Experiences and Observations In Introducing Students To Design and Manufacturing Globalization

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ABSTRACT

During the spring of 2004 a new graduate course was offered at Brigham Young University with the objective of introducing engineering students to design and manufacturing issues associated with global product realization. Learning activities in the course included a study of relevant literature, case studies on globalization issues, team projects, and exercises. The course was culminated with three weeks of visits to design and manufacturing enterprises involved in globalization in the United States, Japan and China. This course was again offered during the spring of 2005. This paper presents some of the motivation for developing the course and our experiences and observations in conducting the course.

INTRODUCTION

During World War II, the United States became the "arsenal of democracy" by designing and manufacturing war materials on an enormous scale. While Europe and Asia's industrial base were largely destroyed during the war, the United States went on afterwards to increase its capability even further in scientific research, product design, development, and manufacturing. Also after the war, the United States helped Europe and Japan rebuild their industrial base through U.S. government intervention and American know how.

One example of American help to the Japanese was Deming's quality ideas requested by General MacArthur, which when integrated with Japanese systems thinking and attention to detail, created highly automated manufacturing processes that became an art form and the envy of the world. While strong U.S. educational programs in engineering, science and business catalyzed innovation as a dominant factor of the U.S. economy, Japan eventually gained a

leadership role in the production of high quality products often invented in the U.S.[1] In today's world, however, "China is making a bold bid to become world class in everything from biology to semiconductor R&D. Indeed, it plans to produce 350,000 newly minted engineers annually, compared to the 100,000 who graduate each year in the U.S."[2]

While the 12 trillion dollar U.S. economy continues to expand at about 3% a year—which still includes the largest manufacturing sector in the world, other countries want more of the action and are working hard to gain it. This year the U.S. will probably exceed a 700 billion dollar balance of trade deficit, largely due to the importation of products manufactured in Asia. While this amounts to only about 5 or 6 percent of the U.S. Gross Domestic Product (GDP), the percentage is growing. While Japan continues in a somewhat stagnant economy, China's GDP growth rate is now about 9 to 10% a year.

All of what is happening has some consequences—not all of which are clear. Nevertheless, high quality, low cost, goods have never been so readily available in the U.S. More ideas and inventions, and even new technologies, are springing up on foreign soil and some traditional U.S manufacturing jobs are shifting overseas.[3] In addition, the U.S.'s growing balance of trade deficit and deficit government spending has put pressure on reducing the value of the dollar overseas. This in turn has reduced the cost of U.S. goods overseas and increased U.S. exports to some extent.

In spite of the reduction in the value of the dollar, most industrialized nations still prefer holding dollars and investments that will make even more dollars. America is seen as having a very large and stable economy and a stable form of government compared with other nations and investing in America is considered good business. China, for example, is now purchasing about 20% of newly issued U.S. Treasury Bills each month with dollars they earned from the sale of Chinese manufactured goods sold in the U.S. China is not just selling their goods in the U.S., they are becoming a "partner" in our economic machine by investing in U.S. government issued securities.

In addition, many U.S. companies are investing in the Chinese economic machine, not just because good quality products can be produced there (sometimes with great effort)[4], but because of the tremendous market expansion possible in China. China has between 1.3 and 1.4 billion people—about five times the market size available in the U.S.—largely untapped for manufactured goods and services. Indeed, some U.S. companies see China, in particular, as the place where their enterprises can flourish and grow in the future.

WHAT ARE SOME IMPLICATIONS FOR AMERICAN ENGINEERING EDUCATION?

Some have argued that no matter what happens globally, teaching the fundamentals in engineering education is what is really most important—but what really *are* the fundamentals in today's environment? Engineering students interested in product design, development and manufacturing are facing a drastically changing world. The President of ASEE recently stated, "Outsourcing is affecting engineering and all the facets that encompass engineering, including research, design, marketing and service. …This is a major revolution in engineering education. We must internationalize our curriculum, to include not only the study of mathematics and the sciences but intercultural interaction as well. We must mold our students to be entrepreneurs, and spirited international adventurers as well."[5]

