



Virtual and Collaborative Project-Based Learning

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Abstract - Project-Based Learning (PBL) methods have been used together with a digitized course management system to enable small numbers of first year engineering students to collaborate, communicate, organize and work in groups to plan, research and develop information for two-page status reports on a wide range of local, national, and global societal and technological issues. A large class comprising 331 first year engineering students was administered, managed and successfully guided through a whole semester of practical 'hands-on' laboratory activities culminating in student presentations to explain their practical lab. project activities to their peers. Students also contributed digitally to the grading of the 56 group research reports that were assembled virtually on different topics and added anonymous evaluations and reviews of the course. 'Super Tweets' were also a weekly feature.

Keywords: Course Management, First Year, Project-Based, Teamwork, Virtual

INTRODUCTION

The acquisition of learning and the satisfaction of curiosity have ranked highly as civilizations have developed. Individuals offering explanations and solutions to the mysteries of the universe have commanded, and often even demanded, wide respect and been followed by the multitudes. It can be posited that once the basic necessities of freedom from hunger, safety, shelter, with future indications of conditions becoming sustainable then spare energies may be devoted to exploration, art, and development of greater survival skills and prosperity. In parallel with the organizational evolution of families, tribes and social structures there will be training and transmission of customs. Learning and skills development would be accompanied by varieties of 'rites of passage.' There would be hierarchies of priests, shaman and other levels of highly regarded instructors [1]. Learning was achieved by following examples and likely repeated replication.

In particular, whether we follow the examples illustrated by the discoveries in the tombs of Egypt, or in the libraries of the Vatican, the monasteries across Europe or at sites in China, India, and elsewhere in Asia or Central and South America records were maintained and leaders taught disciples allegedly accompanied by severe discipline. This education was reserved for a chosen few selected to maintain the traditions and stability of the parent organization.

Similar customs and habits prevailed until around the middle of the nineteenth century. The development of guilds, training programs and elated matters has been covered well by Burton and Marique [2]. Finally 'public' education started to be introduced in an endeavor to develop a more effective workforce, reduce poverty and improve living conditions. Famines and other factors lead to migration to the growing cities in support of the needs of the Industrial Revolution. The importance of both literacy and numeracy was recognized and institutionalized as educational systems developed. As result of strong class divisions between landowners, nobility and peasants or workers together with the after-effects of the 'Enlightenment' or 'Age of Reason' of the eighteenth century the pedagogic structure separated academic and vocational skills [3]. This worked well for creating what passed for wealth in those earlier days of industrialization.

On the academic side it was customary to study under the tutelage of learned scholars, whereas vocational skills or trades were imparted by on-the-job training or apprenticeships [2]. Students were thought to be better equipped to handle the future by in-depth study of the past. Measurement of attainment and competency was achieved by rigorous testing and regurgitation of 'facts' often learned by rote.

The Industrial Revolution was accompanied by a plethora of new technologies, not the least being the printing press, mass production, steam power, plus enhanced transportation systems with increasing national and international commerce and trade [4]. Educational curricula with a breakdown of what had been alchemy into sciences,

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astronomy, chemistry, mathematics, physics and other topics followed. Engineering developed into various and specific disciplines focused on finding solutions to pressing problems affecting local and national needs.

Our academic world, as many others, is noted for in-depth specialization and research aiming to develop ever better solutions to problems, and also as a concomitant benefit to develop new knowledge and innovation. Unfortunately, as human organizational structures grow, it appears that they can only gain strength by constructing imaginary ‘silos’ to protect their specialties and concentrations from contamination by external notions. In the US the accreditation process for an engineering program involves comparisons and measurement against ‘standard’ curricula outlines where there must be certain proportions of this, and that, plus a mandatory number of hours of non-engineering topics, such as humanistic and social studies (HSS), English and the like. This is following the ‘Enlightenment’ academic model that strongly associated development of culture with learning without any necessary relevance to acquiring competencies related to making contributions in the future workforce. The Masterpiece TV series shown on the Public Broadcasting System (PBS) focused on the nineteenth and earlier twentieth centuries exploit these significantly British class differences for dramatic effect [5].

