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ABSTRACT

This document reports the proceedings of a workshop on Technological Literacy. The objectives of the workshop were: to review programs and to identify issues in technological literacy for liberal arts majors; to discuss mechanisms for the stimulation of appropriate additional technological literacy programs; and to develop an action plan for program, course, and faculty development. The body of the document includes the following: (1) opening remarks by the organizer, Dr. Russel Jones; (2) a review of past and present efforts in technological literacy; (3) invited views from the Liberal Arts and Engineering Colleges concerning differences between science and social science courses, the link between liberal arts and engineering, and broader issues in science, technology and society; (4) a summary of the breakout sessions reporting on curriculum development, courseware availability and needs, student recruitment, faculty issues, a new consortium approach to promoting technological literacy, identification of funding sources, and issues of initiation and growth of new technological literacy curricula and programs; and (5) closing remarks. The appendix includes the workshop agenda, a list of participants, greetings from the sponsors, complete reports of the breakout sessions, findings of a survey of current programs, a listing of monographs published under National Liberal Arts support, a list of references, an annotated bibliography, and two proposals made by the workshop. (MDH)

TECHNOLOGICAL LITERACY WORKSHOP

Proceedings

6-8 May 1991

Georgetown University Conference Center
Washington, D.C.

Edited by

Russel C. Jones
University of Delaware

Sponsored by

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and

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Special thanks are due to the several University of Delaware graduate students who supported the Principal Investigator throughout the Project -- from proposal writing to research to conference implementation. These students, all doctoral candidates in the College of Urban Affairs and Public Policy are Jack Dustin, Thulasi Kumar, and Charles Scholz.

The two sponsoring organizations, Accreditation Board for Engineering and Technology and the Association of American Colleges, have played critical roles in this project. Special thanks go particularly to Executive Director David Reyes-Guerra of ABET and Vice President Joseph Johnston of AAC, who worked most closely with the Principal Investigator throughout the effort. A special acknowledgement is due to the National Science Foundation, which provided grant support for this project and its central workshop (grant #ENG-8918893).

The time and effort of the participants in the Workshop -- particularly the speakers and session chairs -- is also gratefully acknowledged. Without their expertise, interaction, and follow-up effort the Workshop could not have been a success.

Thanks also go to Mrs. Carol Pijanowski, who managed the logistic arrangement for the Conference and prepared the manuscript of this proceedings volume. Special thanks also go to Dr. Stephen H. Cutcliffe, Director of the Science, Technology, and Society Program at Lehigh University for his assistance to the Principal Investigator in editing this conference volume.

- Russel C. Jones
Principal Investigator
Technological Literacy Project

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EXECUTIVE SUMMARY

ISSUES IN TECHNOLOGICAL LITERACY FOR LIBERAL ARTS MAJORS: PROSPECTS AND RECOMMENDATIONS

The Accreditation Board for Engineering and Technology, the Association of American Colleges, and the National Science Foundation sponsored a Workshop on Technological Literacy for Liberal Arts Majors at the Georgetown University Conference Center, Washington, D.C. during 6-8, May 1991. The Workshop was organized by Dr. Russel C. Jones of the University of Delaware, Principal Investigator of the Technological Literacy Project.

The purposes of the Workshop were: 1) to review programs and to identify issues in technological literacy for liberal arts majors; 2) to discuss mechanisms for the stimulation of appropriate additional technological literacy programs; and 3) to develop an action plan for program, course, and faculty development.

The invitational Workshop was attended by some 50 participants, most of them deans of liberal arts and engineering colleges, and representatives of various organizations with activities in the technological literacy area. The Workshop was opened with a background and mission statement by Russel Jon- and with greetings from the sponsors. This was followed by a review of past efforts in technological literacy by Rustum Roy of Pennsylvania State University and Barrett Hazeltine of Brown University. Professor Roy documented the need for technological literacy and presented in detail the STS movement's approach to eliminate technological illiteracy. Professor Hazeltine briefly described the evolution of interest in technological literacy and some of the earlier conferences and their outcomes. Later portions of his presentation covered in detail the activities of CUTHA (Council for the Understanding of Technology in Human Affairs) and the Sloan Foundation projects.

Professor John Truxal reviewed the ongoing efforts in technological literacy with a specific example--high speed ground transportation--and generalized into various issues of technological literacy. His presentation clearly established the multidimensional aspects--technical (design), social, economic, environmental, and psychological--of technological projects and the need for technologically literate citizens. He then reviewed constraints such as curriculum, students, faculty, and costs facing technological literacy education, and identified promising approaches.

Professor David Billington of Princeton University presented his work on structures and machines. Through historical case studies of the Iron Bridge and the Rotary Steam Engine, he described how technological literacy is synonymous with defining modern engineering. Included in his presentation were basic principles underlying the steamboat, according to some historians of technology America's first major contribution to modern engineering, and its impact on society.

In his broader issues presentation, President George Bugliarello of Polytechnic University presented the major problems facing society such as poverty, unemployment, and crime, and how technological literacy can help to solve these problems. He then reviewed some of the outcomes of new developments in science and technology such as globalization, environmental problems, and international security. Finally, he indicated that science and technology alone are not sufficient to solve these problems and underlined the need for a multidisciplinary approach, such as that typically envisioned in the STS movement.

Thomas Wasow presented the division between "the two cultures" as viewed from the humanistic fields of study. He outlined the differences between science and social sciences courses. He explained, in detail, the courses and interdisciplinary programs at Stanford University designed to enhance technological literacy of students through a system of distribution requirements to guarantee breadth of study. One such course, "Introduction to Computers," deals with artificial intelligence, databases, spreadsheets, graphics, security and privacy, computer systems, human factors, hardware, and networks, Later he identified problems encountered in faculty cooperation in teaching interdisciplinary courses and in the development of new courses at Stanford University.

