AC 2012-4411: TECHNOLOGICAL LITERACY AS AN ELEMENT IN THE STRUCTURE, ASSESSMENT, AND EVALUATION OF ENGINEERING AND ENGINEERING TECHNOLOGY DEGREE PROGRAMS

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Technological Literacy as an Element in the Structure, Assessment, and Evaluation of Engineering and Engineering Technology Degree Programs

Abstract

The goal of teaching technological literacy is to foster greater technological literacy in society. Efforts in this area have been focused largely on developing technological literacy in students who are not majoring in engineering or engineering technology.

Our majors need to be technologically literate as well. While meeting the specific educational goals of the major area, the program curriculum in engineering and engineering technology degree programs also needs to help students develop general technological literacy. These concepts and dimensions should be considered and included in the design of individual courses and the curriculum.

Concepts of technological literacy are implicit in ABET accreditation criteria for programs in engineering and engineering technology. Each course is expected to contribute to meeting accreditation criteria, and most, if not all, courses are expected to contribute in different areas, including areas that are linked to technological literacy. Criteria for both types of program can be matched to dimensions of technological literacy, and these dimensions can be a useful framework for assessment and evaluation. These dimensions should be considered when revising courses and the curriculum to address issues raised in this process.

This paper will explore the use of the concept and dimensions of technological literacy as a guide for revising and improving individual courses and the curriculum as a whole. This will include discussion of efforts to apply this framework to existing courses ranging from first year to senior year courses in a four year degree program in engineering technology and to identifying places where elements of technological literacy could be added to enhance instruction. This work on specific courses will then be linked to the curriculum as a whole. Finally, assessment of the progress made by students in developing technological literacy will be discussed.

Introduction

A technologically literate person has a basic understanding of technology – what it is, how it affects their life and the lives of others, and how people collectively make decisions about technology and manage change. This has been mapped in terms of three dimensions – "knowledge, ways of thinking and acting, and capabilities."[1] A person who has developed technological literacy is prepared to understand and make informed decisions about technology.

Over the past ten years or so, teaching technological literacy has been recognized as an important topic.[1-3] Faculty members at universities and community colleges have developed courses[4] and minors[5,6] to help college students develop technological literacy. A review of papers submitted for Technological Literacy sessions at ASEE meetings [4-26] shows a range of approaches, including approaches based on examples from the history of technology[7], laboratory exercises in dissection and construction of various devices[8-10], study and reproduction of old forms of technology[11], study of emerging technologies[12,13], and the use of news articles[14] and movies.[15] Courses teaching technological literacy are often similar to introductory courses in engineering and engineering technology.[24,25] Technological literacy is an important element in STEM programs at the K-12 level.[16-21] Activities at the college level should help to prepare teachers to teach in these programs.

In college courses and programs, the primary emphasis has been on helping people who are not majoring in engineering or engineering technology develop technological literacy.[4,6] Majors need to be technologically literate as well.[22] Many dimensions of technological literacy can be linked to topics listed in both EAC ABET and TAC ABET criteria.[16,23] Thinking from the perspective of teaching technological literacy can be helpful in efforts to satisfy - and to document that programs satisfy - these criteria. Concepts of technological literacy are often included in first year[24,25] and design[26] courses and could be given greater emphasis. Considering technological literacy when approaching these and other subjects should be beneficial to students.

Technological Literacy and What We Want Our Majors to Know

The National Academy of Engineering publication, Technically Speaking, lists the following characteristics of a technologically literate citizen:[27]

Characteristics of a Technologically Literate Citizen

Knowledge

• Recognizes the pervasiveness of technology in everyday life.

• Understands basic engineering concepts and terms, such as systems, constraints, and trade-offs.

• Is familiar with the nature and limitations of the engineering design process.

• Knows some of the ways technology shapes human history and people shape technology.

• Knows that all technologies entail risk, some that can be anticipated and some that cannot.

• Appreciates that the development and use of technology involve trade-offs and a balance of costs and benefits.

• Understands that technology reflects the values and culture of society.

Ways of Thinking and Acting

• Asks pertinent questions, of self and others, regarding the benefits and risks of technologies.

• Seeks information about new technologies.

• Participates, when appropriate, in decisions about the development and use of technology.

Capabilities

• Has a range of hands-on skills, such as using a computer for word processing and surfing the Internet and operating a variety of home and office appliances.

• Can identify and fix simple mechanical or technological problems at home or work.

• Can apply basic mathematical concepts related to probability, scale, and estimation to make informed judgments about technological risks and benefits.