Not only do these changes mean the curriculum should be broadened to include an international focus, but the role of engineering is changing such that American engineers need to move "higher up" the innovation curve.[6] "From 2000 to 2003, many product design jobs disappeared and went overseas. Recently, some designers have taken the values and skills honed over decades of developing products and applied them to creating new information, services and experiences for just about everything associated with "things" that are often now produced in China and other parts of Asia." "Cell phones are made overseas, but the graphics, packaging, ads—the products' personality—are being designed by U.S. outfits. It appears that the design profession is starting to shift its core competencies from drawing to thinking, from styling to innovating, from shaping things to visualizing new business paradigms." [7]

Might this also be an important paradigm shift for a least a portion of the engineering

curriculum in the U.S. to consider? Many U.S. manufacturing firms are expanding overseas and want engineers that understand how to deal with different cultures, languages and methods so that they can partner and bring best practices to overseas design and manufacturing efforts.

The initiation of ABET's 2000 accreditation criteria was intended to foster innovation in engineering education and with globalization, innovation appears—even more, to be a necessity. Because U.S. and others companies, are investing more overseas and partnering in products manufactured out of the U.S., engineering students knowledgeable about how to make this happen are in demand. Some see what is happening as an opportunity to innovate and improve—something the U.S. traditionally has been very good at. No doubt, there are tremendous challenges ahead but with challenges come opportunities.

BYU'S GLOBAL PRODUCT DEVELOPMENT COURSE

BYU's new Global Product Development course is intended to expose engineering students to globally-influenced product development organizations in an effort to help students become leaders in their professions. The course is designed using a seminar paradigm for graduate students and/or students just completing their undergraduate curriculum. The course includes travel study to a number of product design and/or manufacturing enterprises as well as other learning activities.

Included are a series of six one hour seminars with experts in the field held near the end of the winter semester prior to the spring term, two weeks of classroom and group study experiences at BYU during the spring term, and a 15 day trip to domestic and overseas sites during the spring term. The seminars included speakers and discussions on Japanese and Chinese culture, global economics, political issues, design and manufacturing method paradigms, and the sharing of experiences by engineers having worked in joint ventures with Asian companies. The travel study visits, are designed to give students first-hand exposure to global product development issues faced by engineers and managers involved with these issues in the actual settings in which they occur.

In developing our class we identified a number of possible course objectives. Because of the special nature of the class, we realized that the objectives for individual students taking the class could vary widely. Some objectives noted in our syllabus for the course have included the following[8]:

- Understand issues associated with a global product development environment, including developing product needs in unfamiliar cultures, design for adaptability, managing distributed design teams and manufacturing at remote and/or distributed sites. Appreciate first-hand how successful global product development companies approach these issues
- Understand design strategies associated with concept selection, product architecture, economic modeling, prototyping and developing manufacturing systems for product development in a global environment
- Appreciate the challenges in managing product development issues across different countries, cultures and languages, and apply appropriate tools and processes to address these challenges
- Understand why outsourcing is such a big deal with U.S. companies
- Gain a greater appreciation for other cultures involved in the business (product development) value chain
- Understand how globalization affects me as an engineer
- Understand the design and manufacturing capabilities of other countries and how to leverage (work with, deal with, and manage) these capabilities in a cross cultural team environment
- Understand the integrated nature of business, engineering, and law in a global economy

There is no textbook for the course, but students are expected to complete three main assignments, and review a variety of readings, cases, handbooks and the internet. In addition, students are expected to search out other appropriate sources of information to complete

their assignments. The three assignments are outlined below:

Assignment One: Product Research Reports

The purpose of this assignment is to use a product family reference frame to enable students to better understand design, manufacturing and engineering capabilities and issues in different countries and hence learn how this capability may impact a country's economic well being. The assignment is intended to be completed by the students in a team setting. At the end of this assignment students should better understand:

1. Where to go to gather product family data both for countries as a whole and for specific types of manufactured products
2. The impact global manufacturing has on foreign and the U.S. economy
3. The implications this data has on foreign economies
4. The impact—and anticipated impact, design and manufacturing capability will have on the U.S.

Assignment Two: Case Studies and Company Research Reports

For this assignment student teams are assigned a case, an article, or a research topic to prepare and present to the class. The presentations are given after at least one of the domestic industrial site visits.