In his presentation on views from the engineering college, Curtis Tompkins cited pros and cons concerning engineering schools offering technological literacy courses for non-engineering students. This was mainly based on a survey of 26 engineering schools. Some of the major concerns of the engineering schools include their small faculty size, problems of cooperation from humanities and liberal arts faculty, financial viability, absence of reward or incentives for faculty, and lack of high school level knowledge of mathematics, chemistry, and physics in liberal arts students. Based on the views expressed by engineering schools, he identified an optimistic goal of increasing substantially the number of individuals, particularly young people, who are motivated, inspired, and prepared to learn on their own on a continuing basis about technological matters. He also noted the interest of liberal arts students in areas such as solid waste disposal, acid rain, global warming, and alternative fuels, and thus the need to provide basic principles about technology to interested students.

Major portions of the Workshop were devoted to breakout sessions on specific issues--curriculum, courseware, attraction of students, faculty issues, logistics, and funding directions. Joseph Johnston and David Reyes-Guerra chaired sessions on the generation of issues for the breakout sessions. Following is a summary of each of the breakout sessions.

The Curriculum Development session was devoted to the discussion of issues such as objectives of curriculum elements, instructional formats, and evaluation techniques for technological literacy programs. The curriculum discussion group focused on the issues of technological literacy as a design problem. As with many design problems, discussion was centered around critical dimensions such as the definition of technological literacy, the relation between technological literacy and engineering literacy, and content and process issues in technological literacy. In the discussion group itself there was an implicit assumption that technological literacy was equivalent to engineering literacy or literacy about engineering. There was also a general consensus that the communication process was more important in any technological literacy curriculum than any particular content.

The Courseware Available session was concerned with the educational materials available to provide background to faculty members and for use in courses and laboratories. The group mainly focused on course content, forms of teaching materials, and results obtained so far. The group identified design process, critical thinking, and problem solving as the three major aspects of technological literacy course content. Historical case studies and business school decision making units were the central focus of discussion on the forms of teaching materials.

Attraction of Students dealt with various issues involved in reaching out to selected groups of students. Issues discussed included the difference between liberal arts and engineering students in their attitude toward courses, and the differences between humanities and social sciences courses and engineering courses offered in a typical local environment. The group also discussed the problems involved in identifying more attractive courses and subjects, and the absence of any data about the students interest. To attract students, the group believed that course content should be aimed at specific target populations, and needed to be linked with the social environment.

The Faculty Issues/Logistics group discussed the problems associated with getting faculty interested in teaching courses, and the logistics of introducing technological literacy courses into the curriculum on a given campus. Attention was given to faculty teaching load, faculty reward system, and faculty member's career patterns. There were also discussions on the availability of funding for technological literacy programs and on the available curriculum materials.

The breakout session on Courseware Needed was devoted to discussion of gaps in the available materials and possibilities for new types of coverage and multiple formats. The group spent a significant portion of its time in discussing book length case studies and explored the possibilities for more historical case studies. Other forms of educational materials discussed included films and videos, interactive and remote-site TV presentations, and computer software.

The Consortium Approach group was concerned with the possible mechanisms for enhancing technological literacy programs, including the idea of consortia. This group identified various institutions currently active in technological literacy and new institutions that can be encouraged or approached to become involved in promoting technological literacy. New mechanisms identified both for promoting technological literacy and for actually incorporating it into the curriculum include a common core curriculum requirement, a top down CEO approach, and state and regional consortia. Based on its discussions, the group also recommended short-term action elements such as declaring 1993 as the year of Technological Literacy, working to make technological literacy a general education requirement for all undergraduate programs, and mailing the executive summary of the conference to the heads of all appropriate engineering and academic societies and organizations.

The task of the Funding Directions group was mainly to identify various funding sources which might be approached to promote technological literacy. The group discussed the general issues related to funding and identified several potential funding sources. They were classified into four main categories: government, private foundations, industry, and colleges and universities. Within the four categories, the group also identified a few specific agencies that are potential funding sources.

The Stimulation of Programs session was devoted to issues of initiation and growth of new technological literacy curricula and programs. The group discussed the various opportunities to initiate new programs, and also to encourage faculty and students to become involved in technological literacy. Some of the opportunities discussed included holding annual conferences, publishing articles in journals, and arranging meetings with engineering deans (perhaps through ASEE) and liberal arts deans (perhaps through the Council of Colleges of Arts and Sciences) to discuss issues of technological literacy.

The Technological Literacy Workshop provided a thorough review of current programs and issues, and set promising directions for the future. It became clear that technological literacy courses and programs should be offered at many more institutions, utilizing the models and materials developed over the past decade or so. Engineering school leadership is centrally important in starting and supporting such programs, but liberal arts faculty should also be involved in the planning and implementation.

It was suggested at the end of the conference that two follow-up thrusts were most appropriate:

- Development of a national clearing house for technological literacy information and materials, building upon the base already developed.

- Development of a mechanism for pilot program initiation at additional schools, utilizing experts from current programs as consultants and providing necessary start-up funding.

The sponsors and leaders of the Technological Literacy Workshop are pursuing these directions.

PREFACE

During the 1960s Americans recognized that they needed a better understanding of the impact science and technology had on society in order to protect the environment, to minimize the discord caused by change, to sustain political and cultural values, and to insure the full participation of citizens in the economic and political system. In a world already reshaped over recent decades by nuclear weapons, new technologies of transportation and communication, and a host of innovations in agriculture, medicine, and many other fields, the pace of change gives no sign of slackening. The capabilities of our political, social, and economic institutions will be limited if a large portion of the citizenry is not aware of the implications of these changes.

