AC 2012-4041: TECHNOLOGY IMPACT: FROM UTOPIA TO WASTE-LAND

Dr. Robert A. Heard, Carnegie Mellon University

Robert Heard is Associate Teaching Professor in the Department of Materials Science and Engineering. Past experience includes 17 years in industry and the past seven years teaching at Carnegie Mellon with particular emphasis on the engineering-based courses, including materials selection and capstone design courses.

Technology Impact – From Utopia to Wasteland

Abstract

A course entitled Materials, Energy, and the Environment has been developed and taught at Carnegie Mellon as part of the effort to educate our students on the intricacies of technologies impact on society, with particular focus on the environment. The course is structured to expose students to the basic science that has influenced the development of civilization and impacted society. Unlike courses that are structured to discuss the history of technology, this university listed course was developed and taught by the Materials Science and Engineering Department in the Carnegie Institute of Technology (CIT), our Engineering college. In one sense, it is a reversal of the typical flow of humanities education into the engineering school. It serves as a technology education outward into the humanity and science schools. There are no prerequisites and the course is open to all students of the university.

The course itself attempts to illustrate that material selection and applications have major ecological implications on energy consumption, material resources and environmental impact. These together, in turn, impact society. Society and social norms also have a tremendous role to play through consumerism. Awareness of the complicated interaction is paramount for continued advancement of civilization. With the scale of industrialization that exists on our planet, consideration of resource management, ethical material selection choices, energy management, and final disposal choices are all necessary to ensure a sustainable future.

Intentions

The idea that the course, Materials, Energy and Environment was developed with the intent of disseminating science and technology from the technical school to the general school population needs to be considered with the understanding that Carnegie Mellon is a bit unusual in our educational programs and that our students are perhaps an unique subset of the university student population. At Carnegie Mellon, we attract students who are generally proficient in technical skills and STEM subject matter. The school educational platform is also rather open and thus offers many multidisciplinary combinations of education which allows cross degree program between humanities and technologies and the sciences if desired.

Previously, a study at Newcastle University had proposed that humanities students avoid technology and science courses for the reasons listed below; [1]

1. little exposure to scientific content
2. differences in modes of teaching delivery between humanities and science subjects
3. perceptions of the relevance of scientific evidence, or lack of it
4. intimidation by what is considered the inflexible logic, or use of numerical or tabular data in science
5. difficulty of technological concepts
6. institutional obstacles, such as the organization of universities in subject based departments

In addition, an attempt was made to determine if resistance to science in the humanities is caused by a combination of the belief in the "two cultures" divide as well as the institutional organization of the education system and pressures from society. Recommendations, to work around these issues were to strip the concepts of mathematics and abstract notions and transform them into narratives for integration into humanistic discourse. The study also notes that

> "*Environmental topics serve to bridge this divide quite effectively. The subject matter is relatively easy to research and certainly there are no shortages of emotional or humanistic comments available for analysis."*[1]

Bridging the two cultures needs to be accomplished via a two way street. In the technical college (CIT) we have embraced a broad focus on humanities. Our engineering students in their undergraduate education must take a minimum of eight humanity based courses, three of which must form a depth sequence of which at least one course in this sequence must be taken at an advanced level. These are not math, computing or technical business courses, but true humanity offerings. The belief is that a balanced curriculum provides the best education for our engineers.

The reverse flow of having humanities students study technical courses is not as widely practiced. Part of the hesitation for humanities students coming into technical course is the requirement of specialized knowledge, most often in mathematics or in the sciences. For humanity students, fewer course offerings in technical fields are available as options because of these limiting requirements. This was recognized as one obstacle that needed to be addressed by carefully choosing the course topic and content. For this particular course, a historical and social reflection of the use of materials and was planned. We do not avoid numbers or analysis, but present these in ways that underline the conceptual point of discussion.

With Materials Science and Engineering, the subject itself carries great breadth dealing with high technical and specialized science through areas of business and impact. It is the latter portion of the field that seems to be well suited to use as a course for humanities students. Here we are discussing materials, applications, and business at a level that impact society in topics such as material resource selection, design, environmental impact, and recycling.

