2006-1822: FRESHMAN COURSE ON SCIENCE TECHNOLOGY AND SOCIETY

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FRESHMAN COURSE ON
SCIENCE, TECHNOLOGY, AND SOCIETY

Abstract

The paper describes an interdisciplinary freshman course offered in Frostburg State University to discuss the interactions of science, technology, and society. The course was developed in summer 2005 as part of the general education program mainly for non science or engineering majors.

The course introduces the main characteristics of scientific investigation and engineering design problems through various applications of technology that have transformed the modern society. The outline of the course, teaching approach, materials, and class activities are presented with examples. The experience gained in the first and second semesters is discussed.

Introduction

The continuous change of the modern society driven by science and technology has motivated higher education institutions to develop curricula to enhance the scientific reasoning skill and technological literacy of students in all majors.

In Frostburg State University an interdisciplinary course titled "Science Technology and Society (IDIS 160)" was developed with the motivation of the Undergraduate Education Initiative (UEI) [1] approved by the Faculty Senate in February 2005. IDIS 160 is designed as a pilot freshman course for mainly non-science/engineering majors to meet the new general education requirements.

The main purpose of the course is to introduce the "models of research, the development of science and technology, and the application and subsequent impact of the developments on society and the environment." The course goal is consistent with the FSU general education program, which specifically focuses on the development of students' core skills in scientific reasoning to "demonstrate foundational abilities to apply different methods of inquiry from various perspectives and disciplines to gather information."

A planning group[1] consisting of five faculty members representing the biology, geography, chemistry, physics, and engineering programs and the Assistant Provost developed a generic course description and identified the course objective and outcomes. The course was offered for the first time in fall 2005 in four separate sections, each focused on a special theme related to the discipline of the faculty teaching the section. These themes are listed below.

- Section 001 – Social Transformation (Physics and Engineering)
- Section 002 – The Energy of Life (Biology)
- Section 003 – Energy and Its Implications (Chemistry)
- Section 004 – What is Earth? (Geography)

This paper describes the contents, teaching approach, materials, and class activities of the section 001 focused on the social transformation created by science and engineering.

An Overview of STS Education in the USA

N. A. Byars [2] refers to the essay *The Two Cultures* by C. P. Snow published in 1959 noting that “a dangerous chasm divided scientists and engineers from literary intellectuals, creating two cultures unable to communicate across the divide.” In fact, many academicians agree on the fact that science and engineering majors are usually more likely to know about the humanities than the average humanities major knows about sciences and engineering. Effective communication and understanding between members of the society with different educational backgrounds is crucial in making better technological decisions that will impact the everyday life, culture, environment and the future generations.

The idea of offering a course on science, technology, and society in general education curriculum for non-engineering students goes several decades back. In late 1960s and early 1970s many institutions in the USA started to develop technology literacy courses (TLC) for students in majors other than natural sciences and engineering, leading to “Science, Technology, and Society-STS” programs. Engineers and scientists have been prime movers in developing interdisciplinary STS curriculum for liberal arts studies. A general overview of TLC programs in American colleges is presented in [2].

Art Hobson [3] points out alarming statistics of 1990s reflecting the science education at pre-college and college level. He states that “*Only 21% of our high school students take any kind of high school physics course, let alone a course that includes socially relevant topics. It is depressing that only 20% of all elementary school science teachers have taken any college physics course, and only 35% took a college chemistry course. And a survey of 1800 college campuses indicates that only 50% of the nation campuses offer any kind of physics course for non-scientists…*”

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[1] Planning group for the establishment of criteria for basic proficiencies in scientific reasoning: Frank Ammer (Biology), Tracy Edwards (Geography), Scott Fritz (Biology), Robert Larivee (Chemistry), Oguz Soysal (Physics and Engineering), Jim Limbaugh (Assistant Provost).

A number of recent publications describe new models for STS oriented courses or programs for liberal arts students in various institutions including University of Dayton, OH [4], Miami University, Oxford [5], North Carolina State University [6], University of Texas at Austin, TX [7], and DeVry University, Addison, IL [8].

The national trend in accreditation of higher education institutions in the USA leads to an interdisciplinary curriculum to enhance technological literacy and scientific reasoning for all majors. In most of the colleges, the only way to ensure the exposition of liberal arts students to the fundamental concepts of science and engineering is the general education program.