Over the last fifteen years universities and colleges, foundations, professional and higher education organizations, and state and federal governments have engaged in a wide variety of innovative activities to improve the science and technological literacy of a broad range of individuals. Thus far, the literacy programs that have been developed are diverse, often divergent, and normally focused on science. Technological literacy has not received the same emphasis, study, funding, or curriculum development as science literacy. Over the last five years efforts to overcome this serious shortcoming have come from individuals and organizations loosely identified with "science, technology and society" (STS) curricula and programs. While credit should be given to those involved in STS, technological literacy continues to be a largely unknown quantity in higher education curricula.

Investigations of literacy have discovered two areas of critical need in higher education. First, engineering majors were deficient in liberal arts learning; and secondly, liberal arts majors were deficient in technological learning. In 1988 the Accreditation Board for Engineering and Technology and the Association of American Colleges completed a three-year study to develop a liberal arts curriculum for engineering majors. This study produced eight model course clusters and serves as a foundation for improving the quality of engineering education. While there are a number of programs underway that approach science literacy in a similar comprehensive fashion, a similar study of technological literacy is conspicuously absent.

In view of the above, the Accreditation Board for Engineering and Technology (ABET), the Association of American Colleges (AAC), and the National Science Foundation (NSF) have developed a project entitled "Issues in Technological Literacy for Liberal Arts Majors: Prospects and Recommendations" under the guidance of Dr. Russel C. Jones of the University of

Delaware. The main objectives of the Project were to study existing programs, curricula, and literature concerned with issues in technological literacy in higher education; to organize a workshop to address various issues identified; and to propose future efforts.

This volume reports on the Workshop held in Washington, D.C. on May 6-8, 1991 as part of The Technological Literacy Project. Its program focussed on:

- Curriculum Development
- Course Development
- Attraction of Students
- Faculty Development
- Funding Directions
- Program Implementation and Evaluation
- Consortium Approach

The Workshop was attended by some 50 participants, many of them deans of liberal arts or engineering colleges, and heads of various non-profit organizations concerned with technological literacy. The diversity and experience of the participants led to very stimulating discussions on these issues.

This report is intended to present the full text of major presentations, and summaries of the proceedings of the Workshop. The last section of the report summarizes the major findings, as well as outlining proposed next steps in the Technological Literacy Project. The appendices of the volume include a list of Workshop participants, a brief report on current programs and a bibliography of books and periodical literature in the technological literacy field.

INTRODUCTION/OPENING REMARKS

Russel C. Jones
University of Delaware

Background

Welcome to the Technological Literacy Workshop. This is the second in a series of projects done as collaborations between the Accreditation Board for Engineering and Technology (ABET) and the Association of American Colleges (AAC). It follows one that ABET and AAC did in 1986-88 to broaden engineering education through optimization of the humanities and social sciences component. ABET has required, for many years, that one eighth of the curriculum of engineering students be in humanities and social sciences. It felt that it was not getting sufficient results for that investment on the part of a lot of students. The first project between AAC and ABET focused on that, and has had some beneficial results.

As a second effort, ABET and AAC have chosen technological literacy for college students other than engineers. With an emphasis on liberal arts majors, including those liberal arts majors who are going to go on into teaching in K through 12, the focus of this workshop will be on technological literacy. We will try to find a way to complement the direction that AAC and ABET effected the first time around by trying to have some input from the technical side of the campus to the science and engineering component for liberal arts majors. Clearly the ultimate goal here is technological literacy for a broad population.

Humanities & Social Sciences For Engineers

Let me give you a capsule of the first study between ABET and AAC. The problem observed by ABET visitors over the years has been that engineering students tend to take an uncoordinated set of introductory level courses in humanities and social sciences. The earlier project first went out and documented this, and presented its results in an AAC publication titled "Unfinished Design." It documents what most engineering faculty members already knew, that engineering students tend to take 100 level courses only when they have to get into H&SS. They will try to get sections where there are at least three or four hundred students so there is little chance of them being stimulated or challenged personally. They will take whatever fits their schedule on Tuesdays and Thursdays at 3:00 o'clock in the afternoon or whatever fits between laboratories and engineering classes. To counter this attitude, the approach developed by the AAC/ABET project team was one of utilizing clusters of courses to provide appropriate depth of exposure. Figure 1 lists the clusters developed by the project team.

Figure 1

SAMPLE CLUSTERS

- Management
- Public Policy and the Environment
- American Studies
- Arts
- Great ideas
- International (e.g. Japanese Studies)
- Cognitive Science
- Not yet chosen

This approach should guide students into taking sequences of related courses with vertical advancement in successive courses so that they will at least understand the ways social scientists and humanists approach problems. The disciplines generally take approaches quite different than the ways an engineer or scientist approaches problems.

Technological Literacy

Our current project (the one we are here to deal with these couple of days) is technological literacy for college students other than engineers. One driving force behind this project, obviously, is the desire for an informed citizenry who can participate in setting policy on difficult technological issues, such as energy policy and pollution control.

An approach related to technological literacy, the Science, Technology, and Society movement, has tried to work at this interface between technology and society. However, I am very concerned that we have drifted in a direction where too few technical people are involved. At any rate, there is a major STS movement which is typically focused on helping technical people understand the way things can go right and can go wrong as they deal with society. I think it is a very valuable movement, but one that would benefit from the addition of further technical content and understanding.

One approach is to see whether we can get appropriate engineering faculty members involved by offering courses for non-engineers. A major issue is how difficult it is to get engineering faculty members to take on additional tasks, particularly when they currently devote extensive time to writing research and development grants and contracts. At any rate, this is something we would like to explore. We can point out that engineering enrollments are declining and this is a way to build their enrollments back up; and we can tell them that this is a way to enter into the intellectual life of a campus instead of working over in a corner with their own professional students.

