2006-701: ASSESSING TECHNOLOGICAL LITERACY IN THE UNITED STATES

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Greg Pearson is a program officer at the National Academy of Engineering (NAE), where he directs the academy's efforts related to technological literacy and public understanding of engineering. Mr. Pearson most recently served as the responsible staff officer for the Committee on Assessing Technological Literacy, a joint project of the NAE and the National Research Council. He also oversaw an earlier project that resulted in publication of the report, Technically Speaking: Why All Americans Need to Know More About Technology.

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Abstract

The challenges to developing tools and techniques for assessment of technological literacy are presented in a panel format, with each panelist above providing a 4 minute summary of his written contribution shown below, followed by an audience questions and discussion. Three distinct sections of this overview provide: a summary of a recently issued NAE report on assessing the technological literacy of K-12 students, K-12 teachers, and the general US population, a case study of assessment of a well established technological literacy course at Hope College, and summary of 12 technological literacy course formats, student learning styles, and assessment and evaluation tools, taken from a 2005 NSF-sponsored faculty workshop on teaching technological literacy. Taken collectively, these pieces identify the current situation for, and future challenges to, achievement of widespread assessment for technological literacy undergraduate instruction.

I. Assessment of Technological Literacy: A National Academies Perspective.
(Greg Pearson National Academy of Engineering)

The idea that all Americans, and U.S. school children in particular, should know something about the nature, history, and role of technology[1] is not new. Over the last several decades, curriculum developers, university scholars, engineering and scientific professional associations, museums, government agencies, foundations, industry groups, and others have invested considerable time and money in a range of efforts intended to encourage greater "technological literacy."   The majority of these initiatives have taken place within an educational system that for the most part does not recognize technology as an area of academic content in its own right.

In the last five years, several separate but related initiatives have seemed to elevate the prospects that both the policy-making and education communities in the United States will begin to view the study of technology as an important issue. The National Science Foundation and the National Aeronautics and Space Administration, for example, funded the development of a set of content standards for the study of technology (ITEA, 2000). During this same period, one of the largest professional engineering societies in the world, IEEE, convened engineering and education school deans with the goal of beginning a dialogue between the two camps about technological literacy and its implications for how teachers are educated. In 2002, the National Academy of Engineering and National Research Council published *Technically Speaking: Why All Americans Need to Know More About Technology*,[2] a report that argues for greater technological literacy for all citizens[1]. The report proposed a model of technological literacy that has three dimensions: knowledge, capability, and ways of thinking and acting.

Unfortunately, as *Technically Speaking* points out, none of these efforts—past or present—has been informed in any meaningful way by knowledge of what Americans actually know about technology. Although the best guess of experts with an interest in the issue is that the level is lower than we would wish, the truth is that no one knows.

Without reliable data on what people know about the technological world and how these understandings change over time, U.S. educators, business leaders, and policy makers are seriously handicapped when it comes to gauging the impact of efforts to enhance technological literacy and to planning future efforts. This is troubling, since substantial federal as well as private monies and expectations are being invested in such things as curriculum, instructional materials, museum exhibits, and television programming that are meant in part or whole to boost understanding of technological issues.

With this problem in mind and with funding from the National Science Foundation, the National Academy of Engineering and National Research Council embarked in 2003 on a major study of assessment for technological literacy. The goal of the project was to determine the most viable approach or approaches for assessing technological literacy in three distinct populations in the United States: K-12 students, K-12 teachers, and out-of-school adults (the "general public").

The project had two specific objectives:

- Assess the opportunities and obstacles to developing one or more scientifically valid and broadly useful assessment instruments for technological literacy in the three target populations.

- Recommend possible approaches to be used in carrying out such assessments including the specification of subtest areas and actual sample test items representing a variety of item formats.

The 16-person study committee, chaired by NAE member and Dartmouth College engineering professor Elsa Garmire, concluded its deliberations late last year. In addition to Garmire, the panel included experts in learning and cognition, assessment, informal education, opinion survey research, and K-12 education reform. The committee's report was to be published late last spring, after this article was submitted to ASEE. Rules of the National Academies prevent public release of the details of its reports before they are published. However, some of the general outlines of the document can be described here.