The accreditation standards of the Middle States Association of Higher Education require that an institution's general education program be designed "so that students acquire and demonstrate college-level proficiency in general education and essential skills" including skills in scientific reasoning. The Maryland Higher Education Commission has consequently mandated that all higher education institutions in Maryland establish specific definitions and benchmarks regarding seven basic skills that consist of scientific reasoning, written communication, critical thinking, quantitative reasoning, oral communication, technological literacy, and information literacy [1].

Outline of the Course Content

The generic objective for all sections of STS set by the Planning Group is "*to gain an appreciation of Science and Technology and its impact on society and the environment*." The following outcomes were defined by faculty members developing different sections of the course:

- Understand the interdisciplinary nature of science and technology
- Understand the scientific method
- Understand science and technology and their interaction
- Understand the impact of science and technology on society
- Understand the major concepts of science behind technological innovations
- Discuss current issues involving science and technology

The physics and engineering section of the STS course described in this paper is focused on the "Social Transformation" that has resulted from scientific discoveries and engineering applications. The interactions of science, technology and society are discussed from an engineering perspective. On the one hand, the needs of the society are driving forces behind engineering, which requires the knowledge of math and sciences to develop solutions. On the other, engineering solutions usually have social, economic, and political consequences.

The lecture topics are outlined below.

- Introduction
- Science, Engineering, and Technology
- Interactions of science, technology, and society
- Forces and structures

- Motion and machines
- Energy
- Heat and temperature
- Energy sources
- Crossing America
- Electricity
- Chemical reactions and processes
- Networks

The course is delivered in 3-credit lecture format integrated with lab and team activities. The duration of the course is one semester. The textbook “Integrated Science” by Tillery et al [9] was adopted for the first year offering of the course. Since the textbook mainly addresses only the “science” portion of the course, additional handouts and slides were developed by the instructors to cover the “technology” and “society” components.

Teaching Approach and Perspective

The section developed and co-taught by the authors mainly focuses on the interdisciplinary nature of science and engineering and the social impacts of engineering applications. Rather than presenting a sequence of principles fostered by different disciplines, the course emphasizes that most scientific concepts and engineering applications were developed as a response to specific needs of the society. The problems to be solved by a scientist or engineer usually require knowledge of different disciplines. The course discusses the differences between the scientific investigation and engineering design methodologies and the interactions between science, technology, and society.

Billington [10] introduces the concept of social transformation and states that the nature supports the civilization through “Structures, Machines, Networks, and Processes.” This approach does not distinguish different fields of engineering as isolated disciplines and simplifies understanding of the interactions between engineering and society.

Examples of structures are bridges, towers, dams, and industrial plants. Machines are needed to convert energy from one form to another. Networks such as roads, electric circuits, traffic, and communication links connect individual elements. Processes are essential to transform natural resources into materials, fuels, and supply. A modern society cannot function properly if anyone of these components is missing. Figure 1 shows the interactions between mathematics, sciences, engineering, and society. The diagram illustrates the role of engineering as a bridge between basic sciences and society using the four basic components. This approach does not distinguish between engineering disciplines and highlights the interdisciplinary character of most technological applications.

Most of freshman students are somehow familiar with the scientific approach thanks to high school science courses and science fair projects. However, the concept of engineering design and differences between science and engineering are usually not discussed adequately at high school level.

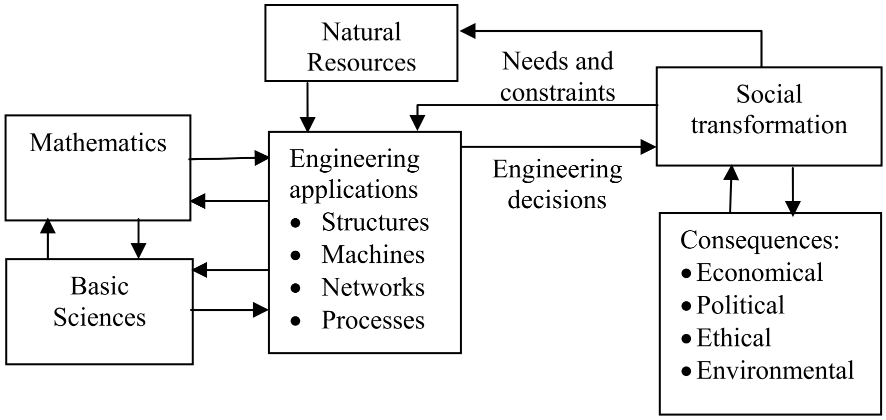

Figure 1 Block diagram illustrating the interaction of mathematics, basic sciences, technology, and society through social transformation

