Embedding Sustainability into the Engineering Curriculum

Keith M. Gardiner, Lehigh University
Mohler Labs, 200 West Packer Av., Bethlehem, PA 18015

Abstract

The background, conception, development and history of a course including the word 'Sustainability' in the title are described. Subsequently the topic is being added wherever appropriate in courses that deal with 'Introduction to Engineering Practice,' 'Organizational Planning and Control,' 'Manufacturing Management, 'Agile Organizations and Manufacturing Systems.' Students exposed to sustainability concepts range from first year through to graduate levels. The original course offered in summer 2003 is now a regular university catalog entry made available alternate spring semesters to remote, and on campus graduate students in the Manufacturing Systems Engineering MS Program and other programs in engineering and business. Examples of student projects, course philosophy and management strategies are described.

Introduction

There is an increasing focus on conservation. Looking in the rear view mirror we may posit that the Industrial Revolution left us with many ills, brown fields together with social and workforce deprivations. Now "Green" is coming to the fore accompanied by "Sustainability." Are ideas of this nature germane for consideration in an engineering curriculum, or are they obsolescent but fashionable passing fads?

In fact, a review of economics history reveals many parallel concepts but perhaps with a slightly different vocabulary (and spin). Adam Smith (1723-1790), the noted Scots philosopher left an excellent trove of ideas relating to wealth creation and the societal importance of engineering methodologies for contributing to the quality of life. Jeremy Bentham (1748-1832),[1] a noted precursor of socialist ideas under the banner of "Utilitarianism" followed with an objective often expressed as the axiom *"It is the greatest happiness of the greatest number that is the measure of right and wrong"* In 1784 Samuel Gregg (1758-1834) opened Europe's largest cotton mill at Styal, near Manchester. David Dale (1739-1806) ultimately assisted by Robert Owen (1771-1858) followed in 1786 with a huge mill at New Lanark in Scotland. Both these mills were situated by rivers in pleasant countryside, away from the grime and pollution that accompanied the Industrial Revolution in the cities.[2,3] The new factories espoused the principles of Bentham providing housing, vegetable gardens and schools for employees and their families. Robert Owen was later associated with development of child labor legislation in the UK, he emigrated to America and in 1825 initiated a similarly integrated urban factory community at New Harmony, Indiana. This latter venture did not prove to be sustainable; however Styal and New Lanark maintained production successfully until 1959 and 1968 respectively. Both sites are now working museums producing product for sale, and New Lanark has adapted one former mill structure into a hotel complete with roof gardens.[2,4]

Thus, the idea of sustainable socially and environmentally acceptable industrial operations is not especially novel, or new. But in the intervening years since the eighteenth century there have been many changes in emphasis and priorities, not forgetting two World Wars, and at least one major depression. Companies in the developed world became very emphatically focused on exploitation of technology, generation of revenues and market share. Markets eventually expanded and gradually became global as both populations and wealth increased. Notwithstanding 3M's three P's program – *"Pollution Prevention Pays,"* of 1975, a main focus was the bottom line until perhaps the seventies. Then with an increase in imports from Japan the additional watchword became "Quality." For the eighties "Just-in-Time," then "Lean" in the nineties, with "Six Sigma" for this decade. Now we have sustainability in the same breath as Life Cycle Management (LCM) and "Green Manufacturing."

Sustainability enters the industrial vocabulary and the Lehigh catalog

A paper at a conference in Bangkok in 2002, *"Management Strategies for Sustainable Manufacturing"* was the author's first published use of the word.[5] Interest arising from the paper lead to the offering of an experimental course in the summer semester of 2003 and work done by three graduate students with an introductory overview was presented at a Society of Manufacturing Engineers Regional Conference in fall, 2003.[6] The concept of manufacturing as a wholly integrated system taking products (and/or processes) from 'cradle to grave' using resources and information to satisfy (even 'delight') customers while generating prosperity and wealth without occasioning trauma for employees, the host community or our planet was becoming more widely accepted.

