technology. In comparison, China awarded 442,463 bachelors degrees and India 139,000 during this same year. Some sources have argued that the United States' annual output of engineering graduates is exaggerated because a sizable portion of these individuals are in fact foreign nationals. The American Society of Engineering Education (ASEE) has reported that in 2004, 92.2% of US four-year undergraduate engineering degrees were awarded to domestic students. Only 7.8% were awarded to foreign nationals who may or may not have chosen to remain in the United States (ASEE, 2004: Bachelor's Degrees by Residency, p. 15).¹

This trend data suggests a slow, yet consistent increase in four-year engineering bachelors in both the United States and India. In contrast, the Chinese MoE Statistical Yearbooks show a massive increase in awarded Chinese engineering degrees beginning in 2001.

It is important to note that these three countries have very different population breakdowns. China has roughly four times the population of the United States, and India is approximately three times as large (World Bank, 2005). If we take the data from Table

¹ Foreign nationals represent a much higher proportion of US graduate degree programs in engineering. For US Masters degrees, foreign nationals were 45.5% of total engineering students in 2004, and for US doctoral degrees, foreign nations made up 57.8% of all students (ASEE, 2004).

2 and normalize it against each country's population in a given year, we can obtain the trend data presented in Figure 2.

Figure 2: The Number of Bachelor's Degrees in Engineering, CS and IT Awarded from 2000 - 2004 per Million Citizens

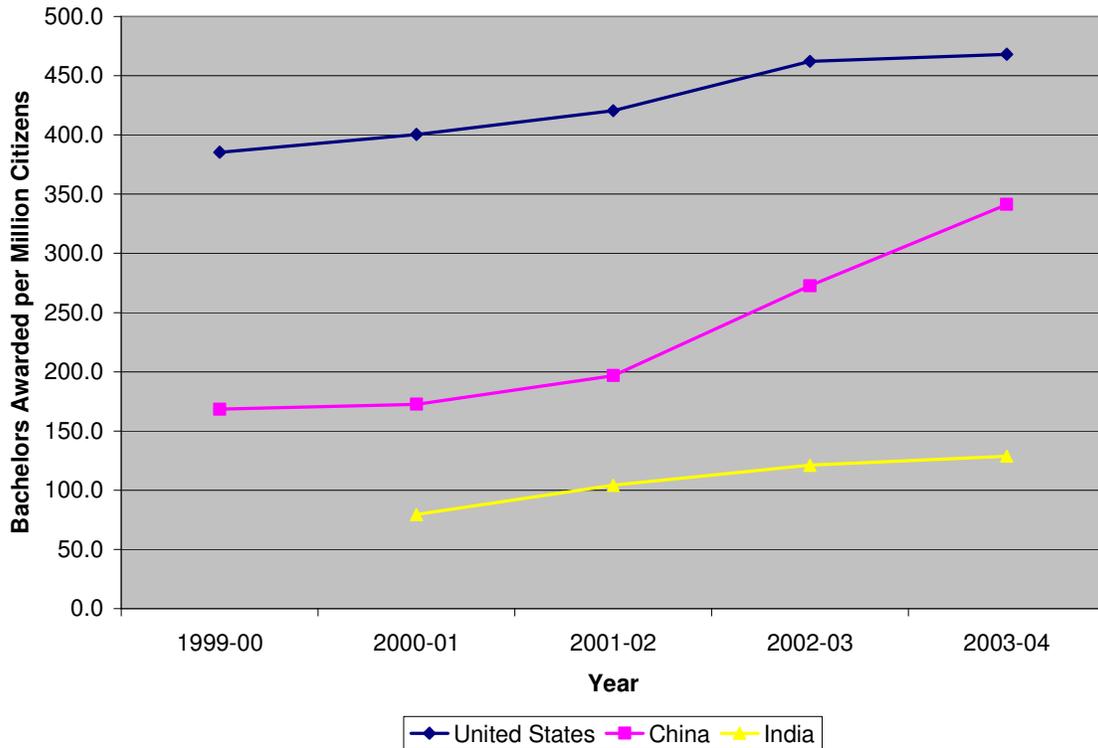


Figure 2 depicts the annual production of bachelors degrees in Engineering, CS and IT awarded per million citizens. These data indicate that in 2004 per every one million citizens, the United States is producing roughly 470 technology specialists, compared with 340 in China and 130 in India. Again, it is important to note that the trend data presented above makes use of the Chinese MoE data that may be artificially inflated.