Let me come back to the particular importance of technological literacy for pre-college teachers. Many of us in the room are very concerned about the quality of K through 12 education. We know that until we fix that pipeline, things are not going to be very good for us in higher education. So in our own enlightened self interest, we need to pay particular attention to those who will go back and work on that pipeline.

Input From Engineering

It is not clear what elements should be in a technological literacy program. It appears that many of the things that are in current STS programs, such as history of science and technology, and the ethics of professionals dealing with the public, need to be included. What will an engineer or other technical person bring to such a program--perhaps jointly done with the philosophers, the historians, the political scientists, and others on campus?

One element that I think an engineer would bring is how technical things work. How does a computer work? How does an automobile work? This will provide a basis for exploring the roles of engineers in creating technology for society in response to its needs.

Engineers would also contribute by exposing students to their unique approach to problem solving. Engineers use quantitative methods, consider tradeoffs, do trial solutions, utilize feedback--our own version of the scientific method perhaps. This approach is something very useful to try to transmit to non-engineering students, probably within something other than a lecture format, perhaps with a case study format.

The third thing that I think engineers might bring to the table is elements of design. This could allow students to work from the front end of a project, instead of doing an analysis of what went wrong at Three Mile Island, or what went wrong in some major bridge collapse. Working frontwards through the design process the way an engineer does would be quite different in approach than most of the STS courses would take. Students would look at the interplay of economics and aesthetics and a variety of other things that go into the design process.

Finally, engineers would expose students to the elements of team work. Most engineers today work less as individuals than as members of a team. How can we transmit that ability to broader society so that we could get more teams to bridge across the traditional liberal arts field and the engineering field?

I hope that you will help to improve this list of what engineers might bring to a technological literacy effort over the next couple of days, because there is expertise available at this workshop to sharpen that up considerably.

Technological Literacy Project

The Technological Literacy project came about because the engineering leadership at the National Science Foundation thought that it was timely, and the appropriate next step after the project on better utilization of the humanities and social sciences component of engineering education. NSF agreed to fund this workshop effort to document and evaluate the current state-of-the-art in technological literacy, and to suggest directions for future efforts.

What I and my graduate student colleagues have done over the past year or so is a reasonably comprehensive review of existing programs. I have visited many of the major programs in the country. We have looked at the curriculum materials, and have tried to provide you a summary of that in the packets you have been sent prior to the meeting. We have looked at the literature on technological literacy that covers what the experts are saying. We sent you a few samples of that type of paper in the packets that you hopefully read prior to coming to the meeting.

Technological Literacy Workshop

With that background we are here to conduct a technological literacy workshop--an invitational workshop of some 50 people in Washington. The outcome of this meeting will include a workshop proceedings covering both presentations and discussions.

During the workshop we hope to identify those issues that are important, and I have tried to sketch those out in the program in terms of broad categories. We will have breakout sessions where we try to focus on such issues in depth, and hopefully make appropriate recommendations. For example, we should address whether there is something in technological literacy efforts to date that is worth trying to propagate across many more institutions than the reasonably small number of high quality programs that are currently in place. If there is indeed something that should be done further, how do we do it? How do we develop and sell a proposal that might result in the resources either on individual campuses or from some external funding source to mount such a program?

Lets look ahead to what we have put together over the next couple of days. We start with a few words of welcome from sponsoring organizations, then a review of past effort in technological literacy by a couple of experts, who have been instrumental in technological literacy efforts to date. Tomorrow morning a review of some ongoing efforts in technological literacy, then a series of meetings that I call breakout sessions will generate appropriate issues to be addressed. After such breakout sessions we will get back together and share our ideas. The program includes a pair of discussions: one on how technological literacy and related fields look from the liberal arts college, and one on how they look from the engineering college. Then for those who want a snapshot of some real live technological literacy education, Professor Billington from Princeton has agreed to give us a demonstration lecture on bridges and society so that you have some idea of what happens in such a course. Then we have a major speaker on broader issues in science, technology, and society for tomorrow evening as part of our evening festivities. Back to work Wednesday morning with another set of breakout sessions on what needs to be done in the future. Then finally, a closing session on Wednesday on suggestions for an action plan that can be put together for groups like ABET and AAC and NSF, and perhaps a consortium of the organizations that are now already active in this field, to move forward with.

That is where I hope we are going to go, but we on the Workshop staff are here to listen and take good notes as well. We will try to understand where it is that this group of distinguished people would hope the field of technological literacy would go, and how it should get there.

TECHNOLOGICAL LITERACY

PAST AND PRESENT EFFORTS

PAST EFFORTS IN TECHNOLOGICAL LITERACY--CUTHA

Barrett Hazeltine
Brown University

"Much have I seen and known; cities of men
And manners, climates, councils, governments,"
Tennyson

When Ulysses got back from Troy, he needed to tell everybody what happened, and I feel somewhat the same. Like Ulysses, I can talk best about what I was involved in. I hope I will not overlook the contributions of others, and I especially hope I will not overlook the contribution of any one in the room.

A question that came up often, especially in the late 1970s, was why one would want to get into this business of teaching liberal arts students about technology. A flip answer was my strong admiration for John Truxal and Mike Visich and the challenge to see if I could do as well. A slightly less flip answer was because my dean was worried about enrollments in 1973 or so--the balance of payments were unfavorable, we were sending engineering students out to take courses all over campus and none of the non-engineers were coming to us.

Actually, a major impetus was a concern that students wanted to change the world but did not have any sense of what could be done. I recall about that time a campus meeting concerned with the Seabrook Nuclear Plant. An otherwise sensible person with some stature on campus pointed out that the plant was not really needed--tidal power would be sufficient as a substitute. Perhaps that assertion was what prompted John Sununu to comment that what government needed was more people who understood the difference between a million and a billion.