LATE TWENTIETH CENTURY NEEDS

Post-Sputnik (1957) there was surge in attention paid to science education in the US. During the late twentieth century there was an awakening emphasis on the skills needed by individuals seeking careers in the industrial workplace – business-awareness, communication, project management/planning, presenting and reporting, teamwork plus integration were being reported as areas of weakness in engineering education by learned professional society groups [6]. Concurrently, in the early eighties, this triggered the establishment of a Manufacturing Technology Institute (MTI) under the aegis of the Corporate Technical Institutes at IBM [7]. MTI was created as an IBM ‘university’ to revitalize and broaden the skill-levels of the IBM engineering workforce. It was soon recognized that these skills also needed promoting among engineering graduate programs, this led to IBM grants for the establishment of cross-disciplinary ‘Manufacturing Systems Engineering’ programs in Asia, Europe and the U.S. – these programs developed new courses and also adopted and adapted offerings from Colleges of Business in collaboration with several disciplines in engineering [8].

In parallel by the nineties these initiatives promoting collaboration, communication, presentation and teamwork skills became widely employed in contests starting in middle schools with events like the Future City Competition, Mathcounts, Odyssey of the Mind, and science fairs etc. [9]. Similar competitions for university students have been promoted successfully for many years by divisions of various professional societies, and are occasionally included in regular curricula activities.

These ‘newly’ identified principles and practices subsequently needed augmentation to recognize the increasing realities of globalization, and major enhancements in the abilities of many industries for broadband communication and commerce [10]. The scale of competition in the service of global consumers and stakeholders is vast and growing exponentially. More recently Lawrence H. Summers has proposed a new view of the responsibilities of twenty-first century education [11]. Here are his re-phrased guesses:

- i) Processing and using information will become more important than imparting it.
- ii) A greater degree of collaborative working will be required as result of the knowledge explosion.
- iii) Modes of delivery and access to knowledge are changing due to new technologies.
- iv) ‘Active Learning Classrooms’ will enhance collaborative experiences.
- v) Education must incorporate ‘cosmopolitanism’ with international experiences.
- vi) Any course work must incorporate integration of data across diverse fields.

MOVING FORWARD

This, then, is the background and to some extent a context of curriculum development. There is little doubt that the US possesses some of the most vaunted institutions and curricula that are envied together with the associated research organizations. Nevertheless US rankings in many areas are not the greatest in the World [12]. It speaks volumes that several leaders of some of our most noted ‘newer’ technology corporations dropped out of college. This is analogous to the fact that sufficient inspection and testing often enables the production of acceptable and even brilliant output from systems that may have appreciable room for improvement. Our engineering educational systems may not be broken, but there is a distinct possibility that change may have value. In particular, curricula

planners must encompass recognition that most of the major problems of our planet and society at large call for wholly cross- or inter-disciplinary investigation and solutions. The current engineering curriculum structure with its disciplinary silos does not adequately prepare students to be effective broad-based contributors or for the travails of the industrial workplace. Often an employee's actual degree title will be forgotten after six months in industry [13]. The newly minted and enthusiastic engineer will likely be working on ambiguous projects solving problems unlike anything encountered in the classroom. These factors highlight the importance of, and necessity for non-discipline specific Project-Based Learning to afford realistic and cross-disciplinary problem solving experiences.

INTRODUCTION TO ENGINEERING PRACTICE

There became a point a decade or so ago that a student desiring to study engineering at Lehigh could be compelled to fill the first two semesters with courses not taught within the College of Engineering. There was an elective 'Engineering Project,' but this was only readily accessible to students entering with Advance Placement (AP) credits. Another 'gap' in the curriculum also implied that it was possible for a student to graduate with a good engineering degree without ever sketching something out and physically making it in a laboratory or workshop. After several experimental courses and much student feedback a new course was developed and finally approved as mandatory for all first year engineers. This was offered every fall and spring starting in 2003. A new feature was the incorporation of two 5-6 week 'Engineering Practice' lab. sessions spread across the seven departments in the engineering college [14]. In fall 2011 as result of other associated curriculum changes it became possible to offer this course in the fall semester for the whole entering class of 331 students. Several new features were able to be incorporated exploiting Project-Based Learning with 'Virtual' collaborations and teamwork as result of using a new 'Moodle-based' course management system (CMS) [15].

