The Perspective of Non-Engineers on Technological Literacy

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Abstract

This works provides a glimpse into the expectations held by non-engineers for courses in technological literacy. Non-science and non-engineering majors were surveyed to determine what types of information they would like to learn regarding science and technology. The students were enrolled in the "Science and Technology of Everyday Life" course taught at Hope College in the Fall 1998 semester. Anonymous surveys were distributed at the beginning and end of the course. The surveys intended to sample student expectations and interests in learning about science and technology. Later students wrote a short essay describing the information and abilities they considered desirable in the areas of science and technology. Focus group discussions were also conducted. The responses tend toward a desire for information and abilities the non-engineers term as practical or useful in confronting the challenges posed by living in a technological society. The ability to understand what is wrong when technology breaks down, and technical knowledge of benefit to the consumer is highly valued. Specific topics of interest include the automobile, the computer, and common household technological devices. While the input from the non-engineering students forms a useful basis for curriculum development, the general nature of the student expectations leaves ample scope for science and engineering educators to develop specific details of instructional programs.

I. Introduction

Colleges and universities are being called upon to improve the quality of education in science and technology for all undergraduates[1]. In the United States, the National Science Foundation is requesting that Science, Math, Technology and Engineering (SME&T) programs concentrate more effort on the 80% of college students who are not SME&T majors. This latest initiative comes shortly after the completion of a major effort by the Sloan Foundation to improve the quality of education that undergraduates receive in the areas of technology and quantitative reasoning[2].

A number of science and engineering educators have begun to create courses intended to specifically address the needs of the non-SME&T students. A review of some historical background information and relevant new developments has been compiled by Byars[3]. A physics textbook for the general student addressing the basic principles of physics in the context of familiar technological devices has been written by Bloomfield[4].

As new initiatives are being developed to reach non-SME&T students, a need exists for guidelines on definitions for scientific and technological literacy. The National Research

Council, and the American Association for the Advancement of Science have published detailed prescriptions on science education standards[5,6] . Suggested elements of technological literacy have been outlined by Wright[7]. A compilation of technological topics is available in a textbook by Hacker and Bardeen for use in technology courses[8].

The objective of the work reported here is to solicit input on a definition of scientific and technological literacy from college students who are non-SME&T majors. As these students are the actual consumers of scientific and technological literacy courses and their perceptions on what constitutes scientific and technological literacy is potentially useful input in creating courses which meet the needs of the non-SME&T population. The preferences of non-SME&T students should not dictate the content of course and curriculum materials. However, their options should be included as an element in the formulation of definitions of scientific and technological literacy. The needs and desires of the ultimate consumers is recognized as a crucial factor in the success of any product. In the evolving area of technological literacy for the general student, engineering educators should make an effort to incorporate the perspectives of this target group into the formulation of a definition of what these non-SME&T students should learn.

II. Methodology

The information used in this research was gathered from the 47 students enrolled in "Science and Technology of Everyday Life (GEMS-151)" during the Fall 1998 semester. This course is intended for non-science and non-engineering majors. It was developed and first taught in the Spring 1995 semester. The course describes how things work, and examines the scientific principles underlying their operation[9, 10]. Science concepts are presented in the context of familiar technological devices. Topics studied include: the automobile, the telephone, the photocopier, television, radio, compact disk players, and medical imaging technologies. The organizational structure of the course is based on technological devices rather than natural phenomena. Weekly hands-on laboratories are included. These involve such activities as taking apart a car engine, building a simple radio, making a hologram, building an electric motor, or making a simple one-octave electronic keyboard. Since the first offering, interest in the course among non-engineering and non-science students at Hope College has been strong. A section of 48 students has been filled each semester. This course can be used to fulfill part of the Hope College science distribution requirement.