That era in the late 1970s, when technological literacy began to attract engineering faculty was another "greening of America time," when greening referred to softer attitudes rather than the environment. Many on engineering faculties felt we had something to contribute. We wanted to be part of the solution, wanted to be part of campus-wide movements, not considered part of the problem. My notes from a meeting at the time contain reference to the 3Ps--the three major societal problems: Poverty, Pollution, and Pornography, all of which have a significant technological component and need some technological understanding for solution.

Students from all over the campus were also interested in learning about technology. Perhaps even then they were worried about getting a job but many were good enough to tell us they enjoyed learning about things they dealt with every day and had never understood. Then, and still, students came up and said how very pleased they were to understand what their parents did. Of course, many were just excited to design and build something and see it work.

External events, beyond the campus, also made the study of technology intriguing. National reports on education were reacting to the pure abstraction of many subjects, the gulf between what was being taught and the real world. One of Samuel Florman's books included the following passage:

> People today would get more pleasure out of the world if they understood more about science and technology. A good education should include enough in these areas so that the ordinary citizen is not deprived of her/his birthright, which includes savoring the engineering creations of the world.

Now I would like to describe some of the things that happened. The major early event, at least for me, was an effort by Ed Krick of Lafayette College to find out about efforts at various colleges. This was reported in a paper in Engineering Education. Of course, history of technology had been a viable academic field before then but its focus was somewhat different.

Jerry Nadler organized a pair of conferences in Madison in 1978. One conference turned out to be international with representatives from Canada, Japan, and the Soviet Union. The topics in the conference included TV programs of the Nova variety produced by the University of Michigan and a description of Moshe Rubenstein's problem solving course. John Truxal described the Man-made World, a technological literacy course used in high schools, and changed the lives of many of us.

One outcome of the second conference was the establishment of CUTHA (Council for the Understanding of Technology in Human Affairs). CUTHA stated its three objectives as follows:

- Collect information on ongoing activities
- Disseminate that information
- Proselyte.

An implied objective, of course, was to get some grants to support these desirable efforts, which we did. Another implied objective was to make the whole field more respectable and attractive.

CUTHA did four kinds of things: held conferences, participated in other people's conferences, facilitated consultation, and published The Weaver.

CUTHA attracted a wide range of participants from both the liberal arts and the humanities at a series of national and regional conferences. The initial focus was on defining what was meant by technological literacy, and as the movement gained experience it increasingly focused on pedagogical techniques that worked especially well for specific courses and programs.

CUTHA representatives have given numerous presentations at such meetings as those of the American Association of Colleges, American Association for Higher Education, Council of Independent Colleges, National Association of State Universities and Land Grant Colleges, and others. Sessions have also been sponsored at several ASEE annual meetings and at least one Frontiers in Education conference. CUTHA also represented the technology literacy, perspective on the study group that produced the ASEE report--The Liberal Art of Science.

Our objective was to be a clearing house for people wanting our advice or other kinds of assistance. I don't think anybody ever called CUTHA asking for a consultant but several of us were called directly. Most of these requests seemed to have been generated from the conferences.

The intention of The Weaver was to publish essays either about teaching technology or about the interaction of technology with other fields. Articles tended to fall into three categories: 1) discussions of the rationale, purposes, context or need for technological literacy, 2) descriptions of specific courses and programs, or 3) introductions to aspects of technology which would be bases for suitable courses. The articles in the next issue will be related to space. The previous issue dealt with technology and the social sciences. It contained, among others, articles about technology as a social product in the context of its time, about the public understanding of risk assessment and about how technology has the potential to engineer control over society. The first editor of The Weaver was Edith Ruina. We are distributing about 5000 copies an issue.

The CUTHA board voted the organization out of existence in the spring of 1990, partly because a niche for the organization did not seem apparent and partly because of the tax exigencies of maintaining a non-profit organization. It is worth mentioning that CUTHA had three presidents: Edward Friedman of Stevens Institute of Technology, John Truxal of SUNY-Stony Brook, and Leon Trilling of MIT.

One reason that the need for CUTHA decreased was that the New Liberal Arts program supported by the Sloan Foundation was so successful. The genesis of the New Liberal Arts program was an essay by Stephen White published by the Sloan Foundation in 1981, with commenting essays. Jim Koerner, who coordinated the New Liberal Arts Program within the Sloan Foundation in its early days edited the volume. Stephen White's essay was entitled "The New Liberal Arts--an Exchange of Views" and spoke to technological literacy, quantitative reasoning, and computer facility as central to the liberal education in the last quarter of the 20th century. The respondents--two college presidents, one engineer, three historians, a mathematician, and a philosopher were supportive.

The New Liberal Arts program itself began at a meeting in Key Biscayne in 1981. During its ten year lifetime, it gave grants to liberal arts colleges and historically black institutions. It ran a series of workshops, some introducing technological literacy and some on specific topics. In the early days, it sponsored a traveling seminar which went through the New England colleges. More recently it has sponsored the writing of books and monographs and the administration of the Stony Brook Center under the direction of John Truxal and Mike Visich which publishes the NLA News and is a source of information and assistance. The Sloan Foundation has not only been generous it has also been willing to experiment with different approaches.

What has been the results of these efforts? Of course it is hard to attribute any success to any cause in education but, technological literacy does seem to be accepted as worthwhile and possible. The Wall Street Journal and Newsweek both have regular columns on technology. I was struck by how different inviting people to a New England regional New Liberal Arts meeting in the spring of 1990 was from inviting people to the first CUTHA meeting at MIT in 1980. Now, at least, people know what you are talking about and are sympathetic. Friends at an African university want to know more, so do people at other United States universities.