In the area of capabilities, majors are expected to reach a much higher level. Majors are expected to be able to be useful members of project teams which will design, build, and manage complex technological systems. The curriculum and the related program learning objectives in an engineering or engineering technology degree program can be linked to a specific list of capabilities.

With experience, our graduates are expected to be able to lead project teams and manage large, complex engineering projects. To do this, they need the capabilities associated with their major. They also need attributes listed here in the areas of knowledge and ways of thinking and acting. Expectations for majors will be different, at least for some items listed. One difference here is that we should expect majors to be able to bring and share a greater understanding with people who will be part of the decision-making process who do not have an engineering background. Again, aspects of a program's curriculum and program learning objectives can be linked to items that would fit in these categories.

While it may not be recognized as such, engineering and engineering technology degree majors need to be helped to develop technological literacy, and elements of this are included in the curriculum. In efforts to meet EAC and TAC ABET criteria, it should be useful to formally consider technological literacy in the process of development, evaluation, and assessment of the curriculum, and to include the holistic development of technological literacy as an element of the student's education.[23]

Technological Literacy and Major Courses

Often, non-majors are likely to encounter technological literacy directly in one course (if at all). Majors in engineering and engineering technology can be intentionally exposed to aspects of technological literacy in many courses. Some courses, such as introductory,[24,25] problem-solving, design,[26] and capstone courses, take a broad view of engineering and technology. While the unifying theme may not be encountered as such, these courses cover many elements of technological literacy. Many major courses are focused on capabilities in specific subject areas – thermodynamics, digital electronics, transport processes, etc. – and on application of this knowledge in practice. Elements of the first two dimensions of technological literacy may be incorporated in these courses as well. An analogy may be found in the dispersion of design content throughout the curriculum. Since the 1980s, textbooks for courses like thermodynamics have been revised to emphasize design content (for example, see subsequent editions of Moran and Shapiro, Fundamentals of Engineering Thermodynamics[28]). In the same manner, content related to other aspects of technological literacy and the associated ABET criteria can be added to materials for these courses. These additions can be useful to help students relate course-specific knowledge to broader engineering problems, as well as helping them develop technological literacy.

Following are some examples of courses (courses taught at one time by the author) of opportunities to add content that is both relevant to the course and will be included specifically to help students develop technological literacy. This is demonstrated here using the "Characteristics of a Technologically Literate Citizen"[27] quoted from "Technically Speaking" and showing specific aspects that can be explored using examples related to the course material. Knowledge of the specific course content will be taken as a given here; this discussion will be limited to other aspects of technological literacy.

Course: Introduction to Engineering and/or Engineering Technology
As noted previously, these courses have much in common with courses for non-majors, and many elements of the course content can be linked to the characteristics of technological literacy.[24,25] One textbook developed for first year engineering courses uses examples from the history of technology to teach engineering; this book and a companion volume are well suited to courses in the history of technology and technological literacy.[29,30] Case studies[31] and hands-on learning activities used to meet the goals of first year classes can be used at the same time to teach elements of technological literacy likewise, laboratory exercises developed for teaching technological literacy[8-10] would also be useful in first year courses. It can be useful to explore these links and to include the development of technological literacy in the formal learning outcomes.

Courses: Problem-Solving; Capstone Senior Design
Where first year courses introduce majors to the study of engineering and technology, upper level courses in problem solving and capstone courses are expected to help students learn how to use knowledge from other courses in practice.[32] Many characteristics of a technologically literate person fit the content of these courses, including the following:

- *Understands basic engineering concepts and terms, such as systems, constraints, and trade-offs.*
- *Is familiar with the nature and limitations of the engineering design process.*
- *Knows that all technologies entail risk, some that can be anticipated and some that cannot.*
- *Appreciates that the development and use of technology involve trade-offs and a balance of costs and benefits.*
- *Asks pertinent questions, of self and others, regarding the benefits and risks of technologies.*
- *Seeks information about new technologies.*
- *Participates … in decisions about the development and use of technology.*

Including these characteristics in planning the course and assessment will give an indicator of progress towards meeting the course objectives.

Course: Engineering Materials
For this course, the learning outcomes include 1) a working knowledge of materials and the ability to apply this in practical applications, 2) a basic background in the science of materials, 3) a general knowledge of the different types of materials, 4) the different ways that materials fail in applications, and 5) an appreciation of the challenges involved in using new materials in practice. A representative text for materials courses, Budinski and Budinski,[33] covers mechanical properties and materials testing and goes into major types of materials, how the materials fail, and treatments for different types of materials in some detail.

There are many opportunities here to relate the course content to aspects of technological literacy. A few are given here:

• *Recognizes the pervasiveness of technology in everyday life.*

A student in a materials course should think about the many different materials they encounter (and, perhaps, take for granted). In the course, they should recognize the many different forms of each basic type of material and the scientific and engineering effort behind producing these materials.