The course starts with a discussion of the scientific methodology. The main characteristics of sciences are explained and differences between science, non-science, and pseudo-science are discussed. The Planning Committee defined "scientific reasoning" as shown in the textbox below to establish a common ground for assessment of the course outcomes. Understanding of the scientific method is important for development of core skills in "scientific reasoning." On the other hand, the discussion of scientific methods provides a background for the comparison of science and engineering covered in the second week.

Scientific Reasoning

Scientific reasoning is the ability to logically solve problems through the application of the scientific method which includes: Problem identification/observation; inductive and deductive reasoning; hypothesis generation; experimentation; interpretation of results; making logical conclusions and critical evaluations."

Following the discussion of the scientific approach, the characteristics of engineering design problems are presented. The role of engineers in applying math and sciences to develop practical solutions for the society is discussed. The definition of engineering design shown in the textbox below constitutes a basis for this part of the course.

Engineering Design

Engineering design is application of mathematics and basic sciences to build a component, device, system, or process to meet given needs under realistic constraints.

Social transformations in the context of structures, machines, networks, and processes were presented with relevant examples of modern engineering. The "Industrial Revolution" is perhaps the most significant experience of the modern civilization. The history of industrialization and its impacts on the social structure is included in the course.

Throughout the course, students learn the concepts of physics such as force, work, energy and power starting from everyday applications that have changed our lifestyle. They use basic mathematical expressions to understand the meaning of physical concepts. Chemical reactions used to extract engineering materials such as iron, steel, aluminum, and copper from ore are briefly introduced. Technical, social, economical, environmental, and political issues related to modern engineering applications and the use of natural resources are discussed. Available alternative energy sources such as nuclear, hydro, wind, solar, geothermal, biomass are presented with discussion on their current use and conservation of natural resources.

Course Materials

In the search for a textbook suitable for the level of the course, the authors surprisingly could not locate a title covering all intended course topics in one volume. Several books titled as "Science, Technology, and Society" ([11] and [12]) are written from the sociological perspective and place more emphasis on social issues. On the other hand, "Integrated Science" texts such as [9] and [13] address the scientific methodology and fundamental concepts of natural sciences; they do not, however, cover the engineering design approach and engineering principles. Introductory level texts on engineering design such as [14] – [16] are written to introduce the foundations of the engineering profession and basic skills needed for engineering majors. Billington [10] introduces the concept of social transformation and discusses interactions between engineering and society. However, a discussion of the scientific methodology and fundamental concepts of natural sciences are beyond the scope of this book.

Facing the challenge posed by the lack of a suitable textbook, the authors decided to adopt Tillery [9] and cover the additional topics by course materials compiled from the texts referenced in [10], [14], [15], and [16]. Slide shows containing relevant visual materials were developed to show that mathematics provides a common language and computation tools for science and engineering while similar scientific concepts can be used in different engineering applications. All slide shows were posted on the Blackboard® course site for students' access after class.

For example, following the discussion of the scientific approach based on the first chapter of Tillery [9], the engineering approach was introduced using slide presentations showing major engineering applications, scientific concepts used in these applications, and their social implications. Figure 2 taken from the course slides illustrates a comparison of scientific investigation and engineering design methods. While studies of basic sciences are usually driven by engineering applications to provide a knowledge basis to solve specific problems, they may not have commercial value. Engineering design work, however, is based on customer needs, marketing, and entrepreneurship. The major issues that differentiate engineering from science are feasibility, cost, and manufacturing. The slide presented in Figure 3 illustrates this difference in terms of fundamental units. In fact, the money unit is an inevitable element of the design calculations.