CATALOG DESCRIPTION, OBJECTIVES AND OUTLINE

Introduction to Engineering Practice: First year practical engineering experience; introduction to concepts, methods and principles of engineering practice. Problem solving, design, project planning, communication, teamwork, ethics and professionalism; innovative solution development and implementation. Introduction to various engineering disciplines and degree programs.

Required Text: Landis, Raymond B., *Studying Engineering: A Roadmap to a Rewarding Career*. Discovery Press, Los Angeles, CA. 3rd ed. 2007. ISBN 13-978-0-9646969-2-1 [16].

Objectives:

1. To afford opportunities for hands-on problem solving that engages students in designing and creating innovative systems and things; actually doing some 'real' and creative engineering in a practical laboratory environment. In other words 'doing what engineers do in the workplace – solving problems to get stuff made, built or otherwise created, implemented and operational.'
2. To get students excited about engineering and help them to understand career options and opportunities related to each discipline in order to aid their choice of major.
3. To offer a broad overview of the importance of problem definition, design, project planning, communication and **INTEGRATION** in developing solutions to ambiguous and open-ended problems with various constraints like time, money and other resources.
4. To emphasize and demonstrate the importance and value of teamwork in the modern workplace.
5. To place engineering in the context of modern life with engineers as 'problem solvers' ethically improving the quality of life leading to the generation of wealth and prosperity.
6. To connect engineering with current events relating to future prosperity, economic health and the sustainability of our systems and our increasingly global society.
7. Above all, the course aims to be memorable and fun! It should not be too rigorous, too demanding or too stressful. Projects should be structured to engender enthusiasm, vigor, teamwork and 'collaborative' competition among teams.

The first week comprises a Monday lecture and also faculty presentations on Wednesday and Friday describing lab. projects. Students select their first round projects within the Course Management System (CMS) and meet in their project labs either on Wednesday and Friday of the second week to commence project activities in separate but parallel

tracks. Project activities continue every Wednesday or Friday afternoon for five weeks. Nominated students and/or teams from every project prepare presentations for their lab section. Students select a different project for the final six weeks of the semester and the process repeats. Thus, every student experiences two projects within two different lab environments and has opportunity to work with faculty members, research assistants, and senior students in different engineering activities. Students are given opportunities to be on their feet explaining themselves and making frequent presentations to their groups.

Meanwhile 50 minute lecture sessions continue every Monday. These sessions include departmental presentations providing brief details of the different engineering disciplines to complement the information in the text, the opportunities, programs and career prospects. The mid- and end-semester student project presentations provide an opportunity for all students to hear about the experiences of their peers and gain knowledge about the wide variety and essentially cross-disciplinary nature of most engineering problems and opportunities. In addition the Monday lectures afford an opportunity for talks plus 'Q and A' sessions with engineering alumni. There are also digitally administered "Super Tweets" and 'virtual' Group Research assignments. The course management system divides students randomly into teams with five or six members, each of the resulting 56 groups were assigned different topics and were responsible for organizing themselves to produce a two page, single spaced, fully referenced, research report. The reports are posted to the web site for student review and nominations to select the best three. Attendance at lectures, 'confidential' assessment paragraphs, the CMS "Super Tweets," the virtual on-line Group Research assignments and any lab. tours are combined to comprise one third of the grade for the course summed with the two lab. project grades to determine a final grade.

FEEDBACK AND ENGAGEMENT

Feedback can be assessed using four methods;

- a) A mid-semester a survey instrument is opened on the Course Management System that requests ratings of each Monday session, and the first lab. project experience; there is also space provided for anonymous write-in comments or suggestions.
- b) This is repeated at the conclusion of the semester.
- c) A paper survey soliciting anonymous ratings of all aspects of the course is also circulated.
- d) Input is also received via e-mails and in casual conversations with students individually and in groups.