Assignment Three: Individual Research Topics

This assignment is an opportunity for each student to investigate a topic of global importance that is of interest to them personally. Each student meets with a faculty member before the overseas trip to select a topic they will work on throughout the course.

Other Assignments:

A list of relevant articles has been identified each year for the two years the course has been offered. This list is prepared by the faculty and a teaching assistant with input from invited seminar speakers from on and off campus. Students are expected to read these articles in preparation for the discussion held each week in the seminar before the domestic and overseas industrial visits take place.

In addition, each student is given a blank paged journal and a list of possible questions they might consider writing about throughout the course including the seminars and industrial site visits. Several of these journal writing questions are noted below:

- In your journal, briefly describe the most significant thing you learned today related to global product realization. Why do you believe this item is significant, particularly once you become a practicing engineer?
- Based on what you learned today, what implications are there for your education? e.g. do you envision switching a class you planned taking for another, etc.?
- Briefly describe the design process used to develop the products you saw manufactured at the industrial site visits you were involved in today
- How does this design process compare with other design processes you have learned about or used previously?
- What suggestions might you have for improving the way things were done at the company that you saw today? What evidence do you have that your ideas would really be any better? Can you identify one or more metrics and quantify how much better your idea might actually be?
- What strengths were evident in the way things were done at the company you visited today? What evidence do you have for making these judgments? What benchmarks have you used to make these comparisons?
- What differences and similarities do you see in things that are valued in this company/culture and your own? Can you

explain why these differences in values might exist?

- If you had the opportunity to go back and visit with people from the company you visited today, are there other questions you would have liked to have asked them? List them
- Describe some of the cultural differences you noticed today. What effect do these cultural differences have on the way products are designed and manufactured in the company you visited?
- As a result of what you learned today, what recommendations would you have for improving engineering education at BYU and in the United States in general?

INDUSTRIAL SITE VISITS

The centerpiece of the course is between 10 and 15 industrial site visits that take place in the U.S and Asia. For U.S. visits, we chose to visit a multi-billion dollar U.S. company that makes laser printers and who has partnered with a Japanese company to develop and manufacture these products. We also chose to visit a smaller company who has partnered with several Asian companies to contract manufacture component parts for their product. We also visited a world class design firm that specializes in providing consulting help to companies all over the world in the identification and development of new products. We chose the design consulting firm as one of the early visits for the students because we wanted to have the students be thinking about the variety of design processes they would see being used by the companies we would later visit in Asia. We chose U.S. visits to companies that had partnered with Asian companies because we wanted to expose the students to the issues associated in partnering globally. In each case the companies were more than willing to share with the students the challenges and success they had in their partnering efforts.

For Japanese companies, we were interested in having the students visit the Japanese partners to the U.S. joint ventures. We also chose a large and highly respected Japanese automaker for the students to visit enabling them to become familiar with highly automated manufacturing.

In Shanghai, China, we again chose a large, joint venture automaker and a state–of-the-art software development company. We also chose a smaller manufacturer of exercise equipment that both designs and manufacturers exercise equipment for both the U.S and European market. We also selected in Guandong, China a smaller ($50 million a year in sales) American owned company that has literally moved all of their manufacturing to China, including several of their U.S. engineers. Also in Guandong we visited an American owned—large elevator manufacturer. In addition, in Shenzen, China, we visited a very large electronics manufacturing company employing approximately 70,000 people and another large (Israeli owned) manufacturer that supplies about 30% of Europe's air conditioning equipment market, all manufactured in China. We also visited China's top engineering school and learned, first hand, the type of "hands on" product development process Chinese engineers are being taught.[9]

Offering a course of this type is challenging. For students, they may not have had much exposure to different overseas cultures previous to the class and there is "a lot to process in so short a time". In addition, some students may not have had much experience inside of factories and hence an ability to discern some of the subtle (and not so subtle) differences that are evident to those that have worked in a variety of industrial settings. In all of the learning experiences of the course we found it important to assist the student in "reflecting on the experience" of each of the industrial visits, seminar topics as well as on their assignments. As faculty teaching the course, we often found ourselves asking the question of our students, "what have you learned from this visit or this assignment or this experience, what are some implications of what you have learned, etc.?"