As a context for its deliberations, the Committee on Assessing Technological Literacy collected some 30 examples of assessments that have been or might be used to measure an aspect of technological literacy, even if they were not developed for that purpose. Most targeted K–12 students, a few focused on out-of-school adults, and just one was intended for teachers. The report will include summaries and committee comments on all of these instruments. No single instrument seemed up to the task of assessing technological literacy, the way it is described in *Technically Speaking*.

Collecting the instruments was a helpful exercise, because it focused the committee's attention on key challenges for assessment in this domain. One challenge relates to the difficulty of measuring the capability dimension. This is the "doing" aspect of technological literacy, and assessment of performance is typically time consuming and costly. One avenue worth exploring in this regard may be computer-based testing, including simulation.

Another key hurdle—at least for assessments used in formal, school settings—will be the development of conceptual frameworks that clearly and convincingly describe the cognitive and the content aspects of technology that should be included in an assessment. This is done regularly for important assessments in other subjects, such as mathematics and science, but it has

not been attempted in technology. In spring 2005, the National Assessment Governing Board, which oversees the National Assessment of Educational Progress, the so-called nation's report card, decided to sponsor a study to test the feasibility of assessing technological literacy among U.S. school children. As part of this work, a framework will be developed. But this framework may not be particularly helpful to efforts to assess what teachers know and can do with respect to technology, or to attempts to glean general public understanding.

Assessments in all three populations—students, teachers, and out-of-school adults—will have to contend with the widespread association of the word technology with computers, rather than the broader view of technology favored by engineers and scientists. And because technological literacy remains relatively undervalued and poorly understood, its assessment cannot move forward without concomitant efforts to convince policy makers, educators, and the public of the fundamental importance of a more tech savvy citizenry. Ironically, assessment data could help make that case.

In addition to describing and discussing the collected assessment instruments, the report includes essential background information on the fields of assessment and cognition; presents five sample cases of assessment to illustrate some of the challenges and opportunities to measurement in this area; and proposes a number of steps to expand and improve assessment of technological literacy in the United States.

II. Case Study of a Technological Literacy and Non-majors Engineering Course
(John J. Krupczak, Jr., Hope College)

Since 1995 engineering faculty at Hope College have taught a course for non-engineering students called: "Science and Technology of Everyday Life" The course examines the science and engineering underlying modern consumer technological devices. Distinguishing features are study of a broad sample of familiar technological devices, construction by students of working devices, and writing assignments on technological topics. Over nine years, the total enrollment of more than 1000 students has averaged 60% women and 26% pre-service teachers. To evaluate student outcomes, the Motivated Strategies for Learning Questionnaire (MSLQ) was applied[3,4]. Statistically significant increases were found in intrinsic motivation, task value, and self-efficacy. A decrease in test anxiety was also found. The results are consistent across all semesters analyzed. The case study shows that non-engineering students can have increased motivation for learning science and technology, increased perceived value for science and technology, increased self-confidence about learning science and technology.

Course Description
The "Science and Technology of Everyday Life," taught at Hope College is intended for students from non-technical majors and includes students from business, history, fine arts, and pre-service education students. First offered in the Spring 1995 semester the objective of the course is to develop a familiarity with both the engineering aspects of how various technological devices work, and an understanding of the basic scientific principles underlying their operation. The course focuses on the wide variety of technology used in everyday life to help in engaging the student's interest. The course has been taught 24 times to a total of 1066 students. The percentage of women enrolled has been consistently near

60%. The largest single constituency for the class is pre-service teachers. The percentage of pre-service teachers in the class has averaged 26%.

