2006-1844: ENGINEERING EDUCATION AND THE GLOBAL ECONOMY: THE SEARCH FOR POLICY

Richard Devon, Pennsylvania State University

Devon is Professor of Engineering Design and the Director of the Engineering Design Program in the School for Engineering Design, Technology, and Professional Programs at The Pennsylvania State University, where he has received several teaching awards. He has directed both the Pennsylvania Space Grant Program and the Science, Technology, and Society Program at Penn State. Devon currently focuses on design education, global programs, and design topics such as design ethics, innovative design, and conceptual design communications.

Elizabeth Kisenwether, Pennsylvania State University

Kisenwether is an electrical engineer with degrees from Penn State University, MIT, and Johns Hopkins University. She is an Assistant Professor and the Director of the Engineering Entrepreneurship Program with more than a decade in professional practice, including many years running a successful start up company, Paragon Technology. Kisenwether is the immediate Past-Chair of the rapidly growing Entrepreneurship Division of ASEE, and she is funded for educational research and development by both GE and the Kauffman Foundation.

Richard Schuhmann, Pennsylvania State University

Schuhmann is an Assistant Professor with more than 8 years of teaching experience including courses in environmental engineering, entrepreneurship, and leadership. He is the Director of the Engineering Leadership Program and an adjunct Assistant Professor in the Department of Civil and Environmental Engineering. Outside of the university, Schuhmann worked as a marine geophysicist, underwater archaeologist, and wooden boat builder before becoming an engineer; he now consults with citizens groups and law firms regarding environmental issues.

Robert Pangborn, Pennsylvania State University

Associate Dean for Undergraduate Studies and International Programs in the College of Engineering. Professor of Material Science. In February 2006, Dr Pangborn will become the Vice Provost for Undergraduate Programs for Penn State

Kim Barron, Pennsylvania State University

Kim Barron is a graduate student in Industrial Engineering at Penn State. Kim has a Bachelor's degree from Penn State in Industrial Engineering.

Engineering Education and the Global Economy: The Search for Policy

Abstract
Engineering education in the United States is confronted with some new realities, both real and perceived. Engineering is increasingly a globally distributed, cooperative activity and the US outsourcing of research, design, manufacturing, and construction overseas is growing. Further, the production of engineers in the United States is falling to around 5-6% of the global supply with clear signs that engineering education is available at lower costs, often far lower, in other countries. Many have viewed this globalization as a competitive situation for engineering education in the United States that we are losing.

We will present the view that in terms of the quality of engineering education (which engineering educators can influence) as opposed to the global economy (about which we can do little), engineering education is still very strong in the US and likely to remain that way. However, we will present some recommendations based on our professional responsibilities in running programs in entrepreneurship, leadership, and design. In particular, we will review survey data collected from Penn State engineering graduates over the last decade which helps define new paths for integrating entrepreneurship, leadership and design into the engineering curriculum. We believe that there are some very real ways in which engineering education can, and should be, responding to the new requirements for success in professional engineering careers that derive from national needs as well as from the globalization of engineering.

Introduction: Engineering Education in a Global Context[1]
There are many different views of globalization and its significance. 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.[2] This list, in turn, is an expansion of the "Seven Revolutions" previously presented by the Global Strategy Institute of the 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.[3] In their convincing representation, the world is changing rapidly and in many ways that can affect engineering and engineering education. However, naming fields like nanotechnology and biotechnology appears to name strengths not weaknesses of the U.S.

Nevertheless, there are signs that many in the engineering education community in the United States are becoming alarmed about the growing strengths of competitors in 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 need for U.S. engineers to focus on innovative and creative aspects of the profession to be globally competitive.[4] This concern is being taken further with the new NAE report *Rising Above the Gathering Storm*, [5] the name apparently being a reference to the 2002 movie about Churchill's prescience about the emerging war threat prior to World War II. ASEE and *Design News* have also raised the issue.[6] And "a new survey of more than 4000 engineers conducted by a Portland firm reveals that most are pessimistic about the future of their professions, the state of the nation's math and science education, and the ability of the US to retain its leadership in technology and innovation."[7] Although we will question this view, there are real reasons behind such attitudes such as "the increasing trend of sending software and electronic design work overseas, and declining performance in math and science by American students compared with peers abroad. Observers note that among other remedies, federal funding for research needs to be boosted if the US is to remain competitive in engineering and technology; it has dropped from 1.25% of GDP in 1985 to 0.78% in 2003." (*Ibid*)

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. Although half the graduates in China are engineers and scientists and China currently produces half of the world's engineers, or five times the number produced in the U.S., 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 U.S. engineers are paid approximately five times as much as engineers in China. Thus, the total 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 reason to study the relationship between the production of engineers and economic growth.[8] 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. This is because there is a very high level of economic cooperation between the U.S. and China (as well as with Japan and South Korea), both for importing inexpensive manufactured goods that lowers U.S. inflation, and for return flows of dollars that finance the U.S.'s federal deficit. U.S. corporations, like those of other countries, have also been quick to see value in investing in China's manufacturing base and pursuing opportunities in its domestic market.[9]

A further corrective to the alarmist view was recently published in a well researched report by Gereffi and Wadha at Duke University,

> "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. These massive numbers of Indian and Chinese engineering graduates include not only four-year degrees, but also three-year training programs and diploma holders. These numbers have been compared against the annual production of accredited four-year engineering degrees in the United States."[10]

Gereffi and Wadha recalculate the annual output for engineering degrees, including computer science and IT, to get a 2004 US figure of 137,437. The comparable 2004 figures for China and India are 351,537, and 112,000. (*Ibid,* p7) They note that the data imply that per every one million citizens, the United States is producing roughly 750 technology specialists, compared with 500 in China and 200 in India.