Quality vs. Quantity

In 2005, the McKinsey Global Institute conducted a survey of Human Resource (HR) professionals from 83 companies in a variety of countries. These HR representatives were asked the following question with respect to the country they operated in: "Of 100 [engineering] graduates with the correct degree, how many could you employ if you had demand for all"? The results obtained from this survey for the United States, China and India are presented in Table 3. This survey shows that a number of factors such as language proficiency, education quality, cultural issues and a lack of accessibility can prevent portions of these country's engineering, CS and IT bachelors graduates from competing in the global workforce (McKinsey Global Institute, 2005).

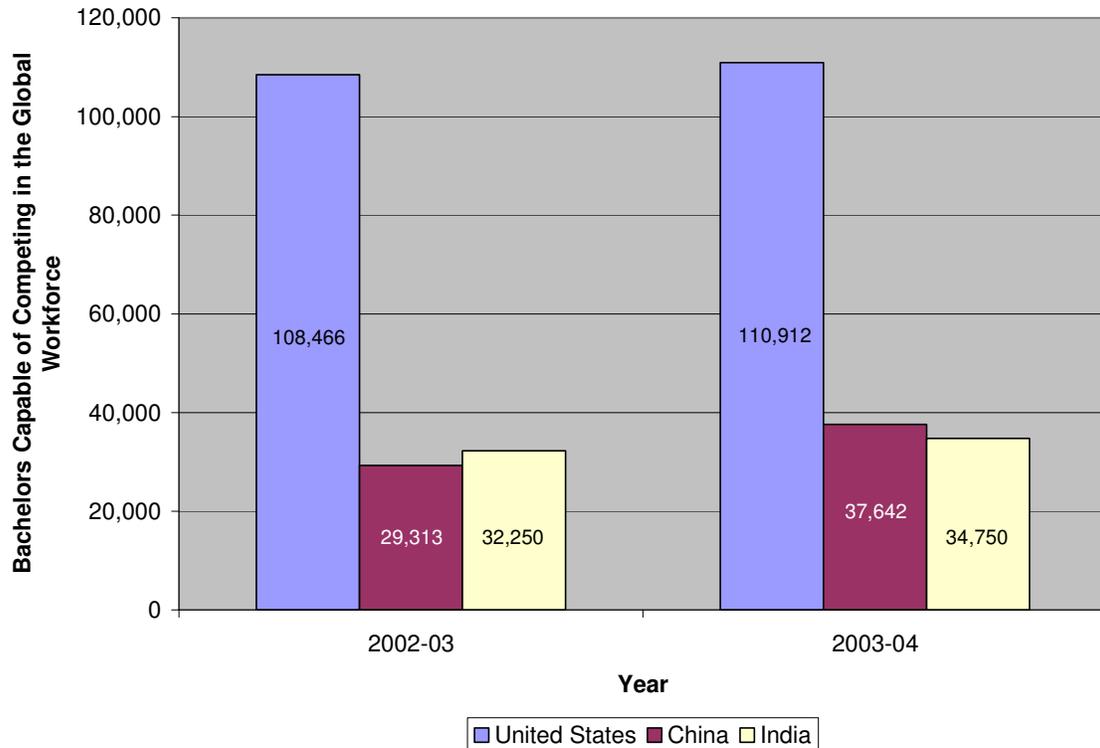
Table 3: MGI: The Suitability of Engineering Graduates to Compete in the Global Workforce

Country	Percentage of Engineers Employable
The United States	80.7%
China	10%
India	25%

Source: McKinsey Global Institute (2005: 40, 52).

In our research of engineering, CS and IT graduation profiles in the United States, China and India, the most grounded and defensible statistics were published by the NCES in the United States, the CERN in China, and NASSCOM in India. If we apply McKinsey's suitability percentages to the above statistics, we can obtain the number of technology specialists at the bachelors level capable of competing in the global economy. These data are presented in Figure 3.