The students enrolled in the Fall 1998 semester came from a range of academic majors including: art, business, history, music, philosophy, social work, and theatre. Women were in the slight majority, averaging 59%. Minority enrollment reflected the college-wide average of 6%. Nearly all of the students fell into the 18 to 22 year old age category. One half of the students were first year freshmen, the balance being mostly third and fourth year students. Approximately 30% of the students in the class were pre-service elementary teachers.

Since the students surveyed already represent a self-selected group, the results obtained cannot be expected to establish the degree of interest among non-SME&T students in courses which

address scientific and technological literacy from a "how things work" perspective. However, it is not the intent of this research to establish that such interest exists. The growing popularity at various institutions of science and engineering courses which attempt to explain modern technology to the general student[11], already serves as a strong indication that this approach has appeal among non-science and non-engineering majors.

The current work was intended to help clarify the conceptions and expectations that the non-science and non-engineering students have in taking a course that addresses the topic of technological literacy. What the non-science student holds as desirable or useful scientific and technological knowledge was to be probed. An attempt was made to see if the expectations were fulfilled at the end of the course.

III. Overview of Survey Instruments

Opinions of students in the "Science and Technology of Everyday Life" course were analyzed using anonymous surveys, focus groups, and student essays. Surveys were conducted at the beginning and end of the course. The student essays were written after the first third of the semester. The focus groups were conducted at the end of the semester. The surveys and focus groups were prepared and administered by the staff of the Frost Center for Social Science Research at Hope College. Participation on the part of students in all activities was voluntary.

Beginning of the Semester Survey

A survey was conducted at the beginning of the semester. Students filled out a written questionnaire during class time. Information requested included gender, year in school, and previous science courses taken. Questions also aimed at extracting student interest in science and technology and the attributes of a science course which might interest the students. Excerpts from the beginning course questionnaire are included in Figure 1.

Interest in Science.

1. Think about the kind of science course that would interest you enough to take it as an elective. What would it be like?

- What would its topic be?
- How would you spend time in class?
- Would there be a lab?
- If so, what would it be like?
- What other features would the course have?

2. Now think about specific things related to science and technology about which you are just naturally curious. What things would you like to know that would be interesting or useful to you? What science and technology questions "pop into your head" as you go about your daily business?

Figure 1: Excepts from the Beginning-of-Course Survey.

Essay Question.

After a third of the semester, the students were asked to write a one-half to one page essay on the topic of scientific and technological literacy. Participation was voluntary and the answers were not graded. However, some incentive to participate was included. Students who completed the essay could turn in one of the required course papers late. The intention was to encourage participation without biasing the students to write things they thought that the instructor wanted to hear just for the sake of a grade. The essay was assigned after the topics of the automobile and electricity had been discussed in class. The text of the essay question is included in Figure 2.

What types of knowledge and abilities would you like to have to feel more comfortable with Science and Technology?

Figure 2: Essay Question on Scientific and Technological Literacy.

End of Course Survey

An end-of-course survey was administered on the last day of classes. As in the beginning-of-course survey, participation was voluntary and anonymous. Many of the survey questions were identical to the beginning of course survey however the questions about experience in previous science courses was omitted. The question regarding things students would find interesting in the areas of science and technology was modified to specifically ask the students if their response had been affected by taking the "Science and Technology of Everyday Life" course. Excepts from the end-of-course survey are given in Figure 3.

Interest in Science.

1. Think about the kind of science course that would interest you enough to take it as an elective. What would it be like?
   - What would its topic be?
   - How would you spend time in class?
   - Would there be a lab?
   - If so, what would it be like?
   - What other features would the course have?

2. Now think about specific things related to science and technology about which you are just naturally curious. What things would you like to know that would be interesting or useful to you? What science and technology questions "pop into your head" as you go about your daily business? Has your response to any of these questions been affected by taking this course?

Figure 3: Excepts from the End-of-Course Survey.