• *Is familiar with the nature and limitations of the engineering design process.*

These can be brought out in the discussion of how materials fail and the design tools that have been developed to predict failure of parts. Including material about specific failures, such as fatigue failures in the early de Havilland Comet airliners,[34,35] helps students recognize limitations in design tools and processes.

• *Knows some of the ways technology shapes human history and people shape technology.*

Steel is one example of a material where changes in materials technology led to changes in other fields. A discussion of these changes and how they changed people's lives can show how technology has an impact on human society.[36] There are also examples here of how public reaction to failures shape the development and use of a new technology.

• *Knows that all technologies entail risk, some that can be anticipated and some that cannot.*

This can be explored with a discussion of design tools based on failure of the material and their limits and on past examples of failures and the public reaction to those failures.

• *Appreciates that the development and use of technology involve trade-offs and a balance of costs and benefits.*

Case studies of situations where one material ("new" and with superior properties) is to be used in place of another ("old") material can be useful here where the advantages must be balanced against uncertainties in the use of the replacement material. New composite materials have remarkable mechanical properties. However, the failure modes of steel are relatively well understood and the new materials are often more expensive.

• *Asks pertinent questions, of self and others, regarding the benefits and risks of technologies.*

• *Participates, when appropriate, in decisions about the development and use of technology.*

Case studies can be used to illustrate these points.

Course: Thermodynamics

Here, the learning outcomes include the application of thermodynamic principles to power and refrigeration systems. Again, there are many opportunities here to relate the course content to aspects of technological literacy. These include:

• *Recognizes the pervasiveness of technology in everyday life.*

Students can link the many heat engines and refrigeration machines they encounter with the engineering effort needed to develop these machines.

• *Is familiar with the nature and limitations of the engineering design process.*

In addition to design examples, consideration of the differences between models based on ideal assumptions (isentropic processes, for example) and tools for predicting the behavior of real machines (ex: isentropic efficiency) can be used to show limitations of the design process.

• *Knows some of the ways technology shapes human history and people shape technology.*

A key element of change in human society since 1700 has been the development of heat engines; these examples can be used to explore benefits and problems. There are many references available in print and on the Internet for this subject; one useful and recent book is Rosen, <u>the Most Powerful Idea in the World</u>.[37] The effect of mechanical refrigeration technology in the form of air conditioning systems on patterns of human settlement in North America can also be used to good effect here as well.

- *Knows that all technologies entail risk, some that can be anticipated and some that cannot.* In the stories of both heat engines and refrigeration machines, there are examples of failures and of unanticipated risks, such as the problems recognized with tetraethyl lead additives in gasoline and chlorofluorocarbon refrigerants. A brief discussion of one or more of these issues can serve as a case study of this aspect.
- *Understands that technology reflects the values and culture of society.* Values, and changes over time in values, can be examined by looking at changes in what society chooses to accept in this area of technology. One example here would be emission control systems on internal combustion engines.
- *Asks pertinent questions, of self and others, regarding the benefits and risks of technologies.*
- *Participates, when appropriate, in decisions about the development and use of technology.* Again, case studies from this area can be used to illustrate these points.

Similar links can be made with other courses.

Application and Assessment

Technological literacy content may be added in many ways. In addition to including at least a brief mention of these issues in the classroom, students can be directed to learn more through readings in supplemental texts or reserve materials. This can also be the basis for writing assignments and presentations.

Materials used here may be unlike the standard course materials. Books on the history of technology or books on science and technology for the general public may be used to supplement regular textbooks. These supplemental readings can help students understand the importance of the technology related to the course, how this technology developed, and how the technology was adopted. Some relevant stories or concepts may be included in works of fiction (especially science fiction) and movies. Machine dissection or design projects may be used to illustrate these topics as well. Ideally, this will add an enjoyable element to the course for the students (and the instructor).

An initial approach to incorporating technological literacy in major courses may be simple and informal. Existing courses may be reviewed individually in light of the dimensions of technological literacy, and material added to highlight these aspects. Building on that foundation, coverage of these topics across the curriculum would be linked, and the technological literacy of students would be assessed.

This is likely to already be assessed in courses, such as first year courses, where many technological literacy topics are already likely to be covered. This is likely to be qualitative material, and assessment would be based on answers to short answer and to longer written answer questions. One measure can be cumulative scores on short answer questions on this material. This gives an overall indicator at a basic level. With time constraints on exams, it is unlikely that the exam will contain many questions on each aspect of technological literacy.

