Hope College: Science and Technology of Everyday Life
Instructor: John Krupczak

Background: Engineering at Hope College

The engineering program at Hope College began as an “engineering physics” degree option offered by the physics department. Due to gradually increasing student interest, and significant enthusiasm and support from two successive Hope College presidents and graduates (who were not themselves engineers), a BS Engineering degree achieved ABET accreditation in 1999 at which time the physics department, which had been housing the engineering program, became the Department of Physics and Engineering. Currently there are seven full-time tenure or tenure-track engineering faculty, about 100 students enroll as freshmen, and in 2016, the engineering department will graduate 62 students.

As is the case with engineering at liberal arts colleges everywhere, the program is fully integrated onto the campus with students of engineering sharing dorms and interacting with liberal arts (and nursing, another applied program). At the time of this writing, 30% of the engineering undergraduates were women and *both* the president and the vice president of the Hope Student Government were engineering students.

From the point of view of the faculty, the course Science and Technology of Everyday Life is not a place to recruit engineering students. The prevailing view is, rather, that it is a good thing for an engineering department at a liberal arts college to be ‘engaged’. In fact, at Hope, engineering is not “segregated” as is so often the case at large state universities. Engineering majors have to meet *all* the liberal arts requirements that students in other majors have to meet.

Origins

John Krupczak, a mechanical engineer and member of the engineering department at Hope College regularly teaches “Science and Technology of Everyday Life,” (a course he originated in 1995) to non majors, twice yearly, in the spring semester and in an intensive “May Term.” The course surveys the structure and function of modern technology from a systems-thinking perspective both because “systems thinking” illuminates specific technologies Krupczak wants his liberal arts students to become familiar with and as a way for non-engineers to appreciate how engineers think and work. Krupczak’s goal is to educate and to empower non-majors, but he is also contributing to the technology education of future generations. That’s because his course is required for science education majors and is selected by many elementary education majors as well.

The proximate impetus for the introduction of Science and Technology of Everyday Life at Hope College was the desire of Jim Gentile, then, the Dean of Natural and Applied Sciences, to spread the responsibility for teaching general education science courses more evenly across the departments in his Division. In the 1990s, the workload was being borne disproportionately by the biology department, pressured to teach an ever increasing number of sections of Biology 100 General Biology or “Baby Bio” as it was known.

John Krupczak was on a one-year visiting assistant professorship of engineering at Hope at the time. A former member of the technical staff of the then recently cancelled Superconducting Super Collider Laboratory in Waxahachie, Texas, he had taken the temporary position at Hope as one of the many SSCL academic refugees.

Krupczak was himself a graduate of a liberal arts college and his interest lay already then in creating a survey of engineering and technology course open to all students, analogous to the Survey of Art and Architecture (Art 101-102) course he had taken while an undergraduate at Williams College. Like Art 101-102, the course would encompass a range of examples to provide an overview of major topics and themes. When their convergence of interests was recognized during a hallway conversation, Dean Gentile provided a small supplies budget, and “persuaded” the physics department chair to support the endeavor. Krupczak began to teach “Science and Technology of Everyday Life” for the first time in Spring 1995.

Science and Technology of Everyday Life

The course is a semester-long 4-credit course with 3 hours of Lecture and one 3-hour laboratory per week. The course fulfills the general education laboratory science requirement for Hope College students. Major course themes encompass technologies familiar to students and which define and enable daily life for most people in the United States today: the automobile, home appliances, audio and video technologies, communications, aircraft, and computers.

The instructor especially wants his students to become familiar with and to appreciate “systems thinking” as an aspect of liberal education. And so he begins: Systems are made up of individual components that provide specific functions that are based, in turn, on underlying natural phenomena (science), with behavior typically modeled using mathematics. The electric motor is one of several examples of the greater utility provided by the assembling of component functions. Technological systems, like the automobile and the electric grid, in turn, have to be understood in their interaction with outside systems: social, cultural and economic.

While Krupczak is the main lecturer, labs are typically managed by other professors in engineering.

Assignments and Evaluation

A typical course enrollment is 50 students in a single lecture section with two laboratory sections per week. The text is David Macaulay’s, *The New Way Things Work,* supplemented by considerable amounts of course notes provided by the Instructor and additional readings.

Assignments and evaluation take the form of quizzes, homework, class participation, laboratory reports, and several 3-5 page papers. The instructor finds that frequent quizzes promote acquisition of vocabulary and familiarity with basic definitions. (Generally, quizzes test the lowest two levels of Bloom’s Taxonomy: remembering and understanding). Not unlike studying the biology of living systems, understanding the engineering of technological systems goes better when students acquire some fluency in their appropriate use of relevant terminology.

Class participation generally takes the form of in-class mini-labs during lectures. These primarily revolve around underlying physical phenomena employed in technological system components. Evaporation, electromagnetic induction, joule heating, sound, and optical refraction, lend themselves to simple but compelling activities that can be carried out with inexpensive basic materials by students working in small groups in the classroom.

Through homework assignments that introduce students to system-level diagrams, students learn how engineers analyze and, when needed, modify systems or subsystems. Homework also affords an opportunity to probe student thinking through reflection or reaction assignments.