Engagement can be surveyed by examining responsiveness to the virtual, or digital, assignments – these reveal that many first year students really experience great difficulties with prioritizing assignments and time management. On the other hand there are very many students that perform almost immaculately. The mid-semester survey gained only 206 (62%) responses from the 331 students, at the conclusion of the semester amid many conflicting priorities, pressures of other classes and a competing paper survey there were 83 (25%) responses. Neither of these vehicles had deadlines, so students could procrastinate, relax and then forget. As compensation though a total of 302 (91%) made the effort to submit some thoughtful often lengthy and decently substantial comments and suggestions. The paper survey administered in class yielded 211 (64%) responses and some 30 of these included some comprehensive comments. In all there were a total of 332 write-in comments received, so clearly at least one student submitted twice!

Many of these comments or suggestions sought (*impossibly?*) more projects, more time, more use of the text and were generally very positive overall. The 'Super Tweets' are a different matter, these were announced and the site opened every Monday and closed at 10pm on Thursdays. E-mails would often flow to the TAs on Fridays and Saturdays with attempts at belated submissions: Numbers of successful responses ranged between 222 and 277 (67-84%). The Group Research Projects were more successful with 100% of the submissions meeting the deadline (likely group pressures increase promptness?). The confidential assessments by the students of the contributions of the colleagues in their team revealed that workloads were not necessarily balanced or equitable. Some students failed to be responsive and thus were non-contributors to the group output. In all 267 (81%) students submitted confidential assessments evaluating their own and their colleagues contributions to the research. Even in the teams with excellent contributions the confidential analyses revealed varying perceptions of the 'value' of the work of other team members. The development of this 'consciousness' is an interesting and worthwhile ingredient of teamwork.

FURTHER QUESTION, RESEARCH STUDIES AND PROJECTS

All this being said though, there remains the question on many students lips, “What is it exactly that engineers do?” “They solve problems,” is one of the answers given in this first semester course at Lehigh. The “Super Tweets” represent a fast track low stress instant response individual assignment ‘problem’ that has an ulterior objective of having the students review certain pages in the Landis text and provide a couple of sentences with their own observations [16], alternately a question may be related to some current news item affecting engineering. The four-day and precisely implemented deadlines reinforce the importance of developing good time management skills, and the message of doing easier things first to reduce the ‘to-do’ list.

The Group Research problem solving assignment is more demanding; deadlines and format specifications are rigorous. The format of this assignment forces students to communicate, develop essential team skills of leadership, collaboration, dependence, commitment and most importantly meeting the deadlines, specifications and managing often conflicting priorities to thoroughly conceive, research, design and develop a finished product. Doing research individually is low stress, but when the input of five or six collaborators has to be assembled and condensed onto two pages then significant collaboration, debate, discussion, and editing and a variety of leadership and negotiation skills are called forth.

Awards to the winning groups last fall were presented during Engineers Week for reports on “Fuel Cells,” “New Batteries,” “Hydrogen,” respectively in the first three places, and “Conservation at Lehigh,” the best runner-up. Honorable mentions included “Ocean Energy,” “Wind Energy,” “Going Paperless,” and “Buy a Volt.” The table below shows the titles of the 56 studies.

The 56 Group Research Project topics utilized in fall, 2011:

Coal Energy	Solar-Photovoltaic	Congestion Charges	"Soft Skills" Training
Liquefied Nat. Gas	Solar-Thermal	Traffic Management	Sustainability
Methane Hydrates	Ultra capacitors	Rail Transportation	Conservation at Lehigh
Oil	New Batteries	Buses	Going "Paperless"
Shale and "Fracking"	Ocean Energy	Feeding the World	Automation vs. Human
Tar Sands	Hydro Resources	Hunger-National, Global	Communication & edia
Hydrogen	Wind Energy	Genetic Eng'ring-Animals	Agricultural Wastes
Algae-As Future Fuel	Electric Vehicles	Genetic Engineering-Crops	Hybrid Technology
Biomass Energy	Diesel vs. Gasoline	Fish Farming	Harnessing Tides
Butanol, Ethanol	Nuclear Waste	Diet & Legislation(FDA)	Bridge Infrastructure
Carbon Sequestration	Nitrogen Cycle	Poverty-Local, National	Levee Infrastructure
Climate Change	Clean Water	Conservation	"Buy a Volt?"
Fuel Cells	Water Supplies	Rare Earth Materials	Natural Gas
Geothermal Energy	Collision Avoidance	Recycling	Monorails

Examples of laboratory projects in different departmental labs.