Essay questions, such as a question asking students to consider the benefits and drawbacks of a specific technology, can give an indicator of abilities at a higher level. Evaluation is more subjective and it may be difficult to separate an evaluation of the student's technological literacy from their ability to write an essay.

To track their progress over time, similar questions may be asked in courses throughout the curriculum. Short answer questions, as well as essays, may be added to other courses that cover this content. Other assignments may be useful indicators as well. If the questions or assignments are designed with the elements of technological literacy in mind, this can give an indicator of the student's progress in this area.

For proper evaluation and assessment, some measure of the student's technological literacy is needed in the senior year. This may be done in senior capstone design or problem solving courses and in exit exams. If this material is integrated into the curriculum, it should be possible to measure technological literacy with questions that are also used to evaluate progress in other aspects.

Also needed for proper evaluation is some standard for technological literacy. At the college level, a recent paper by Gustafson et al[38] discusses the development of educational objectives and outcomes for technological literacy programs. The International Technology and Engineering Educators Association (ITEEA) has developed technological literacy standards for K-12 programs.[16,17] A component of the 2012 conference is to improve engineering and technology education at the P-16 level.[39] College level programs intended to prepare K-12 teachers should include these standards in their assessment programs.

Conclusion

Technological literacy is important for all, and should be formally considered in the development of curriculum in engineering and engineering technology degree programs. Elements of technological literacy are there in these degree programs and are reflected in EAC and TAC ABET criteria. It is beneficial for students and helpful to faculty members seeking to meet (and document that they meet) ABET criteria to think in terms of teaching technological literacy across the curriculum. The characteristics defined for a technologically literate person can be used as a structure for integrating this topic across the curriculum and for assessment. The result will be graduates who are technologically literate and are better prepared to help others understand and make intelligent, informed decisions about technology.

Bibliography

1. Technically Speaking – Why All Americans Need to Know More About Technology, National Academy Press, Washington, DC, 2002. ISBN 0-309-08262-5

2. Krupczak, John, and David F. Ollis, Improving the Technological Literacy of Undergraduates – Identifying the Research Issues, National Science Foundation, 2005.
3. Ollis, David, and Greg Pearson, What is Technological Literacy and Why Does It Matter?, Paper No. 2006-695, Proceedings of the 2006 American Society for Engineering Education Annual Conference & Exposition.
4. Krupczak, John, and David Ollis, Technological Literacy and Engineering for Non-Engineers: Lessons from Successful Courses, Paper No. 2006-744, Proceedings of the 2006 American Society for Engineering Education Annual Conference & Exposition.
5. McGrann, Roy, A General Engineering Minor as a Means to Encourage Technological Literacy, AC 2010-1405, Proceedings of the 2010 American Society for Engineering Education Annual Conference & Exposition.
6. Krupczak, John, Mani Mina, Robert J. Gustafson, James Young, Development of Engineering Related Minors for Non-Engineering Students, AC 2010-1055, Proceedings of the 2010 American Society for Engineering Education Annual Conference & Exposition.
7. Carlson, W. Bernard, Technological Literacy and Empowerment: Exemplars from the History of Technology, Paper No. 2006-1182, Proceedings of the 2006 American Society for Engineering Education Annual Conference & Exposition.
8. Ollis, David, Technological Literacy: Connecting through Context, Content, and Contraption, Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition.
9. Krupczak, John, and David Ollis, Hands-On Activities for Technological Literacy, AC 2006-992, Proceedings of the 2006 American Society for Engineering Education Annual Conference & Exposition.
10. Krupczak, John, and Kate Disney, Portable Laboratories for General Education Engineering Courses, AC 2010-1049, Proceedings of the 2010 American Society for Engineering Education Annual Conference & Exposition.
11. Loendorf, William R., Creating Interest in Technological Literacy by Reintroducing Past Technologies, AC 2011-992, Proceedings of the 2011 American Society for Engineering Education Annual Conference & Exposition.
12. Bishop, Bradley, Teaching Emerging Technologies Using a Socio-technological Development Model, AC 2009-1887, Proceedings of the 2009 American Society for Engineering Education Annual Conference & Exposition.
13. Walk, Steven, Increasing Technological Literacy Through Improved Understanding of Technology Emergence and Diffusion, AC 2010-1945, Proceedings of the 2010 American Society for Engineering Education Annual Conference & Exposition.
14. Libros, Randy, Improving Technological Literacy Through the Use of News Articles, AC 2011-1212, Proceedings of the 2011 American Society for Engineering Education Annual Conference & Exposition.
15. Blake, John, Using Movies to Explore Elements of Technological Literacy, AC 2009-1691, Proceedings of the 2009 American Society for Engineering Education Annual Conference & Exposition.
16. Standards for Technological Literacy: Content for the Study of Technology, 3rd Ed., International Technology Education Association, 2007, ISBN 1-887101-02-0.
17. Gorham, David, Pam B. Newberry, Theodore A. Bickart, ABET and Standards for Technological Literacy, Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition.
18. Newberry, Pam, T. Richard Grimsley, John Hansen, Anne Spence, Research of Project Lead the Way (PLTW) Curricula, Pedagogy, and Professional Development: Activities Regarding Increasing Engineering and Technological Literacy of K-12 Students in the PLTW Network, AC 2006-1115, Proceedings of the 2006 American Society for Engineering Education Annual Conference & Exposition.
19. Perova, Nataliia, Chris Rogers, David Henry Feldman, Investigation of the Successful Effort to Change Educational Curriculum Frameworks in Massachusetts to Include Engineering and Technology, AC 2009-2037, Proceedings of the 2009 American Society for Engineering Education Annual Conference & Exposition.