Another antidote to visions of a future with a million Chinese engineering graduates a year (*Design News,* 12/5/05), relates to quality. Few of China's engineering graduates are considered competitive in the global economy, and many have trouble finding engineering work. And the domination of engineering and science in higher education in China has led to serious shortages in other fields that is hurting economic growth. The McKinsey Global Institute (MGI) recently reported that "While university graduates are plentiful there, new MGI research shows that only a small proportion of them have the skills required for jobs further up the value chain—and competition for these graduates is becoming fierce. … [and] unless the country addresses its looming labor shortage now the global ambitions of Chinese companies will probably be stymied."[11]

Another counterpoint for policy makers in U.S engineering education to consider is the health of the pipeline for engineers in the United States. Our graduates are getting jobs and salaries are up, although some suggest that "the job market for most scientists and engineers in the U.S. has fallen short of the job market in [other] competitive high level occupations."[12] In the past, this availability of well-paid work has always driven the intake for engineering schools in the US. Recently there has been a weakening in the intake to many engineering schools due to a smaller demographic cohort and other factors, such as visa restrictions for international students. However, overall the trends and the signs are good, as "the proportion of the work force in engineering has trended upward, from 0.9% of the work force in 1950 to 1.8% in 2003.[13] Some argue that the weakening inflow of foreign students into U.S. universities may actually benefit U.S. graduates and firms as foreign educated engineers "remain overseas working with older or less productive technology".[14] We are less sure of that dynamic given the diffusion rates of new technology, and it is difficult to measure. Regardless, U.S. engineering graduates still most often find work in the U.S. in small and large companies alike and in the public sector from civil infrastructure to mission agencies like Defense and NASA.

We also have a glimpse of the global penetration in the workplace of our graduates. In a biennial survey of recent engineering graduates from Penn State reported below, we have found distinctly modest levels of importance in the respondents' work assigned to "Importance of Working on an International Project." Although this importance rating has been creeping up since the first survey of 1993 graduates, it is still below a 3 on a 5 point scale. Conversely, the respondents rated study abroad experiences highly (3.5 to 4.5) even if they did not have one, and most did not. So those surveyed have very positive attitudes towards engagement with the rest of the world, but they are not yet rating its significance to their work very highly. Both these findings would seem to challenge the view that our graduates are not ready for a global economy that is already here. The respondents, however, do show that they are increasingly *practicing* "engineering in a global context": from 11% ('93 cohort in '94) to 21% ('00 cohort in '01). So the globalizing trend is clear, if still at a modest level.

It would help if U.S. engineering students were better prepared in foreign languages. However, they are better off than Chinese graduates since English is becoming the lingua franca of professional and business communications. In fact, in a surveys of our undergraduates, we found around one sixth has a native tongue other than English, and at least another third of the students have had four or more years of foreign language in high school.[15] Thus, viewing our

Penn State engineering graduates as mono-lingual is inaccurate, and the provision of intensive mid-level language courses would go a long way to improve their preparedness.

An alternate and optimistic view of the above is that global competition will bring long overdue improvement in global equity among nations. However, somewhat ironically, it is widely believed that all nations are losing sovereignty to the global economy and the trade and multinationals that drive it. So, increasing global equity among nations is paralleled by the decreasing significance of nation states, e.g., the European Union. [16]

In summary, there may be no good support for the argument that engineering education in the U.S. is in any sort of crisis just because engineering education in Asia and the Pacific Rim is undergoing rapid growth. Engineering education is one of the strong factors in a U.S. economy that appears to have a number of real problems elsewhere, such as record trade and budget deficits. Nevertheless, we will propose some changes that can strengthen engineering education for both domestic and international careers.

Engineering Education: Policies that can Work

One of the reasons that engineering education is strong in the United States is its ability to continuously improve, with the impetus for change coming from ABET, IPAC committees and other sources of employers, and feedback from students and graduates. We will take this as our point of departure since, in one regard, there has been less improvement than there could be in some areas: such as professional skills in engineering design, entrepreneurship, and leadership. For example, engineering design skills are the cornerstone of how we define, develop and commercialize innovative products, processes and infrastructure solutions. It is very old news that engineering education has emulated science for the last half a century and neglected design and other practical, professional skills of value in the private and public sectors alike.[17] Most attempts to remedy this on a nationwide basis have been driven by ABET. Admirable as this may be, we will suggest that ABET-driven changes in design have been inadequate. Their approach to design is still very modest and they have yet to endorse the need for preparation for entrepreneurship and leadership in engineering. The oft-quoted eleven (a-k) ABET Criterion 3 objectives (9/2005) are laudable but do not define the specific skills they have in mind when they call for "an ability to…," do this or that.[18] Criterion 3 lists objectives that may be addressed in many different ways in engineering colleges, and this is a good thing, as we note later, that allows for diversity among universities and colleges, but it may dissipate ABET's influence. Further, only one of the eleven objectives is about design (design for everything), and leadership and entrepreneurship skills are not mentioned at all. This has become increasingly quetionable for an economy described for many years now as the innovation economy. Business Week has promoted this idea for the almost eight decades of its existence.[19]

Design, Entrepreneurship, and Leadership

The new School for Engineering Design, Technology, and Professional Programs (SEDTAPP) at Penn State has a unit (EDAPP) at its University Park campus that contains programs in entrepreneurship, leadership and design. These programs have evolved separately over the last decade, but from a common origin: to respond to the stated and perceived needs of the employers of our engineering graduates. These programs have also been organized, fortuitously, into the same unit, and they share the same mission to provide the professional skills that new engineers need to succeed and excel in industry the public sector, or private practice. There is much symbiosis among the three programs with shared teaching duties, meetings, funded projects, and daily interaction.

