AC 2011-182: EDUCATIONAL OBJECTIVES AND OUTCOMES FOR TECHNOLOGICAL LITERACY PROGRAMS AT COLLEGE LEVEL

Robert J. Gustafson, Ohio State University

Robert J. Gustafson, P.E., PhD Honda Professor for Engineering Education and Director of the Engineering Education Innovation Center Professor of Food, Agricultural and Biological Engineering College of Engineering The Ohio State University.

John Krupczak, Hope College

Professor of Engineering, Hope College, Holland, MI USA

James F. Young, Rice University, Electrical & Computer Engineering, Houston, TX

James F. Young received the B.S. and M.S. degrees in electrical engineering from the Massachusetts Institute of Technology, Cambridge, MA, in 1965 and 1966, respectively, and the Ph.D. degree in electrical engineering from Stanford University, Stanford, CA, in 1970. In 1975, he was appointed Research Professor of Electrical Engineering at Stanford University, and taught graduate courses in lasers, directed graduate student research, advised undergraduates, and served in several administrative capacities. He joined the Rice University, Houston, TX, faculty in 1990 and is currently a Professor in the Electrical and Computer Engineering Department. His research topics have included optical parametric oscillators, nonlinear optics in crystals and vapors, infrared image upconversion, and the development of unique laser sources, including extreme ultraviolet lasers and femtosecond, terawatt lasers. He has authored over 70 publications, has served as a consultant to several companies, and has supervised the research of over 30 graduate students. Dr. Young is a registered professional engineer, a Fellow of the IEEE and of the Optical Society of America, and a member of ASEE; he was chosen as an IEEE Lasers and Electro-Optics Society Distinguished Lecturer for 1991-1992. His scholarship now focuses on engineering education, both undergraduate and K12 levels. His interest in engineering education and pedagogy was stimulated by the challenge of teaching Introduction to Engineering Design to a mix of engineering and non-engineering students, and by leading a task force for the Rice Dean of Engineering charged with defining and examining School-wide engineering education goals. This work ultimately led to the creation of the $15M Rice Center for Engineering Leadership.

Dr. Mani Mina, Iowa State University

Educational Objectives and Outcomes for Technological Literacy Programs at College Level

Abstract

This paper presents results of work towards constructing a model set of educational objectives and outcomes for minors, courses or similar programs which can be used by engineering units to develop programs for technological literacy of non-engineers at the collegiate level. Four institutions with varying approaches in this area collaborated for this work as part of a larger NSF supported project. Working definitions for Educational Objectives, Outcomes, Assessment and Evaluation are established to support the work. Available objectives and outcomes from the literature, which would be pertinent to this audience, were used as primary sources. The project team prioritized statements from these sources for how they would apply to the intended audience of non-engineering, college-level students in the context of offerings from an engineering unit's perspective, strengths and resources.

By multiple iterations, highest priority items were combined as appropriate and categorized as Educational Objectives and related Outcomes. This resulted in a set of four Educational Objectives and seventeen Outcomes. The four Educational Objectives include demonstrating: 1) *knowledge* of the technological nature of the physical and natural world, 2) *ability to* meaningfully *engage* with big questions of a technological nature, both contemporary and enduring, 3) characteristics of personal and social *responsibility* in using and creating technology, and 4) *capability* to *synthesize* and *advance* technological accomplishments across general and specialized domains. Three to six Outcomes were related to each of the Educational Objectives. The Educational Objectives and Outcomes were shared with members of the Technological Literacy Division of ASEE for comment. Comments were considered in refinement of the statements. The paper presents a foundational set of Educational Objectives and Outcomes that can be used for multiple pedagogical approaches to technological literacy for non-engineering collegiate level students.

Background

Substantial evidence continues to indicate that over the long term the great majority of newly created jobs are the indirect or direct result of advancements in science and technology, thus making these and related disciplines assume what might be described as disproportionate importance[1]. Despite its importance, technological literacy has not been a significant focus of instruction and assessment in K-12 curriculum or in higher education outside of engineering. Some technological topics are being integrated in other areas such humanities, social sciences, and mathematics instruction but primarily for supporting of instruction within these areas.