Obviously there are financial implications for conducting a course of this type as well. The cost for each student, including 3 credits of tuition, is approximately $3,400 for graduate students and $3,200 for undergraduate students including air fare, room and most of their meals. An individual very interested in assisting in our effort to offer such a learning experience to help our students learn more about global product design and manufacturing issues provided some donated funds enabling a scholarship of $1,000 to be given to each student to assist with this cost. In addition, BYU's College of Engineering

and Technology has been very supportive in providing some extra funds. The college and department consider the course as an opportunity to provide in-service training for the faculty involved and have provided travel costs for the faculty and salary appropriate to teaching a "normal" spring term course. We have structured the course so that two faculty conduct the class each spring term with one faculty member rotating in and one rotating out each year. It is hoped that the faculty involved will find ways to incorporate what they learn from the experience to their students in their other classes, their research activities where appropriate, and also in their university assignments. We have limited the course to 16 students each offering.

The logistics are formidable in setting up and administering all of the industrial visits, the seminar speakers, the assignments and so forth. BYU is very fortunate to have a Kennedy International Study Center that has been a great help in assisting with many of the logistic issues. Without such assistance the time commitment would be nearly impossible. Even with this assistance the time commitment for the faculty in teaching the course is formidable and has become a "labor of love". Clearly the faculty that have been involved see the experience as being very beneficial for students in helping them prepare for their lives in a drastically changing world in the profession of engineering.

Grading of the students in the course is based on both individual and group performance. The instructors evaluate the student deliverables including a discretionary evaluation of the student's participation and their efforts to create a positive learning environment for the class. Some of the factors noted in the syllabus used in evaluating student work include the following:

- Writing of experiences and impressions in the student's journal
- Case preparation and participation
- Student team and individual presentations

COURSE RESULTS

As might be expected, the course has been very well received by the students. Noted below are comments from students as well as significant things learned by the faculty taking part in teaching the course.

Student Comments

Near the conclusion of the course we asked each student to write comments concerning the "most significant things they learned as a result of taking the course". Noted below are a variety of comments from the students.

Comments from both years specific to learning:

- "Can all design be moved to Asia? No. As we've seen with American manufacturers making products for the Asian market, it's essential to have designers who really understand the culture and the way people will use their products. Since much of the market for consumer goods is in the U.S. today, we still need designers here…"
- "In a setting (China) where intellectual property is largely ignored, it is even more important to be honest and direct. If a company gains that reputation, they will be highly valued."
- "Engineers need to understand business better. We can engineer almost anything, but we might also sink the company by wasting time away."
- "Language and customs can be a huge barrier in Asia."
- "My idea of China and Japan were only partly correct. For Japan, my ideas of their skills as engineers and innovators were wrong. They surprised me concerning how innovative they were. For China, I thought the country would be doing much worse and communism would have a much stronger presence. China cannot be ignored."
- "There is a need for breadth as well as depth in engineering education. Engineers need to understand other disciplines like business, manufacturing, different cultures, the design process, different markets and global economics."

- “Lean manufacturing was very much evident in Asia.”
- “The speed at which China is progressing is amazing. The building and architecture of a nation tells a story by itself. Shanghai, Beijing, and Shenzen were filled with very contemporary building design that would make even L.A. and New York look backwards. There is a lot of wealth and because there is wealth, there is a lot of opportunity to invest in business, improve and expand capabilities and consume even more of America’s manufacturing base.”
- “The Chinese are on a shortened learning curve and will in many ways leap frog countries that are more established. They are not constrained to “in the box’ thinking.”
- “By no means are all Asian cultures the same. The two largest in GDP, Japan and China, are in many ways very dissimilar. The Japanese are more introverted and conforming. The Chinese are more open. Both are approachable and with some work on our part can be worked with effectively.”
- “Chinese and Japanese people are in so many ways similar to us. They desire the necessities of life, to be able to learn and work hard and to be given the opportunity to prove themselves.”
- “The Chinese workforce is capable to deal with far greater levels of competency, e.g. high volume, close tolerances in production) than I had previously conceived. I can see what types of jobs/functions could be effectively brought to China in the product realization process and which would be much more difficult such as market research, industrial design, etc.”
- “The most significant thing I learned was that most American engineers are probably ignorant of what is really happening in China.”
- “Given globalization, skills we as engineers must further develop include, industrial design, business acumen, cultural appreciation including cross cultural team skills.”
- “This course has helped me put my career and personal life in the context of a more global market. I now have a much greater understanding of what skills I have that can add value to an international company, given my education and experiences.”
- “I have learned more about doing business and product development engineering in Asia through visiting companies in the U.S. and Asia for two weeks than I ever could in a classroom.”

