Engineering For All
The Temple University Department of Mechanical Engineering General Education Courses

PAUL FAGETTE
Department of Mechanical Engineering,
Temple University, Philadelphia

SHIH-JIUN CHEN
Department of Mechanical Engineering,
Temple University, Philadelphia

GEORGE R. BARAN
Department of Mechanical Engineering,
Temple University, Philadelphia

SOLOMON P. SAMUEL
Department of Orthopedic Surgery,
Albert Einstein Medical Center, Philadelphia, PA

MOHAMMAD F. KIANI
Department of Mechanical Engineering,
Temple University, Philadelphia

The Temple University Department of Mechanical Engineering General Education Courses

Abstract

The Mechanical Engineering Department at Temple University has crafted two courses for the General Education Program that expand the alternatives for students to fulfill their general science credits. The courses are designed for non-engineering, lower division students complete with lectures, labs, demonstrations, exams, extensive reading of both text and peer-reviewed articles, research projects, and presentations. The classes address multiple general education requirements while offering enlightenment and understanding of engineering systems, engineering principles, and design.

Introduction

Engineering curricula centers upon the training and development of engineers and follows a cloistered academic approach. Rarely can anyone outside the discipline take engineering courses. ABET further reinforces this approach in order to maintain rigor and consistency in the delivery of course work. Coupled with traditional academic boundaries, a general lack of understanding exists by the general public about engineering systems, basic scientific/engineering principles, and engineering design. In 2005, the Department of Mechanical Engineering at Temple University responded to a request from the General Education Program to create new courses for non-engineering students across the university.

Accordingly, the Department crafted two new courses: Technological Transformations and the Bionic Human, both of which were targeted to lower division, non-engineering students. These new courses helped to enlarge and expand the nature of general education courses but also brought an understanding of engineering principles, systems, and approaches to a larger segment of the university population. The new curricula followed the guidelines set forth in the General Education request for science/engineering courses which included problem sets, laboratory experiences, research based upon appropriate professional literature, and communication skill development (both written and oral).

Teams within the Department configured unique courses to fit the guidelines. Both courses have evolved through time with feedback from both instructors and students. Accordingly, more discrete skills sets were refined and delivered. The net result is a tandem of courses that engage and expand student awareness about the engineering aspects of their world.

Call to Arms

In 2005, the General Education Program at Temple University challenged the many colleges on campus to create a new series of general education courses to expand the offerings for students and enhance their understanding of the world. This effort included a wider range of classes that would count for general science credit.

In the promulgation it was stated "faculty in all schools and colleges are encouraged to think across disciplinary lines about the best ways to convey the kinds of sophisticated knowledge that will produce Temple graduates able to see connections in seemingly disparate information." This new program summed these efforts with the motto "Dare to know!"

In a descending order, a series of general to specific skills and requirements were outlined. Accordingly, each course had to accomplish the following required goals associated with the general education program:

1. Develop students' thinking and communication skills
2. Expand students' knowledge in the subject area
3. Develop students' ability to make informed judgments in the subject area;
4. Promote intellectual curiosity and life-long learning
5. Develop skills in identifying, accessing and evaluating sources of information

An additional set of desirable goals were to be addressed as applicable:

1. Develop ethics, citizenship, and awareness of current issues
2. Promote collaborative learning and teamwork skills
3. Develop an understanding of and appreciation for Temple's urban setting and its regional and global connections
4. Develop students' ability to analyze and interpret data
5. Develop students' ability to identify and solve problems

The announcement moved from general requirements to more specific definitions. Eight general education areas that crossed most disciplines were defined including natural sciences or technology. The overall purpose was to promote understanding of scientific thinking and associate methods as well as an understanding of how technology affects human life. Classes offered under this heading would partially fulfill the general education science requirement.

The General Education request detailed further criteria made several telling points that affected how engineers could design these classes. These are General Education courses with students from across the student population, virtually all of whom have no basic or conceptual understanding of engineering or engineering concepts. This diversity of skills and backgrounds constitute the major challenge for designing an engineering course applicable to the general student population. Pertinent to the Dept. of Mechanical Engineering, the list of possible classes might include bioengineering and development of technology.