The experimental course was next offered in 2006 and then submitted for approval and inclusion in the Lehigh catalog with intent of offering it every alternate spring semester. It acquired the number MSE482 and the title "Aspects of Sustainable Systems Design"

> MSE482: Aspects of Sustainable Systems Design - Design of sustainable systems for manufacturing that fulfill human needs and generate wealth. Demographic, ecological, economic, environmental, ergonomic, health, and global or local socio-political impacts on design and operation of future systems. Conservation of resources in the design, manufacture and use of products, processes, and implementation systems; life cycle engineering, reclamation, recycling, remanufacture. Research-based term paper required (3 cr.).

Course details

A seminal text by Hawken et al, *"Natural Capitalism – Creating the Next Industrial Revolution"* although published in 2000 remains sufficiently generic and forms an excellent basis for starting discussions.[7] Depending on enrollment students in the course are made responsible for reading one or two assigned chapters (of 15) from the text. They must then prepare presentations to inform the rest of the class what they discovered adding their own conclusions and recommendations. Meanwhile the course continues for fourteen nominal three hour meetings with analysis of relevant current events, engineering and manufacturing systems topics. Students are told that they are being regarded as analogous to employees in a factory where they must collaborate to generate discoveries and learning with the final product being a 'publication-ready' technical report.[8] In this vein students are encouraged to offer items on discussion forums and to develop "Discovery" presentations (or book reviews etc.) to enliven the classroom

proceedings. Voiceover Power Point files, or Elluminate© permit contributions and participation by remote students who may be as far afield as California, N. Carolina, Washington State, or Norway; contributions to the most recent class were also received from a faculty colleague in Japan.

Research papers generated by students in MSE482 in 2008 and 2010
2008
ISO 14001: A Global Approach to Environmental Awareness
Landfill Bioreactors "Garbage to Green Energy"
Commercial Building Sustainability
Naval Sustainability
Lead / Lead-free Sustainability in DoD Applications under RoHS Initiatives
Compliance as a Sustaining Strategy
Safe Drinking Water, and the Pharmaceutical Industry
Sustainability in Manufacturing Processes
Brownfield Revitalization – Pennsylvania
Sustainability Metrics for Bulk Chemical Manufacturing
Sustainable HR System Design: Implications for Recruitment and Selection of Engineers
2010
Department of Defense Renewable Energy Initiatives
Commercial Reactor Protection Systems
Sustainable Technologies in Treating Waste Water
Wind Power
Sustainability of Magnetic Levitation Technology – Applications and Considerations
Quality of Working Life
Fuel Cell Sustainability
Sustainability in Solar Energy
Sustainable Packaging in the Pharmaceutical Industry
Methane Gas production by Landfills: Feasibility and the Future
The Greening of Wal-Mart's Supply Chain
The LEED Program and Green Building
Commercial Greenroofs – Smart, Sustainable
IBM: Building a Smarter Planet Through Smarter Cities

Sustainability and undergraduates

A course, IE334 – Organizational Planning & Control (OPC), is offered every fall for juniors, seniors, and occasional graduate students. For several years the content has been focused on a variety of issues related to sustainability, including energy and food production. Students have individual assignments for about half of the grade, and the remainder is made up of team activities. The 'student-employees' are charged with collaborative team production of a series of research reports and finally a 'publication-ready' research paper.[8] After a preliminary initial team assignment based on examination and review of current issues afflicting industry and society using current news clips and e-newsletter information (from ASEE and other sources) as a starting point (see list). Each team prepares a presentation and executive report aimed at enlightening their colleagues. Subsequently teams are issued with a Request for Proposal (RFP)

seeking bids, ultimately developed into mission statements, project plans, and Work Breakdown Statements (WBS) for the final research output. In recent years the RFP has been focused towards the OPC of energy and food supply chain issues, including use of additives, factory farming, genetic engineering and multiple associated issues. Bids are constrained such that about half of the studies cover each topic area. Needless to say sustainability is a mandatory component of any teams' conclusions, and recommendations for future strategies in their chosen topic area.

IE334: Organizational Planning and Control – Design of organization and procedures for managing functions of industrial engineering. Analysis and design of resources planning and control, including introduction of change in man-machine systems, manpower management and wage administration. Prerequisite Junior standing. (3cr.)