In the rest of the paper, we will,

1. Describe these programs in design, entrepreneurship, and leadership
2. Review studies that show why these programs represent important education for our engineering students for work in the national and global economies
3. Analyze the survey data that Penn State's College of Engineering has collected from its alumni for more than a decade. These data both address how the graduates value the education they received and what tasks they presently perform in their work.
4. Provide recommendations on how design, leadership and entrepreneurship education can help address the stated differences that graduates report in what they perceive are critical skills and how well prepared they were for the workplace

PSEAS DATA

The Penn State Engineering Alumni Survey (PSEAS) is a survey of approximately the most recent two years of graduates that is carried out every two years. The first reported cohort is 1993. The response rate has been around 15-21% for cohorts that are approximately 1,000-1200 in size. We will report on data for up to the 2000 cohort and, in some cases, up to the 2002 cohort. The data provide useful insights into what the graduates are doing and they also rate the importance of various skills for their present work and how well they feel they were prepared for it. These feedback data allow us an opportunity to close the loop between undergraduate preparation and workplace performance to improve engineering education.

Another, of many, data sets in the PSEAS surveys ask about tasks typically performed in their work. These too will be reported since they may be even more relevant to redesigning engineering education as they involve self reported behavior rather than perception. These are discussed within the design section where they seemed to particularly relevant.

In examining these data we found that many skill sets were important in all three programs: design, entrepreneurship and leadership. **Table A** lists responses to perception of preparedness and importance for six skills: Listening to Others, Managing a Project, Dealing with Conflicts, Importance of Managing People, and Teaching Self New Skills. In Table A, preparation in these skills is perceived to be significantly below importance, and importance is high (>3.8 on a scale of 5). Therefore, Table A lists the important skills in which new graduates feel they are under prepared. Table A also shows some good news, such as new graduates perceiving that they are better prepared in four of the six skill areas listed (measured between 1993 and 2002). However, this is effectively the bad report card table: new graduates see themselves poorly prepared in 2002 in these five skill areas.

These are six important skills for leadership, design, and entrepreneurship. The first five in particular are addressed in all three programs. We do not yet see a strong impact, but there upward trends for 4/6 skills. Our programs are new and would not affect most of the cohorts. Data for later cohorts may tell us more, but we will address these areas with a systematic effort.

Table A: Perception of the Preparation for, and Importance of, Professional Skills - 1
Skills where preparedness is perceived to be below importance, but importance is high (≥3.8/5.0 in 2002) and the gap between importance and preparation is ≥0.6.

	Importance in 1993 / 2002	Preparedness in 1993 / 2002	2002 Difference between Prep. & Imp.	Trend in Importance (1993→ 2002)	Trend in Preparation (1993 → 2002)
Listening to Others	4.3 / 4.4	3.2 / 3.6	**0.7**	⟺	⇧
Managing a Project	4.3 / 4.3	3.1 / 3.4	**0.9**	⟺	⇧
Dealing with Conflicts	4.2 / 4.1	2.6 / 3.0	**1.1**	⟺	⇧
Managing People	4.0 / 3.9	2.5 / 2.8	**1.1**	⟺	⇧
Solving Ambiguous Problems	4.0 / 3.9	3.1 / 3.3	**0.6**	⟺	⟺
Teaching Self New Skills	4.3 / 4.3	3.7 / 3.7	**0.6**	⟺	⟺

⟺ Indicates < |0.3| variation in perceived value over the 1993-2002 period

⇧ Indicates > 0.3 increase in perceived value over the 1993-2002 period

Students in entrepreneurship courses and the E-SHIP Minor develop these six skills across time in team projects, developing new products/ventures to meet market needs, and developing complete business plans as a team. In addition, the core courses in the E-SHIP Minor have a problem-based learning foundation, incorporating activities and tasks to target these areas of skill deficiency. This is one program where we can do studies of learning these six skills areas.

Table B: Perception of the Preparation for and Importance of Professional Skills - 2
Skills where preparedness is perceived = importance, and importance is high (≥3.8/5.0 in 2002).

	Importance in 1993 / 2002	Preparedness in 1993 / 2002	2002 Difference between Prep. and Imp.	Trend in Importance (1993→ 2002)	Trend in Preparation (1993 → 2002)
Applying Engineering Skills	3.9 / 3.9	3.8 / 4.0	**0.1**	⟺	⇧
Making Oral Presentations	3.9 / 3.8	3.3 / 3.7	**0.1**	⟺	⇧

⟺ Indicates < |0.3| variation in perceived value over the 1993-2002 period

⇧ Indicates > 0.3 increase in perceived value over the 1993-2002 period

Table B lists responses to perception of preparedness and importance for two skills: Applying Engineering Skills and Making Oral Presentations. In Table B, preparation in these skills is perceived equal to importance, and importance is high (>3.8 on a scale of 5, for data in 2002). Therefore, Table B lists the skills that new graduates feel their level of preparation is appropriate or adequate.