Focus Groups

Focus groups were also used during the last week of the semester. While surveys and questionnaires are useful in obtaining responses to specific questions, the use of focus groups acknowledges that in some cases a more personal and interactive method may also be effective. The format of the focus group also helps to counteract the disinterest that student can develop when subjected to repeated written surveys. Focus groups were conducted during the course laboratory period on a randomly selected subset of the class. The sessions were carried out by Frost Center personnel experienced in conducting such groups. Students were assured that the results would not be shared with the course instructor until after course grades were reported and responses would be kept anonymous.

IV. Results

Beginning and End-of-Course Surveys.

Student response rates for the voluntary surveys were high. The response rate to the beginning of course survey was 43 out of 47 students registered for the class. The number of responses received for the end-of-course survey was 40 out 46 students who continued to be registered at the end of the semester. One student dropped the course.

Results from the beginning and end-of-semester surveys are summarized in Table 1. This table includes the responses to the question: “Think about the kind of science course that would interest you enough to take it as an elective. What would its topic be?” The categories used in Table 1 were developed after reviewing the student responses. The responses were divided into the categories indicated. Each student response was counted in only one of the categories. A number of student responses used the words: “useful”, “practical”, or “related to everyday life” in the response. These responses were considered to have a similar intent and were counted under the practical information category. The biology category includes responses which mentioned either anatomy, biology, botany, genetics, nature, or zoology. Those mentioning chemistry or physics usually mentioned these fields specifically as chemistry or physics. The category “other” includes students who mentioned archeology, the environment, or geology.

These data show a strong interest among the non-SME&T college students for science information that they deem practical or useful to them in their daily lives. This was the most frequently cited topic in both the beginning and end-of-course surveys. The percentage of the responses was 33% at the beginning and 40% at the end. In the start-of-course survey the next highest response were biological topics which scored 29%, essentially equal to the “practical” category. The remaining 30% of the start-of-course responses were split between chemistry, physics, other topics, and no answer.

On the end-of-course survey it is interesting to note that 17.5% of the students specifically mentioned "technology" by name as a topic they would find interesting in a science course. Technology appears as a topic of interest at the end of the course, in contrast to the beginning-of-course responses, in which the word "technology" did not appear even once. This would seem to indicate that a technological focus such as that taken in course such as the "Science and Technology of Everyday Life" course at Hope and elsewhere creates an interest in technology in the non-SME&T students which did not previously exist.

Table 1: Compilation of topics of interest in a science course cited by non-SME&T students.

	Percentage of Responses	
Topic of an Interesting Science Course	**Beginning of Course**	**End of Course**
Practical Information	33.3	40.0
Technology	0.0	17.5
Biology	28.9	10.0
Chemistry	6.7	0.0
Physics	4.4	2.5
Other	13.3	12.5
No Answer	13.3	17.5
	100	100

The results to the survey questions asking if a science course of interest to the students would include a laboratory component are listed in Table 2. More than 80%, the vast majority of the students, specified that the course should include a laboratory component. The percentage dropped slightly at the end of the course.

Table 2: Results from Survey Questions on the Desirability of Laboratories.

	Percentage of Responses	
Would a Science Course That Interests You Have Laboratory?	**Pre Course**	**Post Course**
Yes	86.1	80.0
No	2.3	7.5
No Answer	11.6	12.5
	100	100.0

Specific Topics of Interest in Science and Technology

The results from the beginning of course survey questions seeking more specific information regarding topics of interest are summarized in Table 3. These were the responses from the question: "Now think about specific things related to science and technology about which you are just naturally curious. What things would you like to know that would be interesting or useful to you?" In response to this question, most students mentioned several items. Table 3 is

a compilation of all the responses from all of the students. In general, the student responses are listed verbatim.

Table 3: Specific Things Related to Science and Technology Cited as Interesting or Useful in the Beginning-of-Course Survey.

