ADAPTING ENGINEERING COURSEWORK FOR INCREASED GLOBAL RELEVANCE*

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Abstract
This paper emphasizes the need for enhancing engineering curricula in response to the rapidly changing landscape of the global engineering environment. In particular, rapidly changing technology, particularly information technology, corporate downsizing, outsourcing, and globalization are dramatically changing engineering and the engineering workplace. As a result, the need for undergraduate engineering students to spend part of their education in an international setting has been greatly increased. However, traditional engineering education and engineering courses typically have not been conducive to 'study abroad' type environments. This paper presents a case study where a basic Manufacturing Systems course taught at a campus in the United States within an engineering program has been adapted for teaching as part of the Semester At Sea program. General guidelines for adapting such engineering courses for global relevance are also presented. Finally, we show that student learning and student satisfaction did not suffer (but actually improved).

Background

The Semester At Sea Program operated by the Institute for Shipboard Education is a unique study abroad program designed to incorporate global studies into the undergraduate experience. As such, each Fall and Spring Semester, over 600 students from 200 to 240 different colleges circumnavigate the globe while taking a full semester of "voyage related" courses. During the summer, a 65 day regional voyage is offered, with students taking nine to twelve credits. All courses are provided under the jurisdiction of the University of Pittsburgh, which grants academic credit for participation in the program. The state of art ***MV Explorer*** serves as a fully functional campus with nine classrooms, a library with a significant collection tailored to the international academic focus of Semester at Sea, a computer lab with internet access, a student union, campus store, two dining rooms, swimming pool, fitness center, theatre and medical clinic. Student living areas are arranged much like campus residence hall environments. Built in

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2002 by Blohm & Voss shipbuilders in Germany, it is billed as the fastest passenger ship afloat today with a cruising speed of 28 knots.

The shipboard curriculum provides students with insights into various cultures and societies and allows them to dissect and assess what they observe. Unlike the more traditional one-county emersion study aboard programs, here the focus is on global comparisons. Students not only develop the ability to understand the new cultures that are encountered, but acquire the intellectual tools to relate past experiences to future situations. They also examine critical issues of global concern, e.g., environment, population, foreign policy interrelationships and economics, in the context of the countries visited.

Although the ship becomes the campus on which students work in a traditional classroom setting with classes held everyday at sea, it is the various ports of call that provide the “laboratories” (field component) from which approximately 20% of the credit earned for a course is fulfilled. The integration of classroom and international fieldwork enables Semester at Sea to provide a learning environment unattainable on a traditional land campus. The challenge to engineering education is to find a way to make this laboratory experience valuable and relevant to the coursework.

The authors responded to this challenge by organizing a program directed at engineering and business students interested in manufacturing and operations management issues. From an engineering perspective, the idea would be to adapt “land-based” ABET accredited engineering courses to establish and pilot an Engineering Semester At Sea for the Summer 2004 voyage. A follow-up program will be held for the Summer 2005 voyage. This particular program is jointly sponsored by the School of Engineering (Industrial Engineering) and the International Business Center (Katz Graduate School of Business).

The ports visited during the Summer 2004 voyage included Sitka and Kodiak (Alaska), Petropavlovsk-Kamchatka (Russia), Busan (Korea), Shanghai (Peoples Republic of China), Hong Kong, Halong Bay (Vietnam), Keelung (Taiwan), and Kobe (Japan). This Pacific Rim itinerary provided an important opportunity to build a curriculum around the global supply chain and manufacturing. The actual program consisted of three courses from which students could choose and a fourth course – *Global Perspectives* required of everyone on the voyage. These courses are described briefly below. The remainder of the paper then focuses on the revision of the manufacturing courses to take advantage of the Pacific Rim itinerary.

Geography 1020: Global Perspectives

This interdisciplinary course focuses on the countries visited and is tailored especially to meet the global and comparative approach of Semester at Sea. It is mandatory for all students. In addition to providing basic information about the countries on the itinerary, Global Perspectives also provides a meaningful framework by which to compare data, examine issues, and develop concepts. Participants learn how to understand cultural and social phenomena with which they are constantly coming into contact during the semester and to highlight both commonalities and differences from one society to another. Global Perspectives equips participants with observational and analytical skills for encountering societies different from their own, and different from each other, a key factor in facilitating the integration of class work and field work for all courses. Objectives: 1) To provide basic information about the physical and cultural geography; key historical events; the current social, economic and political situation of each country visited. 2) To present regional and global issues which in various ways affect the countries on our itinerary. Examples include race relations, population, poverty, ethnic/religious conflicts, technology, status of women, human rights, environment and globalization. 3) To emphasize the similarities and differences in the variety of human experiences and to assist students in developing the observational and analytical skills needed to draw cross-cultural comparisons.