Finally, **Table C** lists responses to perception of preparedness and importance for five skills: Applying Engineering Skills and Making Oral Presentations. In Table C, preparation in these skills is perceived to be higher than importance. Therefore, Table C lists the skills that new graduates feel they are over prepared in and the importance is relatively low compared to the skills listed in Tables A and B.

Two observations can be made from Table C. First, the topic identified by graduates as being the most over-prepared is Using General Education Course Materials (AHS). However, some of the skills that the graduates identified as being under-prepared in Table A are those skills that should be covered in the General Education Courses. Further, they are more likely to gain value from these courses as they advance in their careers. The other four skills in Table C are of higher importance particularly in graduate school, where these fundamental skills are key to graduate school success. If we break the data down, we may find that those who are in graduate school may rate these higher while those in the workforce may rate them even lower. And later in their career they may view these general education skills differently as they rise into management positions and have more relationships with non-engineers and may find more uses for their liberal arts knowledge.

Table C: Perception of the Preparation for and Importance of Professional Skills - 3
Skills where preparedness is perceived to be greater than importance, with importance being rated lower than for skills in Tables A and B.

	Importance in 1993 / 2002	Preparedness in 1993 / 2002	Difference between Importance and Preparedness in 2002	Trend in Importance (1993→ 2002)	Trend in Preparation (1993 → 2002)
Applying Mathematics	3.5 / 3.4	4.1 / 4.1	**- 0.7**	⟺	⟺
Applying Science	3.4 / 3.2	3.6 / 3.6	**- 0.4**	⟺	⟺
Experimental Data Analysis	2.9 / 3.0	3.4 / 3.5	**- 0.5**	⟺	⟺
Using General Ed. Course Material(AHS)	2.6 / 2.5	3.1 / 3.3	**- 0.8**	⟺	⟺
Designing Lab Experiments	2.2 / 2.4	3.0 / 3.0	**- 0.6**	⟺	⟺

⟺ Indicates < |0.3| variation in perceived value over the 1993-2002 period

The Engineering Design Program

The Engineering Design Program (EDP) at Penn State has grown out of a general skills program focused on CAD and graphics. http://cede.psu.edu/ed/ Its central mission is education and research in integrated engineering design: that process which integrates the disciplines and people required to address a specific design problem, be it a product, system, process, or service. Design skills cut across all engineering fields and are foundational for traditional discipline-based design such as machine design or the design of steel structures. The EDP uses the new approach to design that has grown rapidly over the last 2-3 decades with many books and research journals based on this multi-disciplinary concept that recognizes design as a social process that includes many disciplines and people. At present, the EDP offers the first-year engineering design course (required for all but one engineering major), senior and masters' level courses, and it plans undergraduate and graduate minors and a masters' degree in the near future. It has developed concentrations in innovative design, systems design, global design, design cognition (decision making), eco-design, and service design. It collaborates with the entrepreneurship program with a product design and development course and the provision of mentors for "E-teams." Its first-year course, which has industry sponsored design projects and is taken by ~1100 students a year at the University Park campus alone, has received national recognition (Boeing Award, 1998).

The EDP has responded to the globalization of the economy for since the mid-1990s with global internships, cross national design teams using information technology and industry tours (in France). It has placed almost 150 students in global internships, over 300 have participated in cross national teams using IT, and 80 have gone on industry and cultural tours in France. It also took the U.S. lead in 2002 in establishing a consortium of seven universities in four countries for design education, Prestige (Preparing Students to Work in the Global Economy).[20]

Particularly in the EU and Asia, but also in the U.S., we see an increasing recognition that there has been an underinvestment in design education, and, in design education the US trails countries like the UK, the Netherlands, and several Scandinavian countries.[21] And new masters in engineering design programs are appearing in India and Singapore and doing well.[22] Conversely, entrepreneurship in engineering education has appeared first in the US and is being emulated elsewhere as it continues to grow strongly. For example, the Stanford University Roundtable on Entrepreneurship Education (REE) [see http://ree.stanford.edu] has been conducted in the U.S. each year since 2000, but has grown gradually over the last two years to now also have events in Europe, Asia and South America on a yearly basis.

PSEAS DATA

The PSEAS survey asked respondents to rate the importance in their work and how good the preparation was for "Designing Components" and "Designing Processes." The importance for designing a component was rated a little above 3 and designing a process was rated a little above 3.5 on a 1-5 scale. Preparation was rated similarly and the trends appear to rise for all data except for the 2002 data, which showed declining numbers. However, these fairly modest numbers assessing design importance and design education based on the perceptions of the respondents were not confirmed by the data for self reported behaviors

When asked what their typical tasks were, design and design type tasks not only appeared with high frequency but the trends are rising strongly. These data are for cohorts 1993-2000.

1. Work in teams: 83% ('93) to 98% ('00)
2. Test products or product components: 29% ('93) to 52% ('00)
3. Solve problems: 85% ('93) to 98% ('00)
4. Modeling and simulation 22% ('93) to 42% ('00)
5. Ensure compliance with codes and standards: 53% ('93) to 69% ('00)
6. Design products or product components: 22% ('93) to 52% ('00)
7. Computer-aided design: 37% ('93) to 47% ('00)

Thus almost all the respondents now work in teams and solve problems, and a half or more of the 2000 cohort respondents report that they design and test components and products, and ensure compliance with codes and standards. We do not know what the percentage is of the 2000 cohort respondents who do at least one of these tasks typically, but it appears it must be at least three-fourths. These findings are quite dramatic and the trends are rising. Perhaps the relatively modest rating of the importance of design has to do with respondents being unaware of how much knowledge of design methods they could have. There may be a "taken for granted" quality to their responses, but we do not know and need to do further research.