Students

To broadly generalize, most all students come into the course with a narrow view of the complexity of these subjects. They have in a sense, an "Utopian" view either embracing the environment and not considering the necessity of industry and economy, or they embrace technology and have not fully considered market driven nature of the economy, nor the full impact of technology decisions and operations.

Historically, this course attracts the humanities students that have interest in environmental issues and are seeking an understanding of how technologies and science are influencing the way and how we live. It also attracts the engineering or science student that seeks to understand the impact of their chosen field of study. The course, Materials Energy and The Environment, is open to all students and as a result we usually have a mix representing several colleges and certainly multiple disciplines. It attracts a significant number of incoming freshmen

from the humanities and pure sciences, and a roughly equal distribution of students from the schools for architecture, design, business, and engineering.

The course usually does not have to bring environmental awareness to our humanities students. It does however, have to bring order to their thoughts, moving them from a more idealistic based toward the more structured and logical technical world. In the teaching of the course material, the desire is to remain neutral and non-biased, no attempt is made to promote or demote any issue or viewpoint. The course presents all issues and offers them for consideration by the students. It is by default a slightly pro-environmental course because of the overarching desire to have students conceptualize necessary steps required to move toward sustainability or sustainable development.

Course Content

We began to build this course under the assumption that many (not all) of the humanity students will have an Utopian view of the environment and no understanding of the technological "realities" of industry, society or economy. This assumption has not proven to be fairly accurate as many of the humanities students are freshmen in their first semester at the university. To be able to provide a course that was acceptable by students of both cultures, a framework was developed that would allow the topics to be classified and taught in progressive content sections, each of which would encompass a certain depth of interaction from the students. In defining these sections, the extent to which students could relate to the course itself and the potential for discourse between the technically oriented students and the humanities students on any particular topic was considered. To encourage engagement the course was structure to address broad topics early and then begin to dissect these in more detail as the course progressed. Conceptually, the three sections progress as; 1) the global influence of technology on society (Societal Level Impact) , 2) how technology and people interact (Human Level Impact), and 3) the reasons and personal level drivers for interaction (Personal Level Impact).

Societal Level Impact

Since all students have some limited knowledge or belief of how society and technology co-exist, we begin our course with the influence of technology on society. Topics are general, and grand in nature. These topics tend to be illustrative of current or known issues or are providing background to more complicated topics by discussing large scale and broad interactions and trends of technology within society. The course began by examining the personality traits as they relate to environmental issues. We start here because every student should recognize how personal views taint the view and the actions each of us take towards the planet. This deliberately non-technical discussion allows every student to participate in the discussions and feel comfortable interpreting or debating data, understanding the view and that others may come from a entirely different reference.

Usually, from these general discussions, it becomes apparent that for deeper excursion, some form of measure and process understanding is necessary. This leads into the topics of how to measure material movement, energy, and thermodynamics. While materials are simple, energy use and the concept of entropy require introduction. Conscious that this is the type of block that could turn off humanity students, this is taught by careful use of examples not with equations.

Reference to energy and entropy continues through the course so conceptual understanding is necessary but students do not really need to have to derive the mathematical representation of thermodynamics. It is sufficient to know the direction of energy movement, conservation, the relative magnitude, and the different ways we measure and report these measures.

The first excursion into the impact of science and technology begins with material flows through the current economy. To get a relative feeling of the magnitude of the issue, the increasing use and sophistication of materials is presented along with the progression of man (society) from the stone age to present time. This history also serves as a "comfortable" topic in which energy and thermodynamics can be reinforced through examples and discussions of the continual sophistication of material processing. Energy fuels are also examined as materials in a similar manner to understand the available types of energy and that energy and material flows are measurable and are tied directly to the economy. The last broad topic we discuss is the economy where the technological impact made on society is explained through the development of an economy for trade, markets, and empires. In this topic, the use of GDP is debated and several internationally accepted index measures of prosperity and living standards are presented.

To develop some understanding of society's use of materials, student work involves the researching of a material flow stream from extraction to use by society and preparing a presentation to the class on the material. In this work, we are looking for the students to make a realization that materials flows are large, global, and energy intensive and that society is dependent on the continual conversion of raw material to useful products.