Frequent Topics	Topics listed once	
25% Computers	Airplane	Fax machine
	Animals	Fixing a copy machine
7% Nature	Astronomy	How things work
Radio	Automobile	Identification of nature
Telephones	Brick	Internet
Television	Cleaning chemicals	Laser
The Environment	Compact disc	Medicinal plants
	Computer networks	NASA activities
5% Camera	DVD	Plants
Cellular phone	Earthquakes	Telephone installation
Microwave oven	Electrical wiring	The downside to technology
	Electronics	Tornadoes
	Engines	VCR
	Environmentally friendly technology	Water recycling

A significant trend noticeable from Table 3 is the overall diversity of student responses. With the exception of computers which are cited in 11 of 43 or 25% of the responses, most items appear in only one or two responses. Topics of specific interest vary widely from tornadoes and medicinal plants to microwave ovens and electrical wiring. Against the back drop of this diversity, a few topics which appear with slightly more frequency than most include the environment, nature, radio, telephones, and television.

The results from the same question from the end of course are summarized in Table 4. Again most of the responses are listed exactly as stated by the students. The number of different topics cited is lower than in the beginning of the course. This is possibly a reflection of the student's developing a lack of interest in the survey questions. Of the items mentioned, several observations may be made. The mention of computers, very prevalent in the beginning-of-course survey, has dropped dramatically in frequency. This may due to computers having been a topic of study in the days just before the survey. Other items examined during the semester such as the radio, telephone, and television also drop off the list. A number of new items such as solar power, the space station, and video games appear which were not on the beginning-of-course list. It may be that the students responding to this question tended to list topics in science and technology which had not been addressed in the course.

Table 4: End-of-Course Survey-Specific Things Related to Science and Technology Cited as Interesting or Useful.

Frequent Topics	
5% Computers	
Fixing my car	
Topics listed once	
Cable TV	Manufacturing of everyday products
Cars	Microwave oven
Circuits	Photography
Electric heaters	Pulley, lever, simple machines
Engines	Quantum physics
Firearms	Solar power
Fixing cars	Space station
How things work	VCR
Internet	Video games
Lasers	What's wrong when something is broken
	Radio Waves

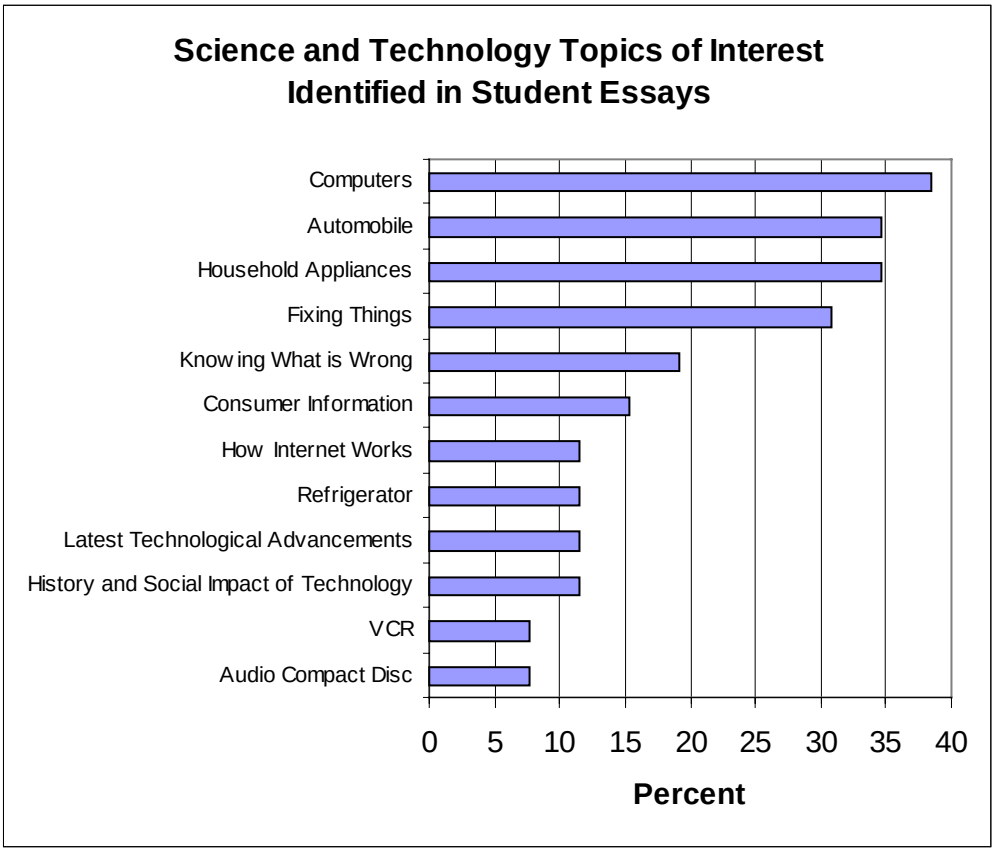
Many students commented in the end-of-course survey about how his or her response to the survey questions may have been changed by learning about how things work the "Science and Technology of Everyday Life" course. A sampling of these comments appears in Table 5.