The Economics of Design Education

Design and innovation skills appear to improve professional productivity, and this idea certainly follows from the previous discussion of the PSEAS data. 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. [23] 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.[24] In addition, cross-national studies show a very high correlation between patents per million and a nation's standard of living.[25] Implicit in these figures is the importance of innovative design and this is one area where the design and entrepreneurship programs collaborate.

If one accepts the significance of design as an economic driver, then it may be that our engineering curricula are typically not giving it enough space in the curriculum. U.S. schools of engineering (particularly large engineering schools) generally teach one design course in the first two years to help students feel good about engineering (i.e., as a retention measure) and one capstone design course in the last year—often unrelated to the first design course—to prepare the students for professional work. Both are typically based on experiential learning with a single project absorbing much of the curricular time available. This reliance on an outdated industry model of how design ability is developed, as opposed to a productive blend of knowledge and experience, looks increasingly anomalous as texts and research journals in design proliferate.[26] In total, this means only 5–7% of curricular time in a typical U.S. engineering degree is devoted to design and even specializing in design is not usually an option that is easy to pursue.[27] We appear, then, to be under-investing in design education.

Engineering Entrepreneurship (E-SHIP) Program

Starting with a grant from the GE Fund (2000-2003), the College of Engineering made the decision to add problem-based learning courses, activities and an academic minor in engineering entrepreneurship. The 18 credit Engineering Entrepreneurship (E-SHIP) minor (http://e-ship.psu.edu) is based in the College of Engineering, designed to serve students from engineering, business, information science and technology (IST), but is open to students from any major. The goal of the minor is to aid students in developing the skills and knowledge to either be an entrepreneur, or an entrepreneurial employee in an existing company. Courses and extra-curricular activities help develop skills, aptitudes and knowledge to enable them to be innovative leaders in existing companies, new start-up companies or to lead new strategic alliance between companies. The goals/objectives to be assessed for the E-SHIP minor were phrased as questions in a recent assessment of the program:[28]

1. How does the minor affect students' motivation and self-efficacy?

2. Are these students more successful in tackling ambiguous problems and thinking innovatively?

3. Are these students more likely to see the connections to aspects of problems outside those related to their individual discipline, especially relating to business and finance?

4. Do these students exhibit better communication, leadership, and teamwork skills?

This study[28] of existing student attitudes found:

- While there were statistical trends that the students in the minor had a higher self-efficacy, no definitive statements could be made regarding this difficult to measure characteristic. Therefore, the notion of self-efficacy and empowerment was further explored with the focus groups. Many students overwhelmingly emphasized the affects of the minor on their self-confidence to become an entrepreneur.

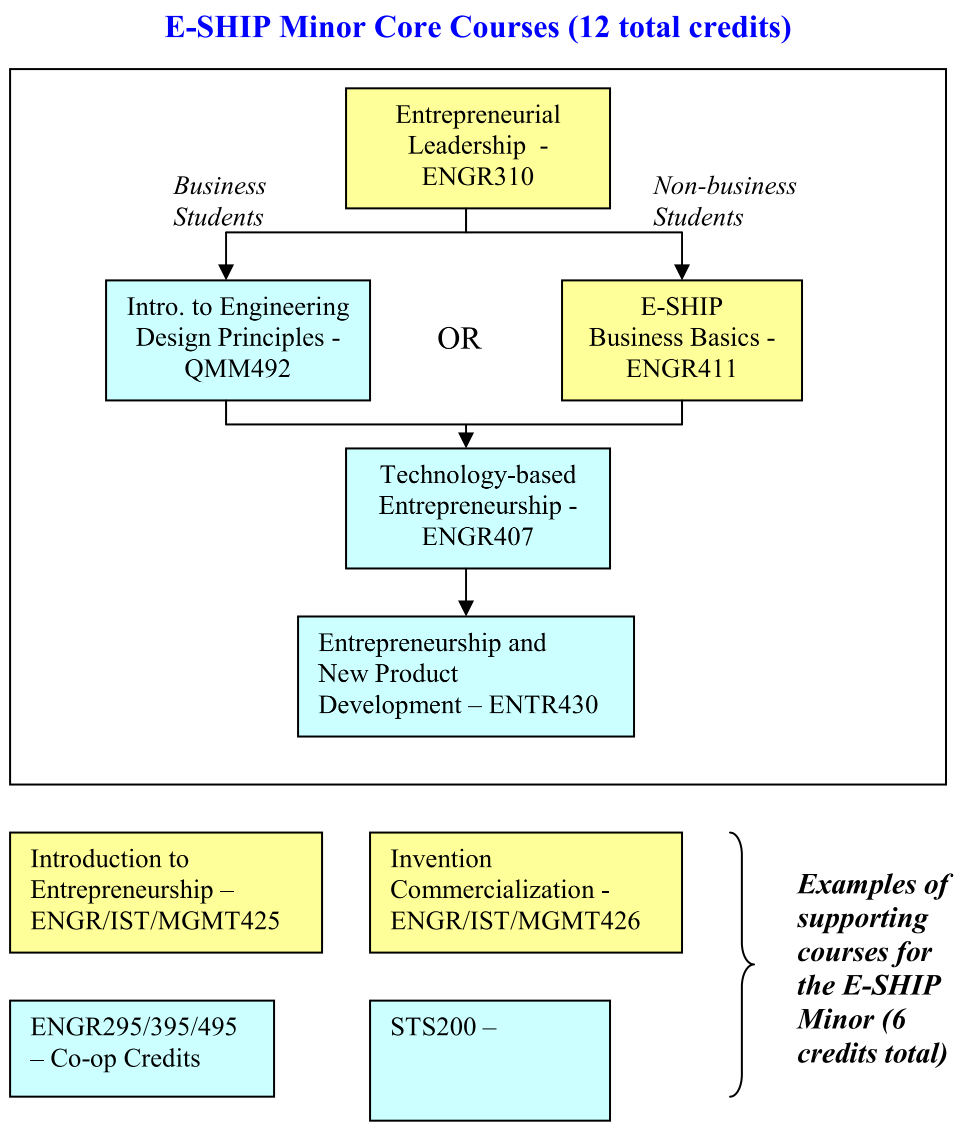
- The students' perception of their ability to generate ideas was significantly different for the pre- and post-test.