Human Level Impact

As eluded to earlier, as the course moves from broad topics, more emphasis is put on analysis and data. To analyze the impact of technological processes and to be consistent when judging material and energy flows, the course discusses and draws continual reference to the tool of life cycle analysis (LCA). The concept of LCA is worked through as a class exercise and the technical burden can be shared in group activities. Once the students have a working understanding of how inputs and outputs are accounted in LCA, we question sustainability and sustainable development of these material and energy streams. As the topic moves into sustainability discussions, the ecological footprint is introduced. The ecological footprint tool was chosen as it is an easily visualized concept and with web-based programs, it can be a simple tool to illustrate current lifestyle issues and the gaps between current conditions on the planet and sustainability goals. As the timing of this section works out to be when students are returning home for a semester break, an assignment is given to use the web-based ecological footprint program to evaluate their families lifestyle and collect information concerning accuracy and possible errors in evaluations. The discussion in class usually turns out to be a very interesting exercise due to the global nature of our student body. The intent of this exercise is to connect the student to the human issues of our chosen lifestyle and illustrates some of the unplanned consequences of our actions or choices.

As we move deeper into sustainability, we begin to discuss IPAT variables and connect issues with population, affluence, at technology level. Here we again go deeper into these

variables, specifically population distribution, and affluence. As we do so, we extensively look at consumerism and its' impact. All of these impacts are taken at a very personal level by the students and thus we really begin to see the two cultures dominate interpretation and discussions. Students have now attained enough awareness and understanding of the complex issues and the course reaches its darkest point in the difficult realization of environmental impact.

Personal Level Impact

For students, the technology - environmental impact or potential "Wasteland" scenario impacts them at very personal level. To learn and incorporate information from outside their chosen discipline at a personal level is a difficult type of learning as it usually requires an uncomfortable comprehension of new data or a new awareness. In this course, the impact of consumerism and the potential of generating a "Wasteland" is related to our personal and societal demands and through the need to produce goods for a market economy. The coverage of this does not need to be at a deep technical level. The consumer market is linked to material and energy through the activities covered in the LCA framework and the personal ecological footprint. The connection between the market place and the impacts made on the planet becomes more personal and we examine personal choices and impacts we as people can make, as part of industry, government or as just as part of society. To conclude the course, we explore new business concepts, technology improvements, and engineering practices that can be used to help alleviate the current crisis if consumers buy into these changes (service concepts, material selection techniques, green design and recycling) and illustrate the tools that technical specialists may use to select materials based on properties for performance, choices in process (such fuels and options for reuse, recycling).

Expected Outcomes

As the course progresses over the semester and moves the student from their "Utopian" outlook to a view where they can foresee the potential for possible "Wasteland" associated with our non-sustainable lifestyle, students need to show an understanding of the economy pressures, industry constraints, policy directions, and consumer wants on the material and energy use intensity. We attempt to evaluate their ability to recognize the connections between and the impacts resulting from the flow of materials, the influence of lifestyle choice (deliberately chosen or default) and their personal choices as consumers. Students must be able to dissect and recognize the complex interactions that make up this technological driven industrial economy. In the final analysis, it is expected that students be able to apply a system boundary to a problem, break it down into measurable flows and issues, then wade carefully through the available information (internet and scientific research) to reach a hypothesis and statement concerning the problem within the system boundary. In presenting their hypothesis, arguments pro and con must be considered and appropriately presented. This is measured through an final written document based on a material, energy issue, or environmental issue of their choice. The students learning outcomes are evaluated using the Critical Thinking Rubric [2].

References

1. Oosthoek J, Teaching science in a humanities context , Final project report , School of Historical Studies, HaSS Faculty Teaching Fellowship , Newcastle University, 2007
2. Critical Thinking Rubric from Assessing Outcomes and Improving Achievement: Tips and tools for Using Rubrics, edited by Terrel L. Rhodes. Copyright 2010 by the Association of American Colleges and Universities." last accessed 3/13/2012, http://www.aacu.org/value/rubrics/pdf/CriticalThinking.pdf