Figure 3: Bachelors Degree Recipients Capable of Competing in the Global Workforce



Sources:

1. United States Department of Education (DoE) National Center for Educational Statistics (NCES), (Assorted years). Current Tables 249 and 253.
2. National Association of Software and Service Companies (NASSCOM), (Assorted years). NASSCOM Strategic Review: The IT Industry in India.
3. China Education and Research Network (April 2005). The Ministry of Education announced in the last two years of ordinary professional enrollment data. <http://www.edu.cn/20050430/3136324.shtml>
4. Source: McKinsey Global Institute (June 2005). Exhibit 11, Exhibit 25. The Emerging Global Labor Market: Part II - The Supply of Offshore Talent. Pgs 40, 52

There are real differences in the quality of education between the United States, India and China. Our study did not analyze this, but available data indicates that discrepancies exist between the quality of degrees offered at US, Chinese and Indian institutions. As India and China increase their graduation rates, it appears that educational quality may actually be decreasing. The Chinese graduation numbers seem particularly suspect as it appears that their educational focus is quantity over quality.

While it is clear that China is significantly increasing the number of engineers and technology specialists it graduates, there appears to be a factory-like approach to turning out some graduates. Degree quality can't be maintained unless academic staff and facilities grow with student populations. One such example is China's technical school system, which is used to educate a portion of China's highly skilled technician population. Despite a 100% increase in technical school enrollment over the past five years (over one million students enrolled in 2004), China has been decreasing its total number of technical schools and their associated teachers and staff according to the Chinese Ministry of Education (MoE). From 1999 – 2004 the number of technical schools in China fell from 4,098 to 2,884; during that same period the number of teachers and staff at these institutions fell 24% (National Bureau of Statistics of China, 2005: Table 21-22). These statistics raise serious questions about the quality of upcoming Chinese technicians' degrees.

While technical schools are designed to provide students with industry-specific skill sets, institutions of higher education educate students in a variety of disciplines, including three- and four-year engineering offerings. The MoE claims that despite the last five years of significant increases in student populations, China's institutions of higher education enjoy a student to teacher ratio of just over 16:1. However, under closer inspection, the MoE acknowledges that full-time teacher numbers include teachers from other schools (National Bureau of Statistics of China, 2005: Table 21-32).

Conclusions and Future Research

Through our research, we have identified two main groups that engineering graduates tend to fall into: dynamic engineers and transactional engineers. Dynamic engineers are individuals capable of abstract thinking and high-level problem solving using scientific knowledge. In contrast, transactional engineers may possess engineering fundamentals, but not the experience or expertise to apply this knowledge to larger problems. We have found that most dynamic engineers are often absorbed by multinational engineering firms offering high paying jobs. Transactional engineers are at the greatest risk of losing their jobs to offshore entities that can perform engineering tasks both efficiently and remotely. Ultimately, it is important for a country to produce dynamic engineers who can both compete freely in the global economy and add enough value that their jobs are not easily outsourced.

High quality dynamic engineers will always be important for global competitiveness. To assess the impact and efficiency of these individuals, we plan to observe the operations of US-based and Chinese R&D facilities. R&D centers are likely to attract dynamic engineers who crave out-of-the-box problem solving and innovative solutions. However, there may also be significant variation in how R&D centers operate in the United States and China, even within the same multinational firm. Contrasting the methodology, training and activities of individuals at these facilities can greatly increase our knowledge of dynamic engineers and their contributions.

The engineering graduation statistics outlined in this report are one important aspect of global competitiveness issue; however they represent only a piece of the larger puzzle. A discussion of engineering graduation statistics naturally leads us to question whether the quality or quantity of engineering and science degrees are more important to a country's competitiveness. This is a difficult question to answer, and one that inherently is problematic to gauge in the form of national statistics or numerical values. To get closer to answering this question and learn more about the corporate rationale behind outsourcing, we have begun a survey project targeting major multinational companies involved in outsourcing practices or utilizing inexpensive overseas labor. Our survey targets corporate executives and HR representatives to learn more about these companies' hiring practices, outsourcing decisions and the competitiveness of engineering populations in different countries. We expect preliminary results of this survey to be available by the Fall of 2006.

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