IE334 first team research projects – fall, 2010: Presentations on 9/23, 28 and 30, 2010
'Food & Beverage Industry' - Review and expansion of a consultant's report
'Impending Disaster' – research on global food supply and poverty based on news items
'China and the Future' – GDP, growth rate, problems and forecasts
'Sweatshop Workforce' – arising from recent news, Foxconn issues and suicides in China
'Insufficient Plenty ' – further research on article in recent ASME magazine
'Future Employment' – expansion of issues raised recently by Andy Grove (Intel ret'd)
'Healthcare Factories' – exploration of possibilities raised by article in New York Times
'About Lean' – review and expansion of consultants report on topic
'About EV's;' – review of latest developments and status
'About Climate' – global warming, OPC status and strategies
'Fusion' – status, strategies and forecasts for our energy supply

This semester, fall 2010, with a record enrollment of first year engineers there are 212 students in the mandatory Engr5 "Introduction to Engineering Practice." The course is being administered and managed using a Moodle-based system.[9] The system enabled digitally dividing the students randomly into twenty teams of ten or eleven individuals that can communicate through a groups facility. Each group has been assigned a collaborative research task to assemble a two page executive summary of the status of a specific issue and their recommendations. Research tasks were taken from the NAE Grand Challenge list augmented with a focus on currently topical and high potential future issues with connection and relevance to sustainability. The Monday lectures give brief overviews on communication, team building, design, problem solving and project management plus being directed to studying related aspects of the text by Landis.[10] The Moodle-based Course Site Management (CSM) system is being used to monitor student activity, collect weekly 'Super Tweets' on current events, issue assignments, distribute materials, direct reading assignments to specific pages in the text and collate grades.[9] Forums are made available for the student posting of research output that can also be rated by their colleagues.

Engr5: 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. Prerequisite: None. Mandatory for and only open for first year RCEAS students. (3cr.)

Engineering 5 – Group Research Topics	
1. Managing the Nitrogen Cycle (NAE)	11. Solar – Thermal and/or Photovoltaic
2. Clean Water (NAE)	12. Solar – Harnessing the Tides
3. Carbon Sequestration (NAE)	13. Geothermal
4. Feeding the World – Opportunities	14. Biomass as an Energy Source
5. Poverty, Climate and Hunger	15. Algae – Future Fuel sources
6. Genetic Engineering – Crops/Animals	16. Fuels and Energy from Agricultural Wastes
7. Future of Oil	17. Electric Vehicles
8. Future for Coal	18. Ethanol, Butanol and other liquid fuels
9. Tar Sands & Shale – Possibilities	19. Urban Infrastructure (NAE)
10. Natural Gas, LNG etc.	20. Transportation

Summary and Conclusions

Sustainability is the latest 'buzz-word' – but it is different. It is a buzz-word that can be understood not only by engineers but also by most thinking individuals and society in general. Sustainability embraces Life Cycle Management (LCM), Total Quality Management (TQM), and it can be supported by "Kaizen" events, elimination of "Muda" (Waste) and Continuous Improvement efforts. It is commonsense and is really governed by forms of ecological and economic thermodynamics. It is certainly worthwhile to pay the topic lip service and offer separate courses with the word in the title, however, from an academic and philosophical viewpoint consideration of sustainability should be embedded in every engineering course as a most important feature integrated into every process and/or product design. In an ideal world sustainability attributes should become pervasive, alongside product longevity, quality, modular up-grades, reduction in wasteful consumption, re-cycling, re-manufacture or 'Equivalent to New' (ETN) reconditioning and greater economy with frugality. This takes us back 160 years or so to the 'Utilitarianism' of Jeremy Bentham[1] and the seemingly 'idyllic' village of Styal[2] and town of New Lanark,[3] but this is unlikely to happen. This would call for a major shift in present human behaviors, habits of acquisition and consumption. As members of society, and as engineers we need to become true conservators of materials and all resources while being effective evangelists for sustainability. New ways of adapting to using fewer resources much more efficiently must be promulgated not only for ourselves, but also for future generations and our planet.

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