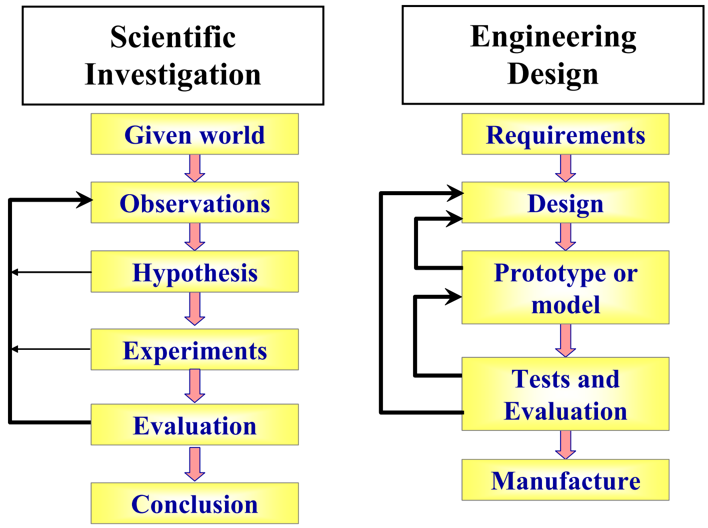

Figure 2 Comparison of scientific investigation and engineering design methods

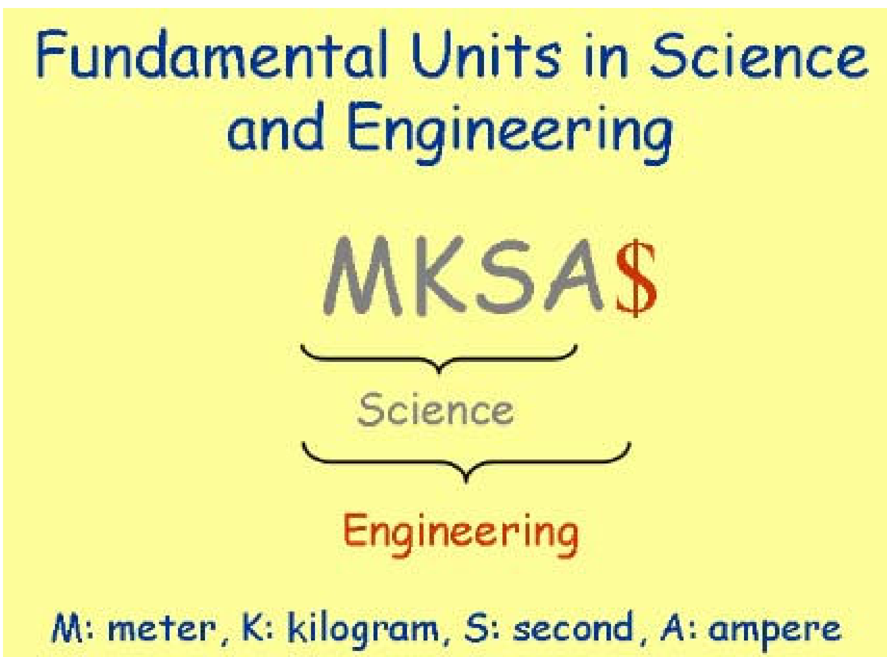

Figure 3 Slide highlighting the difference between science and engineering

The video productions listed in Table 1 were used as support material in the course to illustrate major engineering achievements. A specific quiz was prepared for each video show to check the students' comprehension. Students were asked to answer the quiz questions as they were watching the program. In addition, they were required to write an essay as homework assignment to discuss the socio-economic causes and effects of the presented issue. The essays were posted on a Blackboard® discussion board to stimulate intellectual interaction between students.

Table – 1 Video productions viewed in class

Title	Publisher
Triumph of the Nerds: An Irreverent History of the PC Industry	Ambrose Video Publishing, INC. ambrosevideo.com
Industrial Revolution	Educational Video Network, #1724D, edvidnet.com
What is Energy	Educational Video Network, #1184D, edvidnet.com
Global Warming and the Greenhouse Effect	Educational Video Network, #1686D, edvidnet.com
Ridin' the Rails – Johnny Cash	Webster/Rivkin Production, 1974
Panama Canal	PBS
Lightning	NOVA
Hoover Dam	PBS
Electric Nation	PBS

Class Activities

In fall 2005, 14 students were enrolled in this section. The small class size was helpful to establish an interactive class setting. The class was scheduled in three 50-minute meetings per week in a conventional lecture room equipped with a computer and an LCD projector.