Table 5: Sample of Comments Regarding the Effects of Learning about How Things Work.

Things like sliding doors and cash registers catch my attention. My response has changed because I did not know the complexities of small things. I took these things for granted and now I don't.
I have been more curious about how everyday things work, and have dared to take some apart.
I am constantly wondering how everything works. That is because of this class.
How my microwave works, how the cable TV works... my response is different because I know if I look it up I'll be able to understand the basics.
This course has been very helpful. I was turned off coming in when we started learning about the automobile but the course proved very useful.

Essays

The student essays addressed the question: "What types of knowledge and abilities would you like to have to feel more comfortable with science and technology?" The essay responses provided useful new information about the perspective of the non-SME&T students on scientific and technological literacy. The response rate was 26 out of 46 students. In the analysis, the essays were reviewed and the specific scientific and technological knowledge mentioned was tallied and categorized. Some students described several areas of interest, while others focused on one or two topics. The analysis of the response is summarized in Figure 4.



Some specific technological devices appeared frequently in the essay responses. About 40% of the students mentioned computers as a topic of interest. Automobiles and an understanding of household appliances were also cited by more than a third of the respondents. The "household appliance" term reflects the specific language used by the student responses. It appears that many of the respondents feel upon that term to make a general reference to the technology that they find around their homes without feeling the need to make more specific reference. A few devices that were mentioned by name in several responses included the refrigerator, the VCR, and audio compact discs. Knowledge about the how the Internet works was also a topic of interest.

Beyond the mention of technological hardware, several interesting aspects of technological literacy emerge from the student essays. About a third of the students mentioned an ability to "fix things when they are broken" as an element of scientific or technological literacy. In 20% of the essays "knowing what is wrong" when a technological device is not working was cited as a type of knowledge that would make the students feel more comfortable with science and technology.

Consumer information is also cited as an area of interest. From reading of the essays, it appears that this refers to two separate types of information. The first is the type of knowledge that might help students in getting the most for their money when buying technological devices. A second emphasis is on a perceived need for the type of knowledge that would make individuals less vulnerable to dishonest automobile or appliance repair shops. Consumer information also included the type of knowledge that would help in deciding when a particular type of device is beyond repair and when it could be economically fixed.

Several essay responses indicated an interest in learning about the history or social impact of technology. An awareness of this issue shows that student interests in science and technology are not confined to an interest in how things work or consumer information. Knowledge of the latest advancements in technology also appeared important to some students.

To provide a sense of the types of comments made, excerpts from some of the student essays are included in Table 6 below.

Table 6: Excerpts from Student Essays on Scientific and Technological Literacy.

Teach people to recognize dependency on technology and its impact on their lives
The types of things we have studied is stuff that I did not know about, but that I might feel stupid asking about.
How to run technology. The skills Dad is supposed to teach you.
I want to know exactly what is wrong with my car to avoid being ripped off.
It would be fun to learn to fix a toaster or something...just basic repairs.
[I am interested in] the history of the machines that we couldn't live without.
I feel that as a woman I need to know more about automobiles.
A good understanding of household appliances we use everyday is important.
When I read about one of these items that I want to buy, there are often terms that I don't understand and it would be nice to know what is important and what is not.
I am interested in practical information that I can use on a day-to-day basis.