- Focus group information supported the improvement of students' self-efficacy to become entrepreneurs. For example, students in the ENGR407 class mentioned that they felt "empowered" to become an entrepreneurs.

Because the minor is cross-disciplinary, students work on diverse teams, where diversity is by major, backgrounds, personalities, and priorities. To help students work across "degree differences," the E-SHIP minor has a unique cross-skills segment.

- Engineering (and other non-business) majors are required to complete a business fundamentals course called *ENGR411 – Entrepreneurship Business Basics*. In a 15-week semester, students develop their business acumen in finance and accounting, marketing, and intellectual property management.

- Business students are required to complete *QMM492 – Introduction to Engineering Design Process,* where business students complete two design projects and learn computer-aided design (SolidWorks).



Key: yellow = new entrepreneurship courses created since 2001
blue = courses existing prior to 2001

Figure 1: E-SHIP Minor structure to ensure cross-skill development for all students

Figure 1 shows the suggested core course sequence, as well as two new courses that many students use to complete the supporting course credit requirement: *Introduction to Entrepreneurship* and *Invention Commercialization*. These courses are milestones at Penn State: they will be the first courses which are cross listed between three colleges: business, engineering and information sciences and technology (IST).

Assessment
In the *Introduction to Entrepreneurship* course, another assessment collected data on student change in self-efficacy, leadership, tolerance for ambiguity.[29] These data produced strong student endorsements of the course:

- 95.7 % strongly agreed or agreed that "the course helped me to understand entrepreneurship"

- 90.1% strongly agreed or agreed that "the course is useful"

- 94.4 % strongly agreed or agreed that "the course is a good way to learn entrepreneurship"

- 88.7% strongly agreed or agreed that they "would recommend the course"

We believe that students can develop baseline entrepreneurship skills and attitudes in the university setting, which will allow them to be role-players in the highly dynamic new economy.

The Importance of Entrepreneurship Education Penn State made the decision to establish the engineering entrepreneurship minor for two reasons. First, to keep the United States competitive in the global economy, engineering students need to see themselves as able to create a job, not just get a job. Innovation is key to the success of American products and services around the world,[30] engineers are as innovation implementers need business acumen with the entrepreneurial mind-set. Second, engineering students are fundamentally bright, and many are also highly creative. The standard engineering education, however, is very structured and does not nurture creativity. The E-SHIP Minor is structured to re-ignite creativity that many students have not used in years. Students find the E-SHIP minor courses refreshing and empowering when they realize they have something more than strong technical skills, and that looking for, and realizing, opportunities is as important as looking at problems. Success stories out of the entrepreneurship program include a patented product-focused company (Diamondback Truck covers: www.diamondbackcovers.com) and a web-based company which is using a franchise model for expansion (www.lionmenus.com). In addition, entrepreneurship is growing across Penn State, as shown by the new web site providing university-wide entrepreneurship resources and contacts: http://www.entrepreneurship.psu.edu.

Engineering Leadership Program (ELP)

The Engineering Leadership Program (ELP) at Penn State (http://www.eldm.psu.edu) was launched in 1995 as an initiative of the Leonhard Center for the Enhancement of Engineering Education (http://www.engr.psu.edu/LeonhardCenter/eec/lc/). The ELP embraces the aspirations of the National Academy of Engineering (NAE) especially with respect to developing in students an enhanced technical creativity, an understanding of the importance of sustainability in design, the ability and desire to assume influential leadership positions, and the ability to recognize and adapt to a rapidly changing world.[31]

The ELP offers students across Penn State University the opportunity to earn a minor in Engineering Leadership Development (ELD). There are 120 students currently enrolled in the ELD minor, making it one of the largest minors in the College of Engineering. The ELD minor is composed of 18 credits, 12 credits of which are core required courses including: ENGR 408 - Leadership principles, ENGR 407 - Technology based entrepreneurship, ENGR 409 - Organizational leadership, and an integrating capstone experience ("Creativity innovation and change") where students are tasked to bring their discipline specific and leadership skills to bear in order to affect an innovative positive societal change. The perception that engineers are reticent to engage their skills in human-centered issues, because these issues "tend to be gray and vague, not objective," is regularly shattered by students in the ELP.[32] Students satisfy the remaining 6 credits of the minor with supporting courses that range alphabetically from African and African American Studies (AAA S) through Women's Studies (WMNST).