As defined in the broadly recognized report of the National Academies[2], technological literacy encompasses three interdependent dimensions – knowledge, ways of thinking and acting, and capabilities. Like literacy in other areas, the goal of technological literacy is to provide people with tools to participate intelligently and thoughtfully in the world around them.

Post-Secondary Technological Literacy Classes and Curriculum

Compiling information about technological literacy classes (TLCs) for liberal arts majors at fifteen institutions was intended to provide resources to faculty interested in developing courses[3]. The paper briefly traced the history of TLCs through 1959 through the 1990's and developed a working definition of technological literacy of

> The ability to understand, intelligently discuss and appropriately use concepts, procedures and terminology fundamental to work of (and typically taken for granted by) professional engineers, scientists and technicians; and being able to apply this ability to:
> - Critical analyze how technology, culture and the environment interact and influence one another.
> - Accurately explain (in non-technical terms) scientific and mathematical principles which form the bases of important technologies.
> - Describe and, when appropriate, use the design and research methods of engineers and technologists.
> - Continue learning about technologies, and meaningfully participate in the evaluation and improvement of existing technologies and the creation of new technologies.

Development of engineering-related minors for non-engineers has been the focus of past[4,5,6,7,8] and current collaborative work[9,10] of four universities under National Science Foundation Funding. The work intends to establish a detailed understanding of the value of minors offered by engineering units for non-engineering students. This current work is part of this on-going collaboration.

K-12 Curriculum Development

Following development of detailed requirements for the development of understanding and capabilities related to technology among K-12 students in 2000[11] and the report of the National Academies *Technically Speaking: Why All Americans Need to Know More About Technology*[2] in 2002, a group of diverse experts under the auspices of the National Academy of Engineering (NAE) and the Board on Testing and Assessment at the Center for Education, part of the National Research Council (NRC) was charged with determining the most viable approach or approaches to assessing technological literacy in U.S. K-12 students, K-12 teachers, and out-of-school adults. Their report *Tech Tally: Approaches to Assessing Technological Literacy*[12] defined technological literacy as "an understanding of technology at a level that enables effective functioning in a modern technological society". The committee defined technological literacy as having three major cognitive dimensions: knowledge, capabilities, and critical thinking and decision making in the context of four content areas (technology and society, design, products and systems, and characteristics), core concepts, and connections. A series of twelve recommendations addressing five critical areas of instrument development; research on learning;

computer-based assessment methods; framework development; and public perception of technology was developed.

As reported to the National Assessment of Educational Progress (NAEP)[13], despite its importance, technology has not been a focus of instruction and assessment in our elementary and secondary educational system. Through their framework development, it became clear that the terms “technology,” “engineering”, “information communications technology,” “21st century skills,” and “literacy” are defined and used in significantly different ways in formal and informal education, in standards, by professional organizations, and in legislation. Therefore they recommended a change of title from “technological literacy” to “technological and engineering literacy” to encompass general literacy about use, effects, and designing of technologies. They defined technology and engineering literacy as “the capacity to use, understand, and evaluate technology as well as to understand technological principles and strategies needed to develop solutions and achieve goals.” They recommended that assessment targets be organized around the three areas of technology and society, design and systems, and information and communications technology.

In order to define STEM literacy, three major organizations publications on literacy and K-12 standards were compared and synthesized by examining their differences and commonalities[14]. This provided a holistic view of the relationship among the four fields and suggested core concepts to be included in engineering literacy at the K-12 level. By reviewing and analyzing the scientific, technological, and mathematical standards, three commonalities were found as the intersection of the three areas: process (‘identifying the problem’ to ‘reaching the solution’), modeling (representing relationship and communicating phenomena), and social impact (society on technology development and technology on society).