Focus Groups

Results from the focus groups conducted at the end of the course reinforced many of the interests appearing in the surveys and essays. A summary of some of the major themes is given in Table 7. New information from the focus group is an appreciation on the part of non-SME&T students for a high degree of personal attention when carrying out laboratory projects involving technology. These non-SME&T are highly self-conscious of their lack of familiarity and experience with hands-on scientific and technological activities. They appreciate the opportunity to get help relatively quickly when they become frustrated with problems in the laboratory.

Table 7: Themes Emerging in End-of-Course Focus Groups.

Students like an emphasis on practical applications.
Student feel the focus on applications helps the non-science student learn scientific principles.
Students enjoy hands-on laboratories involving familiar technological devices.
Non-SME&T students appreciate one-on-one attention when struggling with unfamiliar material.

V. Conclusions

From the results of these surveys of non-science and non-engineering majors, the outlines of what the non-SME&T students would like to learn can begin to be discerned. There is a strong interest in information seen as practical or useful in encountering science and technology in the course of daily life. A high value is placed on an ability to troubleshoot and fix common technological problems. Knowledge to help the consumer obtain the most value when purchasing technological devices and to avoid paying for unnecessary repairs is also highly valued. Some students recognize the social impact of technology and consider an understanding of this phenomena as an element of technological literacy. Laboratory experiences are seen as a desirable element in a course for non-SME&T majors.

When looking for guidance from non-SME&T students on specific topics to include in a course on technological literacy an emphasis is given to the automobile, computers, and common household technological devices. Other frequently cited topics of interest include: telephones, the television, radio, cameras, audio compact discs, microwave ovens, video cassette recorders, the refrigerator, and the internet. Beyond these general guidelines there is a diversity of personal interests in a wide variety of technological devices.

It should not be surprising to find that there is a limit to the degree of detail that non-engineering students are able to provide in this effort to define scientific and technological literacy. The

students can describe in general terms the type of information they would like to have however their lack of familiarity with the subject matter prevents more precise specifications. In this work, the non-engineers have helped to set a general direction for efforts at defining technological literacy. It is the now the task of science and engineering educators to develop detailed programs of study which can address the needs articulated by these non-engineers.

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Bibliography

1.) National Science Foundation, "Shaping The Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology", NSF 96-139, October 1996.
2.) O. Ames, "A Program for Technological Literacy in the Liberal Arts," *Journal of College Science Teaching*, March/April (1994) 286-288.
3.) N. A. Byars, "Technological Literacy Classes: The State of the Art," *Journal of Engineering Education*, January (1998)53-61.
4.) L. A. Bloomfield, *How Things Work: The Physics of Everyday Life*, John Wiley & Sons, Inc. New York (1997).
5.) National Research Council, *National Science Education Standards*, National Academy Press, (1996).
6.) American Association for the Advancement of Science, *Benchmarks for Science Literacy*, Oxford University Press, (1995).
7.) J.R. Wright, "The Lexicon of Technological Literacy," *The Technology Teacher*, May/June (1993)3-8.
8.) M. Hacker, and R. Barden, *Living With Technology*, Second Edition, Delmar Publishers, Albany, New York (1992).
9.) J. Krupczak, Jr., "Science and Technology of Everyday Life: A course in technology for liberal arts students," Proceedings of the 1996 American Society for Engineering Education Annual Conference, Washington DC., June 23-26, 1996, session 2261.
10.) J. Krupczak, Jr. "Demystifying Technology," *ASEE PRISM*, October (1997) 30-34.
11.) L. A. Bloomfield, "Institutions Teaching How Things Work," http://www.phys.virginia.edu/Education/HowThingsWork/institutions.html, University of Virginia, (1997).

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