The course format is three hours of lecture and three hours of laboratory per week over a fifteen-week semester. The course topics were selected to represent the technologies most frequently encountered in everyday life and were based partly on the results of surveys of student interests. Topics covered include the automobile, basic electrical appliances, telecommunications, medical imaging, and computers, Laboratories involve activities such as disassembling a car engine, and building a simple electronic music keyboard. Enrollment is about 48 students each semester. The lecture portion of the course is taught in a single section. There are two laboratory sections of 24 students each. Each laboratory section is run by one faculty member assisted by undergraduate teaching assistants.

Case Study Design
A total of 139 students participated during the 2003-2004 academic year: 47 students in the Fall 2003 semester, 54 in the Spring 2004 semester, and 38 in the May Term (four-week summer session) 2004. Students completed several scales of the Motivated Strategies for Learning Questionnaire—MSLQ Specifically, data were collected using these scales:

Intrinsic Motivation: Intrinsic motivation measures the extent to which students are inspired to learn because of the challenge of learning new things, curiosity about the topic, or the joy that comes from understanding complex material.

Extrinsic Motivation: Extrinsic motivation measures the extent to which students are inspired to learn because of rewards such as praise, grades, money, or competition.

Task Value: Task value measures the extent to which students feel that what they are learning is relevant, useful and personally meaningful. This measure is particularly important for this project, as one of the goals of this project is to demonstrate to students all of the benefits that will accrue to those who learn about technology.

Self-Efficacy: Self-efficacy measures students' beliefs about their ability to achieve on school-learning tasks. If students feel competent and empowered to succeed in school, they will have high scores on self-efficacy. This measure also is particularly important for this project, as one of the goals is to increase students' belief that science and technology learning are tasks that they can complete. This will be particularly important to students in this class, as many of them will be elementary school teachers. If the preservice teachers can develop a sense of technological self-efficacy, they can communicate that positive belief to their future students that they, too, can successfully learn about science and technology.

Control Beliefs: Related to self-efficacy, the Control Beliefs sub-scale measures the extent to which students believe that hard work in school will result in positive outcomes. If students feel as though effort will result in accomplishment, they will score high on this scale.

Critical Thinking: A five-item scale measuring the extent to which students analyze and critique arguments and assertions.

These MSLQ scales have been used on hundreds of campuses and translated into several languages. The psychometric properties are reliable and predict achievement, particularly in science and social science courses.

Hope College Results

We conducted paired t-tests to determine if changes occurred from the beginning of the semester to the end of the semester on any of the dependent measures. Table 1 shows results from the Spring 2004 semester. Most of the findings were consistent across all three semesters of study, suggesting the robust nature of most of the findings. Students showed increases in intrinsic motivation, task value, control beliefs, self-efficacy, effort regulation, and decreases in extrinsic motivation and test anxiety. Somewhat puzzling was the changes on the extrinsic motivation scale. There was a decrease in extrinsic motivation. However, given that the course's major focus is on increasing students' interest in science and their beliefs about the value of science and technology, changes in extrinsic motivation (in either direction) were neither sought or anticipated.

Table 1: MSLQ Change Scores Results for Spring 2004.

MSLQ Scale	Pretest Mean	Post Mean	t	p
Intrinsic Motivation	4.67	5.19	4.87	< 0.001
Extrinsic Motivation	4.77	4.41	2.40	0.021
Task Value	5.22	5.70	4.00	< 0.001
Control Belief	5.43	5.80	2.25	0.029
Self Efficacy	5.22	6.02	5.87	< 0.001
Test Anxiety	3.33	2.78	2.85	0.007
Critical Thinking	4.22	4.06	1.23	NS

Hope Case Study Conclusions

The current study uses techniques from educational psychology in a technological literacy context. A course has been developed for non-engineering majors that demonstrated increased motivation, increased task value, and improved adaptive beliefs about science and technology. Given that many of the students enrolled in this course were pre-service elementary teachers who will be teaching science in their classrooms, it is very important to lower anxiety, increased perceived value, and increase motivation for science and technology learning. This course accomplished those objectives and the MSLQ provides a assessment tool.