Anthropology 1787: Special Topics – Political Economies of the Pacific Rim
This course focuses on the interdependence of politics and economics in the countries of East Asia, and how the "East Asian miracle" and later "Asian Crisis" reflect the political economy context that led to the rapid development of China, Japan, Korea, and other smaller states in East Asia. This course will also overview theoretical perspectives in political economy that inform different understandings of economic development, the relationship between politics and economy, and the impact of globalization and new technologies on the region as a whole. To explore the political economy of the Pacific Rim, we will read particular East Asian case studies such as the computer and information technology industry, the steel industry, and the condition of industrial workers in East Asia. Methods of evaluation consist of response papers, field projects, a term paper, and class participation.

Industrial Engineering 1662: Manufacturing Cultures in the Pacific Rim
This course will focus on studying manufacturing and distribution organizational hierarchies with a view towards understanding unique organizational dynamics within different organizations and different cultures. It will allow students to gain an understanding of the unique manufacturing culture of each country visited both at the organizational level and the policy level. We will study a variety of cross-cultural manufacturing paradigms ranging from the Vietnamese spirit of entrepreneurship, the Korean chaebols and super-chaebos, and the Japanese keiretsu. The course will also focus on the complexities of problems in global operations and supply chain management.

Industrial Engineering 1661: Global Manufacturing Systems Engineering.
This course will present the development and application of modern manufacturing engineering principles, methods, and tools, associated using he Pacific Rim ports as a field laboratory. In order to do students will first acquire knowledge of basic manufacturing process and principles. Students will also learn the principles of operating (and evaluating) a shop-floor and manufacturing operations. This will provide students with the ability to analyze and visualize manufacturing engineering challenges and opportunities around the world. Plant visits and interfaces with practicing engineers will allow students to appreciate the following professional characteristics: ethics, the ability to work with others, an appreciation for other disciplines, adaptability, and an appreciation for life-long learning.

The Basic Manufacturing Course. All Industrial Engineering Students at the University of Pittsburgh are required to take the three-credit course: *Manufacturing Process and Analysis* (IE 1052). Students typically take this course during their junior year. Its objectives are:

- Learn the application of modern engineering and business principles, methods, and tools, associated with manufacturing systems and
- Acquire a basic knowledge of manufacturing processes.
- Develop the ability to visualize manufacturing engineering challenges and opportunities.
- Demonstrate effective oral and written communication within the context of completing and presenting manufacturing project.
- Recognize the importance of key professional characteristics: ethics, the ability to work with others, an appreciation for other disciplines, adaptability, and an appreciation for life-long learning.

Plant visits have traditionally been an important part of this course. Students typically visit four or five plants during the semester long course. Upon returning to campus there is usually a class period reserved for discussion on the plant's manufacturing processes, operational strategies, shop-floor philosophy, etc.

There are also two projects associated with the course as follows:

Project 1. ***Manufacturing Processes***. Students are divided into teams of four and assigned a set of processes. At the end of a two-week time period, each group presents details of the assigned processes, evaluating the assigned manufacturing processes from the perspective of process planning for manufacture of a product. Each group is also assigned the responsibility for developing an information packet on one set of manufacturing processes.

Project 2. ***Development of a Manufacturing Engineering Plan***. The objective of this project is to develop a detailed process design for an engineered product (typically with three or four components) with a specified market demand. Each group utilizes industrial and manufacturing engineering techniques taught in class but is encouraged to branch out based on their specific interests. For example, some groups may choose to focus on developing a very detailed CAD design and then outsource the product while another may choose to replicate an existing design. As part of the project, each group is expected to

- Develop a drawing, including design specs and modifications,
- Develop a detailed process plan (s) by studying alternative manufacturing processes/ materials.
- Conceptualize jigs and fixtures needed to produce the component
- Estimate the time required using the principles of work measurement
- Develop a detailed production scheme, and finally
- Estimate approximate costs.

A final presentation (graded by peers and invited visitors) and a detailed plan is also required.

These projects also seek to establish team-building skills that are a part of progressive manufacturing environments.

Adaptation Of Coursework

In order to make the course voyage relevant, the coursework, projects, and plant visits were adapted to the Pacific Rim setting. The adapted course was given a new course number (IE 1661). While some changes were minor, others required major surgery as discussed below:

Topics Covered. IE 1052 is the only required manufacturing course in the Industrial Engineering (University of Pittsburgh) curriculum. For many industrial engineering students, it is the only manufacturing course that they take. The curriculum covers six major areas of manufacturing.