The requirements further requested that students learn how to access scientific or engineering literature along with an emphasis on the nature of engineering or scientific inquiry and research methodology. The basic rationale was that students should be able to understand basic science and engineering technology reports associated with the news, health, environmental, etc. The proposed courses should attempt to achieve student success in as many of the following skills as possible:

1. Know the difference between a law, theory, and hypothesis
2. State examples of laws, theories, hypotheses for content area
3. Be able to conduct an experiment with test, observations, and conclusions
4. Be able to identify relevant facts from irrelevant facts
5. Understand the sequential nature of science (how facts build on one another)
6. Use facts to explain natural phenomena
7. Use content to interpret current news issues related to science and technology
8. Understand the difference between science and pseudoscience
9. Show the importance of quantifying to understand natural phenomena
10. Develop an inquiry-based line of reasoning and use of skeptical thinking
11. Understand how applications of technology evolve
12. Understand the relationships of basic science to technology applications

Clearly not all of these apply to engineering but #2, 3, 5, 9, 11 and 12 do.

In addressing all these guidelines it would appear that the class was basically outlined but the implementations offered considerable latitude. The remaining key was how to assess if students have actually achieved understanding and to what degree. Here the engineers have a distinct advantage. ABET has encouraged a systematic pedagogy about how to address main concepts and assess understanding through a variety of means. General education engineering-based courses could include traditional lecture, research and presentation efforts, guest speakers, demonstrations, even field trips.

Working within these guidelines, the Department of Mechanical Engineering appointed two teams to develop courses that would enlighten students on different aspects of engineering that would meet general science requirements.[1]

The Response

Offering such courses addresses a major need recognized by the General Education Program. Students in the general university population rarely know or understand anything about engineering, engineering principles, or engineering systems unless they have personal contact with an engineer. They exist in a world largely defined and developed by engineering but usually have no clue to its existence. Thus, these courses offer engineering an opportunity to expand awareness of the discipline and its impact on society. The Department of Mechanical Engineering formulated a dual response. One was the Bionic Human, a bioengineering-based course. The other, Technological Transformations, followed the development of older engineering traditions which included mechanical, civil, electrical, and some chemical engineering.

Technological Transformations

Jim Chen headed the effort to create a general engineering course. In the quest for examples and materials, it was discovered that Princeton had in fact an undergraduate course with similar goals. The course was adopted compete with texts and lectures and adjusted to the needs of Temple students. The course requires weekly reading assignments, weekly homework/problem set tasks, labs with write-up, a midterm and final exam, and a final written project with both a written and oral component.

Technological Transformations is designed to explain the origins and workings of many of the engineered devices and systems that comprise our modern world while imparting a sense of the nature of engineering science and its systems, e.g., electrical power system. The material begins with the first Industrial Revolution in Britain focusing on bridge and steam engine design. Following quickly are applications of steam engines in trains and boats. A defining moment is presented with the Lowell hydraulic powered textiles mills and their water wheels juxtaposed to the subsequent introduction of turbine technology incorporating modern engineering techniques and research. Units that define the basis of electrical power and application follow along with the materials of the US industrial development: steel and oil. Moving to the 20th century, aerodynamic design and flow principles are presented with aircraft and automobiles.

Key engineering concepts around which the material is organized include: concepts of work, force, energy (especially inter-convertibility), engineering and how it differs from basic science, how science and technology became more interwoven through time, and how engineers predict and measure phenomena.

Lectures are formulated to introduce the operative physical forces at work; the nature of the engineering problem; the nature of the creative design process and how the presented problem is framed in an engineering sense; the relative nature of materials and understanding of the phenomena in a particular time era; and the operative or constituent equations pertinent to each problem. This approach is reiterated for each chapter/thematic presentation. The accompanying problems sets are simplifications of the complex quantitative solutions but are geared to enhancing a quantitative understanding of problem solving. The qualitative questions are related to the quantitative aspects and force the students to conceptualize the phenomena and then explain the formula. The weekly problems are also assessed in the midterm and final exams which comprise both calculation and short essay response.