Faculty Learning:

As faculty, we have learned that relationships are key to working with companies and others in Asia. We heard this comment over and over again from engineering personnel in the companies we visited. In addition, we have learned that there is no substitute for being “on the ground” in these new settings. Cultural differences and the language barrier necessitate being there working with those that you are partnering with in Asia, especially in the beginning.

It’s not clear what all of the fundamentals are that we might consider diffusing into the undergraduate curriculum but as we know that our teaching paradigms have forever been changed as a result of the experiences we have had with this course. What is clear is that U.S. engineering graduates will be required to perform in an environment not familiar to most faculty and we must carefully find significant value added curriculum items that will give our students an advantage over engineers educated in Asia who presently cost about one-tenth of what a U.S engineer costs.

We have also found that students are willing and anxious to commit time and resources to learning activities that will make them more viable and useful in the changing world of global product design, development and manufacturing.

CONCLUSIONS AND RECOMMENDATIONS

In summary, the BYU course has had as its main objective building on an excellent technical education to create an awareness of international and global issues surrounding

product design, development and manufacturing. This objective is achieved through focused seminars from a variety of disciplines, classroom presentations and case studies, a significant field experience in the U.S. and Asia, and specialized assignments. The field study is the centerpiece of the course and includes industrial visits and cultural experiences. Faculty help to interpret and "process" the experiences with the students and integrate and link them with the course objectives.

It is the hope of the faculty that courses such as the one described in this paper can serve to build the capabilities of engineering students to provide leadership in the increasingly global environment of product development. In parallel, such courses can serve to develop increased awareness and capabilities for the faculty as they teach other courses and carry out their other university responsibilities.

This course has been offered two times with excellent results in terms of student satisfaction and faculty development. Clearly there is much room for improvement in terms of more carefully defining and meeting the course objectives. From our experience, we would encourage engineering educators to embark on new courses of this type. As this is done there will be opportunities to identify and develop several "new" fundamentals for engineering education.

It should be noted that the course described in this paper primarily provides students with a keen awareness of the rapid pace of change and an introduction to some of the issues surrounding the globalization of product design and manufacturing. It does not, however, go into depth in terms of addressing these issues. For example, students become aware that communication is often more complicated when attempted across multi-cultural barriers. Students do not study in-depth strategies and methods for alleviating these complexities, although they learn some hints from practicing engineers as they visit companies, review case studies and relevant literature. We anticipate the need for following up with curriculum which goes into depth on a number of these issues.

Looking ahead to our next course offering of this course, the BYU team is already planning some improvements and refinements to the course itself and its associated field study. We are also interested in cultivation of key contacts in Asia with companies and universities that are interested in developing relationships with BYU.

Although there is probably no substitute for the educational value of the field study experience to learn about globalization, it is resource intensive. We believe there is much that can be gained by students and faculty alike using a minimum of resources. The use of case studies, guest speakers, visits to local companies that are involved in globalization, reviewing vision and mission statements of foreign companies on the web, problem based learning exercises using simulation and other methods, and a review of relevant literature.

Much additional work could also be done in searching out and/or developing instructional materials relating to global economics and engineering decision-making in global product development. We feel we have just scratched the surface in what could be done here and that our students would greatly benefit from more work in this area. We sense that there is a growing body of literature in periodicals but not yet much scholarly work in journal sources. A thorough review of the literature here would be helpful.

For the faculty that have been involved thus far in the course, the learning experiences have been "life changing" and we see a need to share what we have learned with all of our students.

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