Topic 1: Introduction to Manufacturing Systems.

Traditional Course. Types of Manufacturing. Factory Layouts. Shop floor organizational structures.

Adaptation for Shipboard Course. The global scope of a manufacturing system. Outsourcing. A case study of a global corporation.

Topic 2: Applying Process and Work Flow Techniques.

Traditional Course. Review of process flow analysis techniques. The importance of smooth material flow on a shop-floor.

Adaptation for Shipboard course. Group based project to improve the flow through ship's dining areas. See Figure 1 for a before and after schematic.

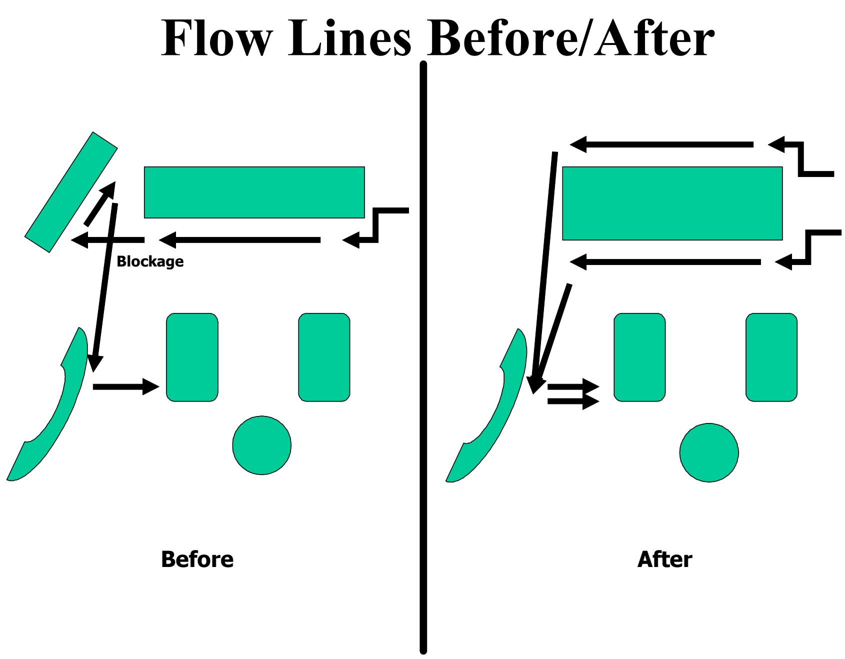

Figure 1: Student Project: Improving Flow in the Cafeteria

Topic 3. Integrated Product Design and Manufacturing..

Traditional Course. Design for X: design for manufacturability, design for assembly, design for environment.

Adaptation for Shipboard course. Collaborative design strategies: Challenges to smooth information flow, the use of virtual design teams. Use of global teams.

Topic 4: Manufacturing Processes and Process Planning (Project 1)

Traditional Course. Overview of manufacturing processes; process planning on a shop floor.

Adaptation for Shipboard course. Study manufacturing within the countries visited. For example, in Korea which has outstanding heavy industry capabilities; focus on manufacturing processes used in shipbuilding and in the manufacture of heavy construction equipment. In Alaska, focus on the timber industry.

Topic 5: Group Technology, Tooling and Cellular Manufacturing.

Traditional Course. Part family formation, cluster analysis, cell operations, tool and fixture design.

Adaptation for Shipboard course. Add a case study on a *make versus buy* decision for a product. Students can utilize principles from engineering economics to make decisions that hinge on labor costs, investment costs in machinery, transportation costs, and the cost of communications. Add a module on the value of intellectual property and risks involved.

Topic 6: Lean Manufacturing and 5S.

Traditional Course. Concepts of lean manufacturing. The principles of 5S and implementation guidelines on a shop floor.

Adaptation for Shipboard Course. The need for efficient manufacturing in the United States. Balancing automation versus labor costs. The addition of a sixth S (safety) when the 5S concept is implemented in the U.S.

Final Project.

Traditional Course. Described above.

Adaptation for Shipboard Course. Require that each team be based in one of the ports visited. Student groups then gather labor and wage rate data when in port and thereby each group focuses on one country.