An illustrative example is Chapter 3 in the text, *Innovators, The Engineering Pioneers Who Made America Modern*, "Fulton's Steamboat and the Mississippi." The historic setting was the need for boats that could go upstream at a determined rate of speed. Fulton applied a Watt steam engine to his design and succeeded. Students are shown how Fulton used a variety of formulae to determine the size and necessary horsepower to drive his boat. Drag calculations, paddle power, paddle wheel area, thrust calculations are explained and outlined. An example of the correlative formulae is how Fulton calculated drag:

$D = pAC_D$ where p = water pressure, A = wetted area of paddle surface, C_D is the drag coefficient.

The subsequent evolution toward the smaller, more powerful high pressure steam engines fostered better understanding of the internal pressures. Boiler axial and circumferential stresses and their measurements are introduced along with new federal safety legislation. The operative equations associated with the new stresses are: $f_2 = Pr/2h$ and $f_1 = Pr/h$ where P = pressure, r = radius, and h = height.

The chapter problems alter the basic numbers in the presented equations and ask students to calculate new answers. An example for Chapter 3 is:

1. To secure the monopoly franchise for steamboat operation on the Hudson River in 1807, the State of New York set 4 mph as the minimum speed a boat had to attain. Calculate the drag that a Fulton steamboat would have experienced if the steamboat had a wetted area of 3,500 sq. ft. (A) and the drag coefficient (C_D) was 0.0022.

Labs are focused on a specific theme, e.g., conservation of energy and mass, parallel and series circuits, and aerodynamic flow. These are one class in length with a pre-lab set up and a post-lab explanation. Again the students are asked to take raw data and calculate a series of answers according to basic formulae. An example here would be the lab on conservation of mass and energy. A model car is released at one end of an elevated track, goes down, gathers speed, goes through a complete loop, exits the loop, and climbs to a stop. Students take a series of velocity measurements and determine the theoretical and actual potential and kinetic energies in the system. Related equations governing this lab are derived from the general equation:
$E = KE + PE + TE = ME + TE =$ constant: potential energy = $PE = mgH$; and kinetic energy = $KE = mV^2/2$.

The final project is a research effort with a formal written essay based on peer-reviewed sources and a short PowerPoint presentation. Students choose a topic from a variety of areas, for example, future energy systems. They focus on a specific aspect of a problem, for example, solar power and the design of solar chips. The student must ask an engineering question and then do the necessary research to determine how the engineering problems associated with the topic are formulated, find the constituent formulae, and how subsequent applications and problems are being addressed. One key here is that they must be able to explain the associative formulae. The student effort on the final project is most rewarding as virtually all embrace the opportunity to examine something of interest to them. For example, one student this last semester, an art major specializing in textiles, explored the latest designs in air jet weaving machines and the engineering basis to their designs. She included several equations utilized in the design of these machines. One was the equation for friction force on the weft (thread): $dF_f = cf + t + d_A$ where dF_f = elemental friction force; c_f = skin friction coefficient; t = shearing stress; d_A = circumfluent surface element; and D = weft diameter. In other words, there is something for everyone.

The justification for the course is illustrated by its ability to meet a wide range of the general and area requirements. The General Education learning objectives are covered in all areas.

Objective 1: quantitative and qualitative tasks in homework and problem sets develop critical thinking and communication skills
Objective 2: lectures, labs, reading, and research project to expand student's knowledge in subject area
Objective 3: discussion, reading, quantitative and qualitative tasks, and research project develop students' ability to make informed judgments
Objective 4: labs and research project promote intellectual curiosity and life-long learning
Objective 5: accompanying readings and research project develop skills in identifying, accessing, and evaluating sources of information

The class further reinforces the second level of goals as it follows a general chronological format and touches on more current issues. This is especially true for the research project.

Goal 1: the research project focuses exclusively on current technological issues.
Goal 2: the labs and research project enhances collaborative learning and team work.
Goal 3. The research project aids in an understanding of Temple's urban setting
Goal 4: The homework both quantitative and qualitative, the labs, and the research project develop students ability to analyze and interpret data.
Goal 5: The entire curriculum, especially the lectures, develop students' ability to identify and solve problems.