We, the technological literacy people, are sometimes asked how we differ from the STS people. We are really friends and the line is fuzzy, but the distinction is worth understanding. We teach courses in engineering, not about engineering. We want students to see the joys of engineering at its best, to design, to build, to learn by doing, to have fun by starting with an idea and making it work, to work in a team because the project is too big for one person. We want them to develop self confidence, a sense of control in dealing with technology. Russel Edgerton said it very well:

> In an encounter with a string of courses, a student can pick up only a tiny fragment of technological knowledge. They can learn some of the ways engineers think about things. But most crucial of all, a course can give students a toe hold of self-confidence about their ability to understand and master things technological. In a proper sequence of courses, this self confidence can grow. Students can learn that, with effort, they can be in charge. That to me is worth fighting for.

And to me also.

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PRESENT EFFORTS IN TECHNOLOGICAL LITERACY

TECHNOLOGICAL LITERACY--the more important goal in engineering, science, and math education

Rustum Roy
Pennsylvania State University

Introduction: Recognition of Importance of Technological Literacy

The awareness of a "national deficit" in math and science education has increased dramatically over the last five years. Regrettably both the academic community and the policy makers have shown little evidence that they appreciate the radically different components of the "national deficit." However, there is now increased agreement that there are two easily distinguished components:

a) The technological illiteracy of 90-95% of the population including parts of the professional scientific community, the Federal Cabinet of the U.S., many CEO's and equally the culture of urban poverty.

b) The insufficient numbers and quality of professional engineers, applied scientists, and scientists in the workforce.

During the last few years while the science community has continued to call for an ever increasing number of scientists, most competent and experienced policy makers have finally realized that it is, first of all, most important to change the content of what passes for science within all of U.S. education today, as made available to a wider audience.

This is no longer only the view of the avant garde, it has also emerged as mainstream consensus thinking. A whole series of quotations from different sectors and levels of education and policy will show how pervasive this now is among the leadership.

> We must now begin to make the case for a stronger and more sustained national commitment to achieving a level of popular scientific literacy in this country sufficient for the needs of a free and democratic society.
>
> Paul Gray, President, M.I.T. (1989).

> We need to realize that improvement is needed...to produce a generation of voters with at least enough knowledge to avoid being bamboozled by foolishness.
>
> Don Kennedy, President, Stanford University (1989).

Teaching science to non-science majors is a national challenge. ...the faculty has created a Council on Science and Technology to assist faculty members in developing new courses and renovating existing ones...and to foster upper-level courses in science and technology that address cultural and societal issues.

Harold Shapiro, President, Princeton University (1990).

The connection of technology to science, and both to societal problems and issues are called for in dozens of reports:

(For Science in Grades 7 and 8) A beginning understanding of the integration of natural sciences, social sciences, and mathematics; familiarity in integrating technologies with experiences in the sciences (emphasis added).

(Secondary Biology) Understanding biologically based personal and social problems and issues such as health, nutrition, environmental management, and human adaptation; ability to resolve problems and issues in a biosocial context involving value or ethical considerations (emphasis added).

(Computer Science) General understanding of the problems and issues confronting both individuals and society as a whole in the use of computers, including social and ethical effects of computers: the ethical issues involved in computer automation (emphasis added).

From Educating Americans for the Twenty-First Century (October 1983), Final Report: National Science Board Commission on Pre-College Education in Mathematics, Science, and Technology:

The need for genuine inter-disciplinarity is expressed rhetorically by virtually every leader--but hardly ever implemented by any administrator.

Liberal education requirements should be expanded and reinvigorated to ensure that students and faculty integrate knowledge from various disciplines (emphasis added).

A "principal aim" of liberal education is "the ability to integrate what is learned in different disciplines," and hence that reform must be based on "collaboration among faculty from different departments," which will "establish specific integrative mechanisms."

From Involvement in Learning: Realizing the Potential of American Higher Education (1984):

These goals are not only for college; the same calls are issued for K-12.

> Science curriculum grades 9-11 be "Structured Around the Interactions of Science and Technology with the Whole Society," with instruction centered around problems that "integrate knowledge" from engineering, physics, biology, earth science, and applied mathematics.
>
> A curriculum "organized around problem-solving skills, real life issues, and personal and community decision making.

From National Science Board Conference on Goals for Science and Technology Education Grades K-12 (April 1983):

The basic common points encompass a tripartite call for:

1. Greater interdisciplinarity.
2. Integration of knowledge, and
3. Connection to social issues, including ethics and values.

Realization of the parallel and synergistic character of the two goals in science and technology education has also now been accepted in Congress. The very first sentence of Title I of the Omnibus Science Education bill introduced by Senators Kennedy and Hatfield in January 1990

declares national objectives to:

(a) improve public scientific and technical literacy
(b) increase the supply of scientists, engineers, and technologists...

The STS movement from its birth twenty years ago has been the initiator and sustainer of the national push for this "scientific and technical literacy" for the majority of citizens.

To close this section which establishes the new "legitimacy" of technological as opposed to scientific literacy two quotes from opposite ends of the spectrum of commentators will suffice:

> First the N.Y. Times Education Editor shows that the idea has, at least, reached the leadership in the media. On January 31, 1990 he titled his column, "Lessons, Teaching Technology, the subject that offers no single best answer to problems."
>
> Second, Ernest Boyer of the Carnegie Foundation, also in 1990, redefines a new balance among the functions of the university thus:

(1) We describe in the report (Scholarship Reconsidered, Carnegie Foundation for the Advancement of Teaching, 1990) a four-part model with the advancement of knowledge as one of the quadrants.

(2) We see scholarship involved in the integration of knowledge.

(3) We also propose that notions of scholarship should include the application of knowledge. We propose a more even relationship between the two--one in which we recognize and appreciate the wisdom of practice. We need to take practice more seriously and benefit from the relationship between the two.

(4) Finally, we propose a component of scholarship we call representation. Here we argue for a scholarship that supports teaching.

The "integration" and "application" of knowledge are key rationales for assuring for all citizens, and certainly all college students, a level of technological literacy.