Comparing the concepts and principles that are recommended for technology education courses for grades K-12[11] with the outcomes specified in Criterion 3 Program and Outcomes and Assessment of engineering accreditation in 2002[15], showed clear connections between the two[16]. All of the 20 standards were denoted to have a correlation to more than one of the ABET outcomes.

Development of Educational Objectives and Outcomes

The process for development and refinement of a model set of educational objectives and outcomes for minors, courses or similar programs which can be used by engineering units offering technological literacy to non-engineers at the collegiate level was lead by the first author of this paper. Development started with a review of literature and materials regarding objectives and learning outcomes from leading organizations supporting work of this type. Five primary sources utilized were:

1) Technically Speaking, Why All Americans Need to Know More About Technology[2]
   This source, developed by the National Academy of Engineering, noted characteristics of a technologically literate citizen in three categories of a) knowledge (7), ways of thinking and acting (3), and capabilities (3).
2) Current ABET Engineering Criteria[17]
   Both definition for terms and the Criterion 3 – Program Outcomes (a-k) for engineering programs were considered.

3) Current ABET Engineering Technology Criteria[18]
   Again the Criterion 3 Program Outcomes (a-k) and definition of terms were considered.
4) Report of the Liberal Education and America's Promise (LEAP)[19]
   This program of the American Association of Colleges and Universities is organized around a robust set of "essential learning outcomes", all of which they propose are best developed by a contemporary liberal education. They are in the categories of a) knowledge of human cultures and the physical and natural world (1), b) intellectual and practical skills (6), c) personal and social responsibility (3), and d) integrative learning (1).
5) Standards for Technological Literacy[20]
   Although directed primarily towards secondary schools, the International Technological Education Association, has developed standards statements for a) nature of technology (3), b) technology and society (4), c) design (3), d) abilities for a technological world (3), and e) the designed world (7).

A listing of the items from each source is listed in Appendix A.

Draft definitions, later slightly modified, for Educational Objectives (EO) and Program Outcomes (PO) based on current ABET terminology were established.

Eight persons, five members of the NSF project team plus one graduate student, one instructor and one laboratory staff development person engaged with first-year engineering courses at Ohio State, then contributed ratings for each of the 66 items in the context of applicability to a minor or course as either an educational objective or a program outcome using the draft definitions of those two terms. Each item was rated on a 1 to 4 scale as: 1-Not applicable, 2-Secondary impact, 3-Consider in Modified Form, 4-Should be included. Comments space was available for each item. Suggested edits for the definitions were also solicited.

After review of the consolidated responses, it was decided to work further with those items that ranked above the median for either EO or PO. The objectives based on the Technically Speaking[2] report, minus the capabilities section, were the most uniformly supported. The capabilities as described tended to be directed at hands-on activities and actual operation of specific technology. The group seemed consistent that teaching about design and design process was appropriate but implying expecting students to do engineering design was not. Therefore some of the ABET objectives naturally fell out. The remaining items were consolidated and modified until all items that rose up to the mean of the rating system were accommodated. This resulted in a system of four Educational Objectives with three to six Outcomes under each for a total of eighteen Objectives. It was also agreed that Objectives should be worded such that they would be assessable. Revised definitions for Educational Objectives and Outcome statements were also developed, along with definitions for Assessment and Evaluation.

The same eight persons reviewed and suggested revisions to the consolidated and revised definitions, Educational Objectives and Outcomes. This iteration resulted in refinement and improvement of wording, but did not change the basic structure or content of the materials.

In an attempt to gain input from a broader base of potentially interested person, a memo was send (via email) to all members of the Technological Literacy Division of ASEE. The memo was in the form of a Word document requesting that persons respond to the proposed material within comment boxes and with the Track Change function of Word. Although only two responses were received, the two responses supported the overall content and structure. They also made some useful editorial suggestions on wording which were incorporated.

Model Educational Objectives and Outcomes

Based on the process and inputs outlined in the previous section, the following set definitions, objectives and outcomes are offered such that a consistent understanding and terminology can exist. While it is recognized that it is the prerogative of institutions to use and adopt the terminology of their choice, it is important to recall that the context for these is offerings in the domain of technological literacy for non-engineering, college-level students done by engineering units. With that premise, the following are offered.