The course design also follows the format suggested in the Natural Science/Technology guidelines. Assessment follows multiple methods with significant writing exercises; experiential learning through labs and demonstrations. Competencies include: student understanding of engineering problem formulation, the role of quantitative measurement, inter-convertibility of energy; student ability to utilize relevant formulae; and an understanding of engineering methodology.

Student feedback has been positive on the course but through time many wearied of the emphasis on calculation-based problem sets. There was a two-pronged response. First, there was a shift to more qualitative questions in the weekly homework. Instead of having the students only answer a variation on Joseph Henry's use of a formula that determines the resistance in a coil, $R = \rho L/A$, students are instead asked to explain the formula relative to the forces at work, e.g., How does an electromagnet work; how do you measure the amount of potential work it can do? This was more challenging but it was good preparation for the essay questions on exams.

The second response was to build a list of supplementary articles that would allow the students to read and understand specific aspects of engineering problems. A series of articles drawn from *Scientific American* post-1945 were assigned to the relative chapters. Each explores an aspect of a chapter in the text more succinctly. For example, one focuses on the Wright Brothers Flight Control System and another on De Forest and the Triode Detector. These articles are discussed in class so the students are taught how to critically read such articles. Quizzes were also given to insure that they did the reading and understood the main concepts presented. This shift certainly falls within the objective and goal regarding critical thinking and writing skills. The emphasis on conceptual writing on a weekly basis and the critical understanding of the articles lays an excellent basis for the stronger accentuation on both the midterm and final exam. The qualitative effort also prepares the students more acutely for the written final project.

These classes are primarily intended for freshmen and sophomores. As such, their skills are not always what you might expect. The old adage of assuming nothing is very true regarding this age group. When the shift from more quantitative to more qualitative took place it created an emphasis on article-based reading versus the textbook. Thus, a new skill area had to be addressed and calculated into the teaching matrix.

The Bionic Human

A team comprised of Mohammad Kiani and George Baran from Mechanical Engineering and Solomon P. Samuel from Albert Einstein Medical Center developed the bioengineering-based course. The Bionic Human uses an inquiry based approach to explore current healthcare issues related to bioengineering. An important goal of this course is for students to become better healthcare consumers and be able, for example, to ask intelligent questions about their healthcare from their doctors. Again, no matter the material, students are expected to understand an engineering approach and the associated concepts. This area moves beyond the base scientific knowledge of physics, chemistry, and mechanics to human physiology which presents an entirely different array of problems for engineers. Nevertheless, the students are expected to learn the basic physical principles behind the operation of medical devices. As an example, the discussion on biomedical imaging systems starts with a presentation of the Lambert-Beer Law and its applications to living systems.

The major engineering concept is how multiple disciplines converge into bioengineering in order to resolve basic science/physiology issues and work toward ultimate treatment and device development. Utilizing scientific articles and review papers students will come to understand the challenging path toward development intertwined with government regulation and a host of ethical considerations. There are currently no textbooks available for a course such as this; available books on the subject are either written for experts in the field or at the very simplistic level for lay audience. A textbook based on this course is currently being written by the developers of the course.

Whereas Technological Transformations begins with a mechanical world derived from Newton and universal law, the Bionic Human sets a different standard. All engineering and scientific work begins and ends with human physiology. In other words, the body sets the standards and workplace criteria; all research, development, and application must conform to this challenging environment, no exceptions. This is an excellent opportunity for students to understand the difficult path to success in bioengineering and the limitations that make the work so difficult, expensive, and lengthy. Hence, basic human physiology and pathology comprise each unit.

The class begins with health issues associated with aging: arthritis, vascular stenosis, etc. The next section includes a detailed discussion of various imaging modalities, including ultrasound, X-ray, CT, MRI, and contrast agents. A large section of the course, comprising almost 20% of the lectures, is dedicated to the discussion of the mechanics and physiology of the musculoskeletal system and biomaterials. This section is then followed by modules covering drug delivery systems, gene therapy, and medical devices. A few lectures present a brief overview of ethical and legal issues surrounding the use and application of medical technologies. Not surprisingly, the latter module attracts the most attention from students as it discusses issues such as the impact of technological development on cost of healthcare and end of life decisions.