20. Macho, Steve, A Functional K-12 Conceptual Framework for Teaching Technological Literacy, AC 2010-1942, Proceedings of the 2010 American Society for Engineering Education Annual Conference & Exposition.
21. Bartholomew, Scott, Geoff Wright, Ron Terry, Developing and Assessing STEM Curriculum with the Intent of Promoting Technological Literacy, AC 2011-2385, Proceedings of the 2011 American Society for Engineering Education Annual Conference & Exposition.
22. Newberry, Bryan, Engineers and Technological Literacy, AC 2007-2245, Proceedings of the 2007 American Society for Engineering Education Annual Conference & Exposition.
23. Blake, John, Technological Literacy, EAC ABET, and TAC ABET Accreditation Criteria, Paper No. AC 2010-1588, Proceedings of the 2010 American Society for Engineering Education Annual Conference & Exposition
24. Ohland, Matthew, First Year Engineering Programs and Technological Literacy, AC 2006-1282, Proceedings of the 2006 American Society for Engineering Education Annual Conference & Exposition.
25. Blake, John, Technological Literacy and First Year Courses for Engineering and Engineering Technology Majors, AC 2010-1582, Proceedings of the 2010 American Society for Engineering Education Annual Conference & Exposition.
26. Ollis, David, and John Krupczak, Teaching Technological Literacy: An Opportunity for Design Faculty, AC 2006-620, Proceedings of the 2006 American Society for Engineering Education Annual Conference & Exposition.
27. Technically Speaking, pg 17
28. Moran, Michael J. and Howard N. Shapiro, Fundamentals of Engineering Thermodynamics, 6th Ed., Wiley, 2008, ISBN-13 978-0471-78735-8.
29. Billington, David P., The Innovators: the Engineering Pioneers Who Made America Modern, Wiley, 1996, ISBN-13: 978-0471140269.
30. Billington, David P. and David P. Billington Jr., Power, Speed, and Form – Engineers and the Making of the Twentieth Century, Princeton University Press, 2006, ISBN-13: 978-0-691-10292-4.
31. Manoharan, Ashok K., P.K. Raju, Chetan Sankar, Use Of Multimedia Case Studies In An Introductory Course In Mechanical Engineering, AC 2010-1369, Proceedings of the 2010 American Society for Engineering Education Annual Conference & Exposition.
32. Fogler, H. Scott, and Steven E. LeBlanc, Strategies for Creative Problem Solving, 2nd Ed., Prentice-Hall, 2008, ISBN 978-0-13-008279-4.
33. Budinski, Kenneth G., and Michael K. Budinski, Engineering Materials - Properties and Selection, 9th Ed., Prentice-Hall, 2010, ISBN 0-13-712842-8.
34. Newey, Charles et al, An Introduction to Materials – The Skin of Concorde: Unit 16, The Open University Press, 1974, ISBN 0 335 02669 9.
35. Verhovek, Sam Howe, Jet Age – the Comet, the 707, and the Race to Shrink the World, Penguin, 2010, ISBN 978-1-58333-402-7, pp 149-177.
36. Billington, the Innovators, pp 159-177.
37. Rosen, William, The Most Powerful Idea in the World – a Story of Steam, Industry, and Invention, Random House, 2010, ISBN 978-1-4000-6705-3.
38. Gustafson, Robert. J, John Krupczak, James F. Young, Mani Mina, Educational Objectives and Outcomes for Technological Literacy Programs at the College Level, AC2011-182, Proceedings of the 2011 American Society for Engineering Education Annual Conference & Exposition.
39. International Technology and Engineering Education Association website: http://www.iteea.org/