The Importance of Leadership Education

The ELD minor allows students to supplement their major field of study and enhance their education with the 'communication, project management, and leadership skills' necessary for success in the global economy of the 21st century.[33] Students from the ELD program report enhanced interest by recruiters and are regularly surprised by the extensive amount of time allocated in interviews to discussion of the ELD minor vs. the time allotted to their discipline-specific degree. Graduates of the ELD program are sought after and placed with top industries, often on a management fast-track in corporate leadership training programs.

PSEAS Data

Survey data from the Penn State College of Engineering (COE) indicate a dramatic increase in COE alumni perception of the importance of the ELD minor; in the year 2000, alumni reported that on a scale of 1-5 (with 1 being the least important and 5 the most important), the importance of the ELD minor to their job was ~2.8, in 2001 this figure had jumped to ~4.25, and in 2002 increased to ~4.7 which exceeded the perceived importance of an engineering co-op experience for that survey year (~4.4). This trend is very encouraging.

Globalizing Leadership Education

According to the UN, "by 2015, 80 percent of the money spent for infrastructure construction will be spent in developing countries."[34] These countries will require significant technical leadership for the construction of this proliferation of infrastructure, and U.S. engineering graduates with leadership training and skills, especially those with international savvy and experience, are essential if the United States is to maintain its global leadership position in engineering. This need in engineering undergraduates is not specific to civil engineering and crosses departmental and college boundaries. Even engineers who will never leave the United States during their careers benefit from an enhanced contemporaneous and projective world view as nations and economies become more connected.

Recently, the ELD program, in conjunction with the E-Ship program, initiated an effort designed to internationalize the curricula. A pilot class in International Entrepreneurship was offered for the first time in spring 2005, and currently (spring 2006) the programs are offering a course in International Entrepreneurship and Organizational Leadership. Both the pilot course in 2005 and the current offering involve students working through the spring semester in non-isotopic, multicultural, interdisciplinary teams with economics students from Corvinus University in Budapest, Hungary with students traveling to Budapest for a follow-up 1-week on-site collaboration with their counterparts at Corvinus University in the first summer session. Demand for the class has doubled from 2005 to 2006 and is at its capacity (*i.e.* filled with 16 students). Some comments from students in the 2005 class include:

> "This class taught me about one of the most important parts of business relations—communication. Even if you don't have a common language, communication is possible and is completely necessary to get things done and done properly."
>
> "I have learned a lot about the Hungarian culture and lifestyle. It was an unforgettable experience. I built a concept of what it is required to start a business. I understand how to find the needs of a foreign economy."
>
> "This class made me start thinking about how commerce works and how business in different societies and regions of the world all are in different stages and work differently."

As noted earlier, the PSEAS survey data indicate that after years of declining perceived importance, there has been an increase in the last several years in the alumni perception of the importance of a study abroad experience; at its nadir in the year 2000, alumni reported that the importance of a study abroad experience to their job was ~2.4, and by 2002 this figure had leapt to its highest point in a decade, ~4.40. Within the same time period, the perceived importance of work or an internship abroad jumped from ~2.3 to ~4.75.

While the reported importance to ones job of a study or work or internship abroad experience has increased, the participation rate has remained consistently below 10% over the last decade. In the last (2004-2005) academic year, only 105 College of Engineering students (approximately 1.5%) participated in an international program. In 2005-2006, the nascent ELP-E-Ship international program will be one of the three largest study abroad groups in the College.

Engineering students find it difficult to make equivalent progress towards their degrees in semester-long internship or study abroad programs and this may be a causative factor in the low participation rate among undergraduates, along with the cost of the programs. Thus, as with the industry tour in the EDP, we find short 2-3 week international programs attractive because of the low cost, the high impact, and the minimal disruption on the path to graduation. An integral part of the ELP mission is to promote a robust contemporaneous and projective world-view in students and user-friendly international programs are a significant part of this effort.

With respect to leadership education and internationalization, the ELP curriculum appears to be on target with alumni perceptions and the program will continue to build upon and refine its mission to educate World Class Engineers. Students will be taught leadership in a global context so that they are sensitive to cultural differences and aware of the world and that people and nations are interconnected; as part of this effort, additional short-term international experiences will continue to be built for our students. The program will continue to encourage students to be passionate in their belief that the creative use of their engineering skills can improve lives by providing them with hands-on domestic and international service leadership opportunities. Finally, students will be presented business principles framed through the lens of sustainability so that business viability and success is placed firmly in an environmental and ethical context (http://www.sustainability-indexes.com). Focusing on these elements enhances engineering education within the College and helps prepare our students for success in their professional careers, whether those careers are centered domestically or internationally.

Conclusion

Although funded more heavily than their European counterparts (*Economist*, 9/23/04, "Battling for Brains; The parlous state of European universities") the strength of higher education in the United States lies primarily with its autonomy from central governmental planning while at the same time having a strong academic administration, and through competition between universities which ensures continued innovation within the curriculum (*Economist*, The World in 2006, "The class of 2006; Why American universities will lead the world"). European universities and their Asian offspring tend towards a more standardized monolithic model with centralized control. While standardization may be appealing to some here in the United States (*New York Times*, 2/9/06, "Panel explores standardized tests for colleges"), it begs the question as to whether our primary academic strength should be mortgaged in response to a desire by some for "McDegrees." Moving in this direction would reduce our educational and innovative edge and move towards parity with our international counterparts.