Laboratories are an integral aspect of the course and include both hands on and virtual (computer based) assignments on tissue and biomaterial properties, surface treatments, drug coating, and cardiovascular effects of caffeine and energy drinks. In addition, in a discussion session students participate in a scenario where they pretend to work for a company that has to deal with the rising cost of health insurance. In this scenario, the employees (i.e., the students) are asked by the insurance company to undergo genetic testing and other procedures to determine their risk for certain diseases. The students then can see how their decisions may impact their future prospects for obtaining health insurance and employment.

Assessment is made through 3 multiple choice exams and a final research project focusing on a medical device or technology. The students are required to use primary sources to discuss the technical principles underlying the operation of the device, its clinical use, costs, and related social/ethical issues. Many of the questions in these exams require the students to analyze, rather than regurgitate, the information they have learned in class. For example, in the following question the students need to combine their knowledge of how X-rays penetrate various biological materials with their basic understanding of osteoporosis to come up with the correct answer (b):

If Mary has osteoporosis, what will be observed in X-ray images of her hip bones over time?

a. The hip bone images appear lighter over time
b. The hip bone images appear darker over time
c. The hip bone images do not change over time
d. The gray level of X-ray images has nothing to do with bone density

Justification for this unique course is based upon its ability to fulfill virtually all of the goals outlined in the general and area requirements. Additionally, the class consistently commands the attention of large groups of students. In Tech Transformations, many students find it interesting to actually learn what a transformer attached to a telephone pole is doing in front of their house but many more are attracted to the inner workings of the human body and the technologies that are used to treat our illnesses.

Again, the General Education learning objectives are covered in all areas again in a mechanical engineering course.

Objective 1: quantitative and qualitative tasks in homework and problem sets develop critical thinking and communication skills.
Objective 2: lectures, labs, reading, and research project to expand student's knowledge in subject area
Objective 3: discussion, reading, quantitative and qualitative tasks, and research project develop students' ability to make informed judgments
Objective 4: labs and research project promote intellectual curiosity and life-long learning
Objective 5: accompanying readings and research project develop skills in identifying, accessing, and evaluating sources of information

The Bionic Human also reinforces the area level of goals especially in regard to current and ethically complex issues.

Goal 1: the research project focuses exclusively on current technological issues.
Goal 2: the discussion session fosters collaborative learning and teamwork skills.
Goal 3. The research project aids in an understanding of Temple's urban setting
Goal 4: The homework both quantitative and qualitative, the labs, and the research project develop students ability to analyze and interpret data.
Goal 5: The entire curriculum, especially the lectures, develop students' ability to identify and solve problems.

This course design also follows the Natural Science/Technology format. Assessment follows multiple methods with significant writing exercises; experiential learning through labs and demonstrations.

Conclusion

The Department courses have fulfilled the requirements of the General Education Program Directive and enhanced Temple University student understanding of engineering. Table 1 illustrates the interest and success of the courses as seen in the numbers of registered students. Clearly the Bionic Human is a showcase class but Technological Transformations also holds steady numbers and has expanded through time.

Table 1: Registration for Mechanical Engineering General Education Courses

Academic Year	Tech. Transformations	Bionic Human
2007-2008	13	59

2008-2009	67	243
2009-2010	89	341
2010-2011	168	405
2011-2012 (projected)	240	500

Teaching non-engineers, many of whom have only rudimentary math skills, the complexity of design and calculable phenomena, is what we call in the trade a teaching challenge. ABET has inculcated the concept of self-reflection and addressing how we succeed in teaching base concepts. Grades and student feedback are neither always sufficient nor accurate in determining teaching success. Instructors must take an active, critical role. Accordingly, each of these courses have been analyzed regarding key conceptual elements and refinement has taken place, further verifying that teaching is an evolutionary process based on more than the internal shifts that come with inculcating new research.

Engineering has an important, integral knowledge base that can be made available to a broader audience while fulfilling general education requirements. It can be argued that the modern world from the pyramids at Giza to our modern communication system has been shaped by engineers. Yet, few understand what the term means. Engineers can fill this vital gap by taking the initiative and reaching out beyond their academic boundaries.

Bibliography

1. General Education at Temple University: “Dare to Know!” Temple University, 24 Oct 2005.