A significant fraction of student effort is invested in several 3-5 page papers. As described in more detail below, assignments are designed to allow an in-depth analysis of a specific subject within the major course topics. Some flexibility within the broader outlines of the assignment encourages students to align their paper assignments with their individual interests. The instructor has found over time that papers are a better and a more familiar way to engage liberal arts students than hour exams.

Enrollment spans the gamut of Hope College liberal arts majors. The course enjoys a strong following from majors in fine arts, management and economics, elementary education, English, and religion. The ratio of male to female students in the course follows the overall gender ratio of the institution.

Example Topics

The Automobile: Understanding its 15,000 parts.

The automobile section starts by posing a question: If a typical automobile has 15,000 individual parts, how is it possible to understand all these components interacting to achieve a specific function? This introduces a fundamental aspect of an engineering system: as facilitating both engineering design and the analysis of complex technologies.

In fact, an automobile is comprised of (only) seven *major* systems: the engine, powertrain, brakes, steering, suspension, electrical system, and the body. Each major system in turn is composed of subsystems: the engine, for example of fuel and air, exhaust, cooling, lubrication, ignition and starting systems. Thus, as is characteristic of most technology, the 15,000 component automobile is really a set of nested systems within systems.

A typical take-home assignment for this section is a 3-5 page paper analyzing a problem a student once *personally* had with a car. The assignment is meant to focus on the material students have acquired about the automobile focused on one specific instance. Which were the system and subsystem(s) involved? Which, the specific components? How did the component(s) fail and why? How did the failure lead to the symptoms or outcome? What needed to be done to repair the problem and why? What could have been done to avoid this problem? What lessons can be extracted from this experience? Students are encouraged to make use of internet sources (such as autozone.com).

Student quote:

> *Prior to this class, I thought of the car as being one big machine working to make the car go and stop….however I've come to realize the car is numerous systems all with their own purpose working together to make the car function…*

Home Appliances: A motor, a heater, or a motor and a heater

Home appliances illustrate groups of related systems, or what are sometimes called technological domains around a set of components, which share common underlying scientific principles. Most home appliances rely on an electric motor (for example a blender), an electric heater (a toaster) or a heater and a motor combined (a clothes dryer). In general, home appliances are in a class of technological systems whose primary function is to convert energy from one form into another: electrical into mechanical (blender) or into heat (toaster), replacing in each instance human muscle power.

When they learn to associate a portion of the physical form of a technological system with a well-defined task, students are learning functional analysis or functional decomposition. Functional analysis can be mapped to show, for example, how the overall purpose, such as spinning the blades of blender, is achieved by system components. While traditionally taught to engineering seniors (Otto and Wood's *Product Design*, Ullman's *The Mechanical Design Process*), the subject does not really require extensive prerequisites. Functional analysis is highly visual, and, as a result, accessible to liberal arts students.

Meanwhile, in the laboratory, students are learning to disassemble and reassemble several home appliances. In the process they identify the main components and create functional analysis diagrams of each device. Students eventually learn to construct an electric motor from simple components.

In their paper assignment for this section students are asked to identify a home appliance (not analyzed in class) that they might like to buy and to analyze how it works, a description that must include a functional analysis diagram. Surprisingly, vacuum cleaners seem to be the most frequent choice. One enterprising student enlisted several friends in the course to help determine choices in her wedding registry.

Communications Technologies: Semaphore and Carrier Pigeons

Audio and video communications technologies are pervasive in daily life as are rapidly evolving technological systems. A major challenge for students in this section of the course is to sort out constituent elements using the basic structure for technology systems transferring information. All information systems consist of encoding of a signal onto a carrier, transmission via the carrier, and then decoding of the signal at the destination, all derived from earlier methods of communication over a distance, such as semaphore, signal flags, bugle calls, Morse code, or even the use of carrier pigeons. Topics include the nature of audio and video information along with the difference between analog and digital information and signals.

Their assignment: In a series of laboratory projects spanning several weeks, students construct a simple audio amplifier, a primitive radio, and design and construct an electrodynamic speaker.

Introducing the Decision Matrix

Engineering claims to embrace *problems of decision making under constraint* and such a practice is incorporated into this section. The array of options available to consumers of audio, video, and telecommunications technologies can be overwhelming and the engineering decision matrix is well-suited for both evaluating options and serving as a record of how multi-parameter decisions were accomplished. Exercises with the decision matrix are used for the fictitious purchase of products such as a TV.

The paper assignment for this section asks students to reflect on and analyze the impact of changing technology on their daily lives. Examples are to be taken from smart phones, digital photography, and GPS navigation. Reflections are to be informed by questions such as: What is new, different, and “improved” compared to earlier devices? Did I need it? Were any of these changes expected or predicted? What are some unexpected or unanticipated changes caused by this technology? For this paper, students are encouraged to broaden the discussion to include observations from friends or family members with different perspectives and time frames.

The Path to Institutionalization

Since the first offering in 1995, Krupczak has taught *Science and Technology of Everyday Life* 43 times to more than 2,250 Hope College students. (He also regularly teaches the Intro course to Freshmen Engineers). After the second year, a three-year term for the instructor followed, along with an NSF grant to support development of laboratories specifically for non-engineering majors. In 1998, the course received mention on the front page of the *Wall Street Journal* and was noted as well in *The Chronicle of Higher Education*.

Krupczak received tenure at Hope in 2000 and was voted Hope Outstanding Professor by the graduating class in 2009.