Perhaps the non-professional's view is the most telling because it connects teaching about technology to teaching STS. Technology involves values: hence the STS route is not only an excellent gateway to technological education, it is part of education about technology. Here is Ed Fiske of the N.Y. Times again

> Teaching technology poses a challenge to schools because it does not fit into the traditional academic categories.
>
> For example, science--the search for the rules that govern the natural world--has absolute standards. Students' answers are usually right or wrong. By contrast, technology--the study of how people re-shape nature--forces students and teachers alike to deal in the gray area of value judgements, tradeoffs and multiple solutions.
>
> Perhaps in technology education--an arena where factual knowledge and value judgements must be dealt with simultaneously--educators have at least found a way to bridge this gap.
>
> Technology education even turns traditional "hands on" education on its head. Science laboratories, for example, are usually intended to show the application of information learned in class. In technology classes students start with a problem and then gather the information they need to solve it.

WHAT THEN IS TECHNOLOGICAL LITERACY (T.L.)?

1. T.L. is a Complex Multidimensional Reality

Victor Frankl uses the simple example of the visual perception of a solid object to illustrate how different the same object looks from different viewpoints. T.L. looks very much different when looked at by different groups.

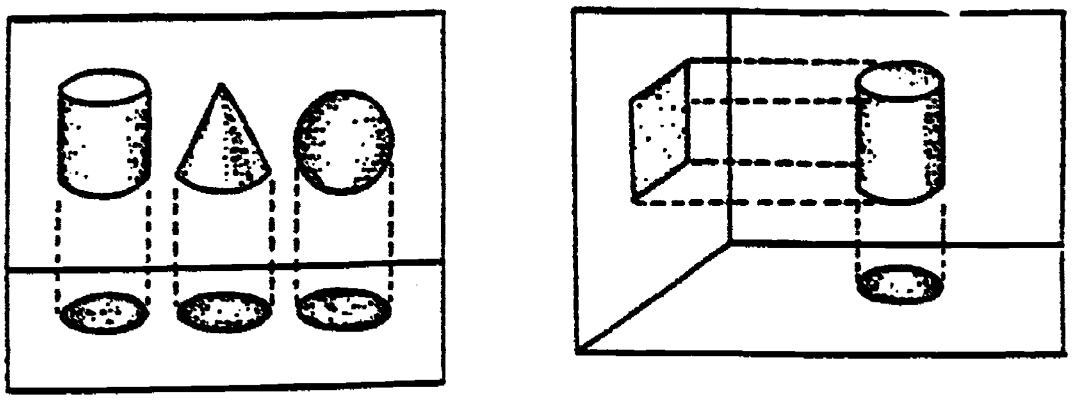


Figure 1. The reality perceived is drastically affected by the direction from which it is viewed. Viewing from more than one direction may give an unexpected addition (in this case the 3-dimensional nature) to our model of reality. (After V. Frankl.)

The industrial manager looking for more technologically literate employees, the college dean concerned about her B.A. degree holders, and the anti-nuclear activist probably have rather different views of T.L. Yet all these apparently contradictory views may describe the same total reality.

2. T.L. is a Slogan

Slogans are extremely valuable as general rallying points for the masses. "Technological Literacy" as a slogan conveys accurately--though not precisely--what we would like it to convey. Nonetheless, one should not expect too much of such terms. We all agree that "technological illiteracy" is a "problem." Fritz Schumacher of "Small is Beautiful" fame in his Guide for the Perplexed distinguishes between convergent and divergent problems. The former we can solve, bring to a sensible conclusion, wrap up. The latter "divergent" problems we can address, discuss, work away at, knowing that in essence they cannot be "solved." Technological Literacy" becomes the slogan for gathering a heterogeneous group of concerned citizens to address the problem. The lack of precision in the term may be made into a virtue, so that a variety of individuals with differing approaches may still cooperate in that part where their interests do overlap.

T.L. is a Paradox

This observation forms a key component of my thesis. Humans developed many technologies to quite sophisticated levels millenia before they were literate (i.e. able to use an alphabet to make words which they could pronounce and/or understand). Could the term "technological literacy" therefore be an oxymoron. Clearly technological competence, i.e. carrying out certain technological procedures does not require the ability to read or write. In the developed world many of us experience this in dealing with the very competent automobile mechanics who are almost technological experts in car maintenance but may be illiterate. In the developing world this is commonplace. Thus M.S. Swaminathan discussing the transfer of agricultural biotechnologies to the third world also reported that in many developing countries quite complex biotechnologies of plant breeding and pest control have been passed on from generation to generation by totally illiterate villagers. Indeed to train personnel to perform the same tasks by the standard procedures of literacy, training in science, and learning the techniques would be a formidable, indeed prohibitively difficult and complex task for a local government. Literacy is clearly neither necessary nor sufficient for technological competence. We will therefore be forced to attempt some definition of the terms we use, and I try below to add some new terms which are helpful in the development of this topic.

4. Technological Literacy is Not Analogous to "Scientific Literacy

Ivan Illich, who questions literacy as a panacea in his book with Barry Sanders, "ABC: The Alphabetization of the Popular Mind," shows that the development of the alphabet both constrained human communication and simultaneously made it much easier to communicate with large numbers of people at lower levels of "intensity." The scientific alphabet--of mathematics, symbols, and equations--continued this trend and generated an enormously powerful communication tool, albeit useful to a correspondingly narrower and narrower group of individuals. Just so, since science requires the use of letters and symbols, scientific literacy is a meaningful and non-paradoxical term. Technological literacy in some aspects, as noted above, does not require the 'literate' approach.

5. T.L. is Better Described as a Continuum of C^3T: Comfort with, Competence in, and Control of Technology

In order to discuss this in some depth let us attempt some definitions of the terms as we are using them here.