After the introductory section on the characteristics of scientific investigations and engineering design problems, each week was dedicated to a specific topic related to the evolution of modern technology. During one hour, two instructors made a joint presentation using highly visual support materials. One class meeting was allocated to a guided video show or class discussion on the topic. During the third class meeting of the week, students were engaged in an inquiry based team activity such as case study, experiment, or design work. For lab experiments, either portable experimentation sets were brought to the classroom or the students were taken to a laboratory to watch demonstrations such as electro-mechanical energy conversion, renewable energy, and properties of sound.

The experience gained in the fall semester showed, however, that a traditional classroom setting was not convenient for this type of course due to the limitations to engage the students into inquiry based learning experience. In spring 2006 the class was scheduled in a physical science lab with 24 seats for two 75-minute long meetings per week. This schedule allows more time to finish lab experiments, simple design activities, case studies, and video presentations followed by guided discussions.

By taking advantage of the lab setting, new hands on activities were developed in spring 2006. The experiments were designed to enhance students' scientific reasoning and engineering design skills.

Case studies were developed to engage students in discussions on real life problems involving interactions of science, technology, and society. Figure 4 shows an example to engage students in a real life problem that requires scientific reasoning to solve a social problem with environmental implications. The "hypothetical" letter of Figure 4 was given to six teams of four students to develop a research plan and outline a proposal. Another case study was given to discuss the environmental implications of electric generation using wind turbines in Western Maryland.

Additional activities consist of class work, homework assignments, quizzes, tests, essays, online discussion through Blackboard© Forum, and term paper. The homework topics assigned through 2005 fall semester are shown in Figure 5.

Dear Mrs. Soysal,

Several deer-related highway accidents were recently reported to our office in Western Maryland. We are extremely concerned about the death toll and injuries in these accidents as well as the costly damage to the vehicles. Some area residents claim that the deer population has significantly increased over the last few years while some other residents say that the population has not actually increased, however deer herds coming to the highways more frequently than before are the main reason for the accidents.

The local highway authority is soliciting proposals for a scientific research project to investigate the reasons for the accidents and develop a humanly and ethical procedure to reduce the risk of accidents involving deer on the highways. We are also aware of the importance of the ecological balance and don't want to cause the deer population vanish in the area.

Please submit a proposal that includes the following information:

1. Proposed qualitative observation and data collection strategy to investigate the causes of reported accidents
2. Outline of the proposed scientific method to estimate the deer population in the area and determine the rate of change over a reasonable period of time
3. The proposed hypothesis and method to test the hypothesis
4. Outline of the strategy to control the number of deer coming across the highways
5. Discussion of the possible environmental implications of the proposed strategy

We are looking forward to your proposal.

Sincerely,

John Doe,
Western Maryland Highway Safety Manager
15 Maryland Street, Maryland

Figure 4 A hypothetical letter describing a case-study problem

Homework 1: By using Microsoft word, write an essay (one or two pages) about the impact of using PC in your life. Please discuss advantages and drawbacks based on your experiences.

Homework 2: Please write an essay about "Industrial Revolution" and post it on the discussion board.

Homework 3: Please write an essay about "Trains and the transportation network in the USA" and post it on the discussion board.

Homework 4: Solve the problems from 1 to 6 (included) on page 46, Group B.

Homework 5: By using Microsoft word write an essay (not less than 500 words) to discuss the pros and cons of obtaining energy from wind, solar radiation, oil and coal.

Homework 6: Please write a comprehensive essay and analyze the features of the engineering marvel Hoover Dam in terms of

- structures
- machines
- networks
- processes

Figure 5 Homework assignments

Conclusion

The pilot section of the Science Technology and Society course described in this paper has met the objective set by the planning committee. In fall fourteen students, in spring twenty three students were enrolled in the section. The students developed scientific reasoning skills through inquiry based class activities. They also discussed major engineering applications that transformed the modern society. The experience gained over the first semester showed that a lab setting is more convenient to include more hands on and experiential learning activities. The course will be offered every semester as part of the general education program to expose an increased number of liberal arts students to science and engineering methods. Due to the lack of a comprehensive textbook covering such a diverse content, additional course materials were developed to introduce major engineering applications and their social impacts.

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