GENERAL GUIDELINES FOR ADAPTING COURSEWORK

1. **Tailor the curriculum to suit the environment**. For an engineering study abroad or semester at sea course to work, it is critical that the coursework be adapted to the new country or countries visited. The authors found that students related especially well to lectures where they were able to integrate their classroom learning with their in-country experiences. For example cellular manufacturing concepts that originated in Japan were first discussed. Then, students witnessed the Japanese obsession to detail and time during a Mitsubishi Electric plant visit, and also in taking a shinkansen (bullet train) or in a grocery store where individual tomatoes and other vegetables are carefully washed and arranged.

2. **Plant tours are necessary but not sufficient**. Students visited eight factories in five countries. While the some plant study visits were fascinating, others were no different from those in the United States. The real value of the plant study visits came after the tours, in structured discussion sessions where workers, supervisors, and plant executives discussed issues of interest with students. Questions from the students ranged from routine (how many hours is a work week is China?) to controversial (why are there not any women executives at this factory?). Many students also established mental role models for themselves after meeting American executives who seamlessly work in multiple countries and multiple cultures. See Figure 2.

Figure 2: Q&A Session with executives at Chroma and Dynascan Inc., Taoyuan, Taiwan (Lead author is standing on the left)

3. **Inexpensive Internet access is crucial.** While Internet access is taken for granted on U.S. campuses, this may not be the case during a study abroad, and certainly was limited and expensive (30 to 50 cents per minute) on the Semester at Sea experience. However, in order to offer a meaningful upper level engineering course that incorporates projects and homework, it was found that the lack of inexpensive Internet access adversely affected the quality of projects.

4. **Be flexible.** These programs are typically a one-time effort by faculty similar to a new course preparation. . Due to the dynamic and unpredictable program's nature, it is important to be flexible. For example, it was our experience that we had prepared excess materials for each lecture and had to trim some content from each lecture to make it a meaningful learning experience. Teaching at sea introducing other problems – rough weather may make it difficult for faculty to teach and students to learn; a passing pod of whales may interrupt the class. On this past summer's voyage, the delays in the cafeteria not only backed up the start of class, but did provide a case study for streamlining this process. As a result, a process flow analysis was added to the syllabus. The projects not only made a positive impact on the

dining situation, but also helped raise the visibility of the engineering program in the shipboard community. (See Figure 1)

5. **Recognize that there is significant extra-curricular learning.** Students at port interact with the local community more easily than one would expect. We found that at each port, students interacted with factory workers, engineers and local businessmen outside of the academic environment. Having students relate these experiences in classes revealed their growing understanding (as the voyage progressed) of Asian cultures, philosophies and also the potential impact of Asian economies on the United States. These experiences were unique and unattainable in a traditional land based campus.

6. **Utilize local resources**. At a few of the ports, visits to local universities and meeting with engineering students were arranged. We found that both the plant study visits and port experiences were more meaningful for students when they interacted with local faculty (as they did with professors at the Tung Nan Institute of Technology, Taipei) and students (from the University of Ulsan, Korea). Internet cafes at the ports were useful information gathering stops for class projects.

Results

Thirty-one students from thirteen different universities participated in the course. The average incoming GPA of the students was 3.45. Students' feedback was generally positive with an average evaluation of 4.13/5.00 versus a typical evaluation of 3.75/5.00 for the equivalent traditional course at the University of Pittsburgh. The student evaluations were higher for the shipboard course despite encountering major problems with audio-visual equipment, a noisy classroom and expensive Internet access.

The plant study visits were a major highlight of the course. Prior to the voyage, students that had visions of Asian sweatshops were amazed to see the modern working conditions and the technological capabilities in factories across Asia. The warmth, welcoming nature and hospitality of plant personnel throughout Asia was a pleasant (and unexpected) experience for the student group.

Bibliography

Note to reviewers: References will be added when the final paper is submitted

Biographies

Bopaya Bidanda is the Ernest Roth Professor & Chairman of the Industrial Engineering Department at the University of Pittsburgh. He coordinated and was the primary faculty member responsible for the Engineering/Business Program during the Summer Voyage of 2004. He is a member of the American Society of Engineering Education and a Fellow of the Institute of Industrial Engineers.

Larry Shuman is the Associate Dean for Academic Affairs and a Professor of Industrial Engineering at the School of Engineering at the University of Pittsburgh. He served as the Academic Dean of the Spring 2002 Semester At Sea voyage and helped design the curriculum and participated in the Summer voyage of 2004 as an inter-port lecturer.

Kate Thomes is Head of the Bevier Engineering Library at the University of Pittsburgh. She served as the ship's librarian on the Summer 2004 Semester at Sea voyage.

Ozlem Arisoy is a doctoral student at the University of Pittsburgh. She has a Bachelors degree in Industrial Engineering from Bogazici University and has a research interest in international engineering and logistics.