Definitions

Educational Objectives are broad statements that describe the personal and professional characteristics that the students are preparing to achieve after graduation.

Outcomes are narrower statements that describe what students are expected to know and be able to do by completion of the educational experience.

Assessment is one or more processes that identify, collect, and prepare data to evaluate the achievement of outcomes and educational objectives.

Evaluation is one or more processes for interpreting the data and evidence accumulated through assessment practices. Evaluation determines the extent to which outcomes or educational objectives are being achieved and results in decisions and actions to improve.

The following Educational Objectives and Outcomes, developed by the process outlined, are offered as a foundation for engineering college units developing technological literacy type programs for non-engineering, collegiate level students.

Educational Objectives

The minor, course, certificate, or similar program should contribute to the basic liberal[1] education of the students such that in their personal and professional lives students upon completion will demonstrate:

1) *knowledge* of the technological nature of the physical and natural world,
2) *ability to* meaningfully *engage* with big questions of a technological nature, both contemporary and enduring,

[1] Liberal education in the sense of education "to cultivate those skills and habits of reasoning which constitute intellectual competence, the capacity to think logically and clearly, the ability to organize one's thoughts on any subject on which essential facts are possessed or obtainable."[21] All elements if the curriculum can contribute to liberal education.

3) characteristics of personal and social *responsibility* in using and creating technology, and
4) *capability* to *synthesize* and *advance* technological accomplishments across general and specialized domains.

Outcomes

These outcomes relate to the knowledge, ability to engage, responsibility, and capability objectives and what students acquire as they progress through the experience. At the completion of the minor, course, or similar program students should be better able to:

Knowledge	
1	Articulate the pervasiveness of technology in everyday life.
2	Define basic engineering concepts and terms, such as systems, constraints, and trade-offs.
3	Describe the nature and limitations of the engineering design process.
4	Explain some of the ways technology shapes human history and people shape technology.
5	Compare the benefits and risks that all technologies entail, some that can be anticipated and some that cannot.
6	Identify the effects of technology on the environment.
Ability to Engage	
7	Describe the development and use of technology and evaluate trade-offs including a balance of costs and benefits both economic and social.
8	Identify technology that appropriately reflects the values and culture of society for which it is intended.
9	Give examples of relationships among technologies and connections between technology and other fields of study.
Responsibility	
10	Can identify and analyze professional, ethical, and social responsibilities as related to technology.
11	Participates appropriately in decisions about the development and use of technology.
12	Demonstrates an interest and ability in life-long learning and self-education about technological issues.
Capabilities	
13	Formulate pertinent questions, of self and others, regarding the benefits and risks of technologies.
14	Obtain and interpret information about new technologies.
15	Discriminate the role of problem solving for troubleshooting, invention, innovation, research and development.
16	Function effectively on teams with varying technological expertise.
17	Communicate effectively, both orally and in writing, regarding technological issues.
18	Think critically and creatively regarding technological issues including an ability to assess,

rank, or to compare proposed designs on the basis of the desired outcomes, consequences, and constraints.

Discussion/Conclusions

The model set of educational objectives and outcomes are generally congruent with work of ITEA and ABET but put in a form consistent with current practice of engineering programs. They do deviate from the ABET criteria in that they do not imply expertise in design, but rather a familiarity with the design process and the capabilities needed to participate as a non-engineer in design and technological issues. The most significant deviations from the ITEA Standards for K-12 are that they do not include understanding and ability to select and use specific technologies (medical, agricultural and related biotechnologies, energy and power, etc.) or use and maintenance of technological products.