We believe that engineering education in the United States is strong and not facing any crisis due to the emerging strength of the global economy, although the US economy itself may be. Nevertheless, we recommend that engineering education policies in the United States should emphasize the professional skills of design, entrepreneurship, and leadership much more than they do at present. As this occurs, developing innovative educational programs in these areas that are fully cognizant of the needs and changes in both the domestic and the global economy makes sense. These programs are also well suited for including adaptations in the engineering curriculum to the effects of the global economy on engineering careers, and we do see the need even if we think it has been overplayed by some.

References

[1] Some of the text here first appeared in, Richard F. Devon, Sven G. Bilén, and Javier Sánchez Sierra, and Peter Olfs, "Teaching global engineering design," *15th International Conference on Engineering Design*, Melbourne, Australia, 14–18 August 2005.

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

[3] Peterson, E.R., "Seven Revolutions: Looking out to the year 2025 and the major forces shaping the world," available at http://www.csis.org/7revs/index.htm.

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

[5] *Rising Above The Gathering Storm: Energizing and Employing America for a Brighter Economic Future.* The National Academies Press, 2006.

[6] http://www.designnews.com/article/CA6286283.html

[7] http://www.bizjournals.com/portland

[8] "An emerging and critical problem of the science and engineering labor force: A companion to Science and Engineering Indicators 2004," National Science Board, 2004, available at http://www.nsf.gov/sbe/srs/nsb0407/start.htm.

[9] Yougang Chen and Jacques Penhirin. Marketing to China's consumers. *McKinsey Quarterly*, Special Edition, 2004. http://www.mckinseyquarterly.com/article_page.aspx?ar=1472&L2=16&L3=14

[10] Gereffi, Gary, and Vivek Wadwa. *Framing the Engineering Outsourcing Debate: Placing the United States on a Level Playing Field with China and India*. Duke University, Master of Engineering Management Program, December, 2005. P2.

[11] Diana Farrell and Andrew J. Grant. "China's Looming Talent" Shortage *McKinsey Quarterly*, Number 4, 2005.

[12] Freeman, R.B., *Does Globalization of the Scientific/Engineering Workforce Threaten U.S. Economic Leadership?* National Bureau of Economic Research, June 2005.

[13] U.S. Bureau of the Census Statistical Abstract, 2004, table 597 and U.S. Statistical Abstract, 1953, table 224.

[14] Freeman, op. cit.

[15] Devon, Richard, Kristine Lalley, Kim Barron, & Robert Pangborn. "Going Global: The Foreign Language Capacities and Global Interests of Engineering Students." *International Journal of Modern Engineering*, Volume 5, Number 2, Spring 2005

[16] Guehenno, Jean Marie. *The End of the Nation State.* Univ of Minn Press. 1995.

[17] "Are Engineers Losing Control of Technology? From 'Problem Solving' to 'Problem Definition and Solution'." Engineering Education, Trans IChemE, Part A, *Chemical Engineering Research and Design*, 2005, 83(A6): 583-595.

[18] Accreditation Board for Engineering and Technology (ABET). http://www.abet.org/forms.shtml

[19] The Innovation Economy: Photo Essay: 75 Years in Covers. *BusinessWeek Online*, October 11, 2004

[20] Richard Devon, Alan de Pennington, and Alison McKay. "A Consortium for Global Engineering Design." J*ournal of Engineering Design and Innovation.* Volume 1E, 2005.

[21] 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.

[22] Personal communication. Design Technology Institute, National University of Singapore, and the Centre for Product Design and Manufacturing, Indian Institute of Science, Bangalore.

[23] Design Council, "The Impact of Design on Stock Market Performance: An Analysis of UK Quoted Companies 1994–2003," February 2004, available at http://www.designcouncil.org.uk/resources/assets/assets/pdf/Research/Impact%20of%20Design%20on%20Stock%20Market%20Performance%20February%202004.pdf . Also go to http://www.designcouncil.org.uk/ and see their report on 1500 companies in Design In Britain 2004–5.

[24] Schwartz, E.I. "Sparking the Fire of Invention," *Technology Review.com*, May 2004.

[25] "Global Invention Map," *Technology Review.com*, May 2004.

[26] See Devon et al. Ref. 21

[27] See Devon et al. Ref. 21

[28] Bilén, S.G., Kisenwether, E.C., Rzasa, S.E., and Wise, J.C., "Developing and Assessing Students' Entrepreneurial Skill and Mind-Set," *Journal of Engineering Education*, Vol. 94, No. 2, 2005, pp. 233-243.

[29] Hanke, R., Kisenwether, E.C. and Warren, A.. "A Scalable and Adaptable Problem-based Learning Course in Entrepreneurship"; *2005 National Collegiate Inventors and Innovators Alliance (NCIIA) National Conference proceedings*, San Diego, March 2005.

[30] National Innovation Initiative - Interim Report: *Innovate America*, July 23, 2004. Council on Competitiveness, http://www.compete.org/nii/interim.asp

[31] *The Engineer of 2020*, National Academy of Engineering, Washington, DC, 2004

[32] Bonasso, S.G., "Engineering, Leadership, and Integral Philosophy", *Journal of Professional Issues in Engineering Education and Practice*, January 2001, pp. 17-25.

[33] Brown, J.L., "Wanted: Civil Engineers", *Civil Engineering*, July, 2005, pp. 46-49.

[34] ASCE Inaugural Address, William P. Henry, P.E., F.ASCE, October 23, 2004, Baltimore, Maryland.