III. Summary of Technological Literacy Course Formats, Student Learning objectives, and Assessment Tools and Techniques (David Ollis, North Carolina State University)

In the spring 2005, NSF sponsored and NAE hosted a faculty workshop on Technological Literacy of Undergraduates, attended by about 40 university educators and NSF

and NAE personnel[4,5]. The majority of the participants have developed and taught technological literacy courses in an undergraduate setting. The participants displayed both similarities and differences in their approaches to course organization, collaborative teaching and assessment tools and techniques utilized.

Student Learning Objectives
　　　　Within the context of engineering education, student learning objectives are important as they provide the foundation for outcomes-based assessment: did student learning result in achievement of the desired outcomes? Three illustrative cases are summarized below. While some commonality exists, the diversity of student learning objectives is appreciable. This diversity of learning objectives makes comparison of assessment methods difficult.

Technology and the Human Built Environment (K. Vedula, University of Massachusets)

Students will develop:
- an understanding of the nature of technology including relationships among technologies and the connections between technology and other fields.
- an understanding of Technology and Society including the cultural, social, economic and political effects of technology; effects of technology on the environment; role of society in the development and use of technology, and influence of technology on history.
- abilities to apply the design process, use and maintain technology and assess the impact of products and systems.
- an understanding of the design world including selecting and using medical technologies, agricultural and biotechnologies, energy and power technologies, information and communication technologies, transportation technologies, manufacturing technologies and construction technologies.

Engineering in the Modern World (M. Littman and D. Billington, Princeton Univesity)

Students will
- develop an understanding of the transformation of the modern world through engineering (e.g., agriculture to industry, isolated to connected, etc.)
- define modern engineering through examples of innovations (structures, machines, networks, processes from the start of the industrial revolution to the present); understand the historical context (political, social, economic) for engineering innovation; understand the underlying science; recognize the influence of technology on society as expressed by artists (painters, photographers, writers)
- develop an understanding of the key people who were responsible for engineering innovations- what they did, when they did it, and why they were successful.

Technology Literacy: How Stuff Works (D. Ollis, North Carolina State University)

Students will:
- develop a basic vocabulary and conceptual framework for describing the technical and historical origins of modern technological devices
- explain the conceptual operating bases of current and prior technologies which address similar societal needs
- use and dissect devices to develop understanding of the relationships between technical subsystems of a device (e.g., the optical, electrical, and mechanical subsystems of a facsimile (FAX) machine), and their influence on device design and operation.
- develop and understanding of the impacts (technical, economic) of a device in a given context, through lecture and individual analytic written papers.

Assessment Tools and Techniques

   A survey was conducted of instructors offering undergraduate technological literacy courses. Most courses used several assessment tools and techniques. The average number of tools and techniques per course was about 6, probably larger than the average number used within a typical engineering course. Shown in Table 2 are the most common along with additional individual approaches indicated in category (i), and including individual or team-written term papers, web-based projects, lab reports, robot simulations, and book analyses.

Table 2: Summary of Assessment Tools and Techniques.

Method	YES	NO
Pre/post course student survey	5	5
Student interviews	7	2
Formative course assessment	7	4
Summative course assessment	9	3
Written exams	10	2
Oral presentations	8	3
Lab team performance	9	2
Other:		
individual (1) or team-based (1) term paper	2	
Web-based projects (1), lab reports (1)	2	
robot simulations(1), book analyses(1)	2	

   The lack of a consensus definition for technological literacy noted earlier makes comparison of evaluations among different courses awkward. Similarly, the relative lack of student learning objectives also diminishes the potential effectiveness of the evaluations for other courses presented, since the students themselves may not have been aware of the instructor expectations in all cases.

Research Issues for Technological Literacy Assessment

   The workshop final report included recommendations for study, development , and execution of tasks aimed at broad implementation of TL instruction in undergraduate courses. Under assessment the following issues were articulated:

Measure Decreased Fear. A way to measure the in fear of science and technology. Assessment should provide means of evaluating overcoming fear and building confidence about understanding science and technology. Methods are needed for evaluating technological literacy courses and their impact on changing attitudes of the student population.