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Appendix A. Objectives and Learning Outcomes from Base Sources

Outcomes/Goal/Objective	Outcomes/Goal/Objective
ABET Engineering[17]	**ABET Engineering Technology**[18]
(a) an ability to apply knowledge of mathematics, science, and engineering	(a) an appropriate mastery of the knowledge, techniques, skills, and modern tools of their disciplines
(b) an ability to design and conduct experiments, as well as to analyze and interpret data	(b) an ability to apply current knowledge and adapt to emerging applications of mathematics, science, engineering, and technology
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability	(c) an ability to conduct, analyze and interpret experiments, and apply experimental results to improve processes
(d) an ability to function on multidisciplinary teams	(d) an ability to apply creativity in the design of systems, components, or processes appropriate to program educational objectives
(e) an ability to identify, formulate, and solve engineering problems	(e) an ability to function effectively on teams
(f) an understanding of professional and ethical responsibility	(f) an ability to identify, analyze and solve technical problems
(g) an ability to communicate effectively	(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	(h) a recognition of the need for, and an ability to engage in lifelong learning
(i) a recognition of the need for, and an ability to engage in life-long learning	(i) an ability to understand professional, ethical and social responsibilities
(j) a knowledge of contemporary issues	(j) a respect for diversity and a knowledge of contemporary professional, societal and global issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	(k) a commitment to quality, timeliness, and continuous improvement
ITEA 2007. Standards for Technological Literacy[20]	**Technically Speaking**[2]
Nature of Technology	Characteristics of a Technological Literate Citizen
Students will develop an understanding of the:	Knowledge
• Characteristics and scope of technology.	• Recognize the pervasiveness of technology in everyday life.
• Core concepts of technology.	• Understand basic engineering concepts and terms, such as systems, constraints, and trade-offs.
• Relationships among technologies and connections between technology and other fields of study.	• Is familiar with the nature and limitations of the engineering design process.
Technology and Society	• Knows some of the ways technology shapes human history and people shape technology.
Students will develop an understanding of the:	• Knows that all technologies entail risk, some that can be anticipated and some that cannot.
• Cultural, social, economic, and political effects of technology.	• Appreciates that the development and use of technology involve trade-offs and a balance of costs and benefits.
• Effects of technology on the environment.	• Understands that technology reflects the values and culture of society.

• Role of society in the development and use of technology.	Ways of Thinking and Acting
• Influence of technology on history.	• Asks pertinent questions, of self and others, regarding the benefits and risks of technologies.
Design	• Seeks information about new technologies.
Students will develop an understanding of:	• Participates, when appropriate, in decisions about the development and use of technology.
• The attributes of design.	Capabilities
• Engineering design.	• Has a range of hands-on skills, such as using computer for word processing and surfing the Internet.
• The role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.	• Can identify and fix simple mechanical or technological problems at home or work.
Abilities for a Technological World	• Can apply basic mathematical concepts related to probability, scale, and estimation to make informed judgments about technological risks and benefits.
Students will develop abilities to:	
• Apply the design process.	**LEAP Essential Learning Outcomes[19]**
• Use and maintain technological products and systems.	*Knowledge of Human Cultures and the Physical and Natural World* (Focused by engagement with big questions, both contemporary and enduring)
• Assess the impact of products and systems.	• Through study in the sciences and mathematics, social sciences, humanities, histories, languages, and the arts
The Designed World	*Intellectual and Practical Skills, Including* (Practiced extensively, across the curriculum, in the context of progressively more challenging problems, projects, and standards for performance)
Students will develop and understanding of and be able to select and use:	• Inquiry and analysis
• Medical technologies.	• Critical and creative thinking
• Agricultural and related biotechnologies.	• Written and oral communication
• Energy and power technologies.	• Quantitative literacy
• Information and communications technologies.	• Information literacy
• Transportation technologies.	• Teamwork and problem solving
• Manufacturing technologies.	*Personal and Social Responsibility, Including* (Anchored through active involvement with diverse communities and real-world challenges)
• Construction technologies.	• Civic knowledge and engagement—local and global
	• Intercultural knowledge and competence
	• Ethical reasoning and action Foundations and skills for lifelong learning
	Integrative Learning, including (Demonstrated through the application of knowledge, skills, and responsibilities to new settings and complex problems)
	• Synthesis and advanced accomplishment across general and specialized studies