Computer Animation (Alice)
 Detection of Copper in Water and Wastewater
 Detection of Toxic Lead in Water
 Earthquake-Resistant Structural Models
 Engineering Better Queuing Systems
 Food Wrap Comparative Evaluations
 Fuel Cell Performance Studies
 Golf Clubs – Redesign, Manufacture and Test

Inerting Airplane Fuel Tanks
 Lego – Omnidirectional Holonomics Platform
 Mobile Game Programming for Fun and (non) Profit
 Robotics, Line Following etc.
 Sensing Soil Moisture
 Solid State Powder Mixing
 Toy Factory Projects – Key Ring Items
 Wireless Remote Sensing

SUMMARY

The introductory narrative traces the evolution of systems of education and curriculum development over the ages. There is particular focus on the ideas of Sir Kenneth Robinson and more latterly Lawrence Summers [3] [11]. Briefly,

they eschew the traditional notions of acquiring learning by means of accumulating facts originating across specific disciplines and accompanied by testing of memorization. The revised pedagogy proposed emphasizes the processing and use of information, knowing how and where to acquire this information, likely collaborative analysis, integration and problem solving. The ideas of Confucius around 450 B.C. could be applied as an endorsement of Project-Based Learning: "Tell me, and I will forget. Show me, and I may remember. Involve me, and I will understand." [12][17]. The application of Project-Based or experiential learning in the "Introduction to Engineering Practice" course was deemed to be successful. It was feasible to adapt this technique and manage the progress and inputs from over 300 students using course management software. The task of providing a global, business and economic view of engineering was dealt with by means of 'Weekend Reading' e-mails comprising relevant paragraphs extracted from ASEE and SME daily e-newsletters, weekly ASME Capitol Updates together with items found in many other technology and/or business newsletters, not forgetting Design News, NASA Tech. Briefs and Popular Science etc.

Students, although some were initially puzzled, or surprised, adapted well and a large majority proved responsive. There were a large volume of positive comments and suggestions confirming the fact that students became thoroughly engaged. For the offering of the course in fall 2012 ideas of using video clips, or brief voiceover Power Point files from alumni are being considered as responses to the question "What is it exactly that engineers do?"

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http://www.lehigh.edu/~inmse/gradprogram/faculty_cmse.html

Addenda (material included in the presentation on April 28, 2012)

Additional Source:

Rawlings, Hunter R., "Research Universities Must Pay More Attention to Student Learning," article from a speech at the De Lange Conference, Rice University, Feb. 28, 2012; downloaded from "Insider Higher Ed." April 2, 2012; <http://www.insidehighered.com>

"In brief, students learn by solving problems, not just by listening to someone else, not by positively absorbing concepts; they learn best in groups of peers working things out together."

Final grades: A 218 (65.9%); A minus 98 (29.6%); B+ 9 (2.7%); B 3 (0.9%); W 3 (0.9%) – 331

Sampling of Appreciation Indices (Max. 5)			
Mid-semester (206)		End-semester (83)	
Introduction	4.14	"What do Engrs do?"	3.92
Comm. & Teams	3.92	"Licence to Learn"	3.92
Dept. A	3.76	Ethics & Prof.	3.99
Dept. B	3.93	Career Planning	3.92
Dept. C	3.82	Study Abroad	3.81
Dept. D	4.16	Visions & Strategy	4.28
Dept. E	3.80	Innov. & Pr. Solve	4.00
W/e Reading	3.76	W/e Reading	3.46
Course Mng. Sys.	4.14	Learning Exp.	3.81
Text	2.71	Text	2.61
First Project	4.09	Second Project	4.16 ²⁵

Institutional Survey (21 questions)			
Paper questionnaire handed out on last Monday (117) (94)			
2. Overall quality was good	3.81	4.03	
5. Instructor gave good examples	4.22	4.20	
8. Instructor was well prepared	4.56	4.57	
9. Instructor enthusiasm	4.66	4.61	
14. I learned a great deal	3.44	3.54	
16. Grading was fair	4.28	4.28	
17. Text/Readings valuable	3.21	3.62	
20. Amount of work appropriate	4.22	4.19	

5 point scale: Agree Strongly (5), Neutral (3), Disagree Strongly (1)