Competency Model. What do technologically savvy people do that non-tech savvy people cannot do? What kinds of things can they do? What does a technologically savvy person look like? Developed a competency based approach that can be measured.

Longitudinal Study. A longitudinal study of students who take technological literacy courses should be done. Such long term tracking would help establish if and how people who take such courses are changed by them.

Measure Ability to Understand Unfamiliar Technology. There is a need to measure if technological "savviness" has been enhanced. For example this might be a reliable method to assess the ability to make sense of unfamiliar personal technology or technology based problems. Such tools could then be used to assess the technological literacy of the nation.

Assessment definition. An assessment of technological literacy might include such components as ability to address technical problems and seek solutions, ability to engage in debate on technical issue, accuracy in making scientifically sound arguments, capacity to consider the multi-dimensionality of solutions, and use of scientific principles to explain observed phenomena.

Assess Crossing Boundaries. What are methods for assessing scholarly contributions of faculty who cross disciplinary boundaries? How can it be established what research is worthwhile, especially in technologically savvy areas?

Inheritability of Technological Understanding. Conduct a study of the inheritability of technological savvy from parents to children and teachers to students.

Assessment based on Explaining an Unusual Phenomenon. How does a rattleback work? This is an elliptically-shaped solid that, when placed on a surface, will first rotate in one direction then the other seemingly without outside interference. Go to a cross section of society in all areas and write a narrative account of what is encountered. Use these results to inform how to assess technological literacy.

Link Course Assessments with National Data. If or when national data on technological literacy is available, compare course assessments to national data. Correlate national technological literacy exam results with performance of students using an appropriate scoring rubric.

Rubric for Socio-technical Projects. Develop a rubric for evaluating socio-technical design projects. Such projects include both social and technical innovation.

Assess Individual Motivation. What are the factors that influence someone to become, or want to become, technologically literate?

IV Conclusions

The concept of technological literacy itself remains open to debate and discussion. While recent work by the National Academy of Engineering has helped to consolidate a working definition of the topic, the results of these initiatives have yet to propagate through the classrooms and teaching laboratories of America's colleges and universities. Assessing technological literacy has proven to be even more challenging than achieving a consensus on the knowledge and abilities need to understand the modern technological landscape. A number of educators have conducted courses at the undergraduate level that have shown success in

improving some of the dimensions of technological understanding among the target populations. This work has contributed to identifying some specific aspects of assessing technological literacy that can serve as a starting point for future efforts.

Bibliographic Information and References

1.) In this piece, the word technology is used in its broadest sense to encompass not only the tangible artifacts of the human-designed world (e.g., bridges, automobiles, computers, satellites, medical imaging devices, drugs, genetically engineered plants) but also the larger systems of which the artifacts are a part (e.g., transportation, communications, health care, food production), as well as the people and infrastructure needed to design, manufacture, operate, and repair the artifacts.

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3.) Pintrich, P.R., Smith, D., Garcia, T., and McKeachie, W. (1991). A Manual for the Use of the Motivated Strategies for Learning Questionnaire. Technical Report No. 91B-004. National Center for the Improvement of Postsecondary Teaching and Learning, University of Michigan.

4.) VanderStoep, S.W., Pintrich, P.R., and Fagerlin, A. (1996). Disciplinary differences in self-regulated learning in college students. Contemporary Educational Psychology, 21, 345-362.

5.) Krupczak, J.J and D. Ollis, "Improving the Technological Literacy of Undergraduates: Identifying the Research Issues," Final Report to the National Science Foundation, DUE-0444677, December 15, 2005.

6.) Krupczak, JJ, D. Ollis, R. Pimmel, R. Seals, G. Pearson, and N. Fortenberry, "The Technological Literacy of Undergraduates: Identifying the Research Issues," *35th ASEE/IEEE Frontiers in Education Conference,* October 19 – 22, 2005, Indianapolis, IN.