Technology is the means by which humans utilize natural and human resources to attain a goal.

Literacy is the ability to communicate through written letters and words.

Uncomfortable with technology is the state where, due to ignorance, one is both wary and afraid even of the means one must use on a daily basis to attain one's goals.

Comfortable with technology is the state in which a human being is at home with the technological means that she or he uses but unable to assess their impacts on persons or society.

Competence in technology is attained when one has acquired the skill to operate competently the means needed for attaining one's goals.

Control of technology requires, in addition to operation, a level of understanding of the process to shape and adapt it as necessary to achieve even new goals based on an assessment of its potential for good and ill.

Perhaps the use of an analogy will help illuminate these terms (see Fig. 2).

a. ILLITERATE in native tongue.		
One can manage, millions do!! How? Led around by others. Sign language, Use pictures, maps Trial and error.		Uncomfortable No competence Little control
b. BERLITZ Course		
You <u>do</u> it and put words to it <u>Walk</u> around city <u>Eat</u> in restaurants <u>Visit</u> castles	Minimal interaction	Some comfort Little competence No control
c. FLUENT in local language		
Participate in life of city WORK, INTERACT		Comfort Competence Control

Figure 2. Levels of C^3T. Tourist Metaphor: How to get around city?

A tourist in a foreign land needs the technology of the language. The person who has no familiarity at all with the language feels at a major disadvantage, has to use sign language to order food or find the bathroom, and can develop a real sense of isolation. At a slightly higher level of understanding the vast majority of citizens in the developed world surrounded by a myriad of technologies are faced with discomfort caused by gross ignorance of a functioning system in which they have no choice but to participate as cogs. Such persons are not only "illiterate" in the native tongue, but cannot speak of understand it either.

A second group of tourists, in preparation for their trip, will have taken a crash course in the language, acquired a phrase book, or taken the Berlitz course in it. While they are still not literate in the new language they are <u>much</u> more comfortable in their environment. They can "manage," without discomfort, but since they cannot read signs or a newspaper still can have no sense of competence.

A third group has studied the language (or grew up with it) so that they can be rather fluent in it. It is only they who can experience CT. There is, of course, a fourth group which is a subset of the third. These are the writers or poets of the language. They are sufficiently in control to invent new expressions, alter meanings--shape the language itself.

<u>STS as the Route to Technological Literacy</u>

Science, Technology and Society--STS--has become the flagship of the movement for **integrative general education.** By definition STS is the most integrative subject matter one can find in higher education--it covers by far the widest range of disciplines. In many ways it is the reinvention of the University within the "Multiversity." It represents the very antithesis of the "distribution" requirements among the disciplines. It is the structured unification of these disciplines into a new melded general education--which is what the University was all about in the first place. Figure 3 attempts to portray this graphically.

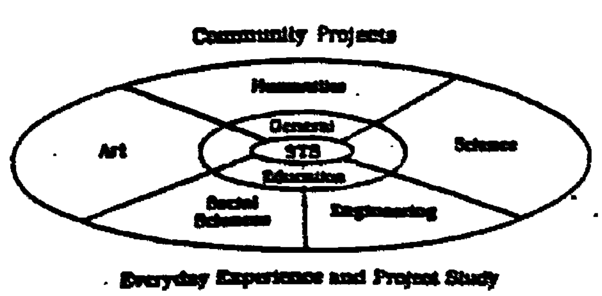


Figure 3. STS has become the core of integrative general education, thereby taking over the core function of the uni-versity, but doing it within the university.

- STS is an intellectual field which started as a response to the questions raised by various critics of science and technology's effect on society. Ellul's seminal work The Technological Society marked the kick-off of this campaign, but Ellul must not be confused in any way with what STS contains today. In the quarter century since that book was published (in English), STS has become a focal point in interdisciplinary general education in U.S. postsecondary education. STS pedagogy provides a structure to look at the grave problems that have arisen due to the compartmentalization of knowledge, especially separating S/T from the rest of learning. Societal problems always cut across academia's arbitrary divisions of fields of knowledge. Addressing them requires input from many areas. STS examines each problem utilizing all the relevant "disciplines" needed.

- From a pedagogical and epistemological viewpoint, STS represents a unique change in western academic development. Instead of prolonging the fissiparous tendency built into academic science, STS attempts to synthesize the widest possible range of disciplines. "Macro-STS" is a new Gestalt or paradigm breaking down the domination of the university paradigm of specialization and departmentalization of knowledge.

- The emergence of the STS movement has created the potential for a major paradigm shift in education. A radically new way of looking at the relationships between science and technology is developing. This new look also puts science and technology into the historical context of worldwide human society. Knowledge is considered in integrative interdisciplinary terms instead of the present rigid, ever more specialized disciplines. Values, morals, and concerns for the larger society are dealt with along-side of scientific equations.

- STS responds to a study of the real problems facing the world by proposing an integration of knowledge. It is the systematic study of the interactions of science, technology, and society outside of strict disciplinary bounds. It looks at science and technology as two independent but related social forces and examines how they impact each other, government, policy-making, business, and everyday life in a myriad of ways. It uses biology as well as business, art as well as physics, engineering as well as philosophy. It is assumed that all disciplines have information of potential value to society.

- STS constitutes a major advance in holistic thinking as it looks at societal implications as well as scientific laws. It calls for moral guidance or humanistic understanding of all work in science and technology. It reminds us that ignoring moral and humanistic standards is itself a choice with far-reaching implications. Mindful of this, STS seeks a thorough reform of scientific education as now practiced.

The rapid increase in interest and support of STS in the United States and abroad shows that the STS "paradigm shift" has started and probably cannot be stopped. STS has grown into formal programs on over a hundred college and university campuses, and into courses at two thousand.

STS - A Paradigm Shift, not just new courses

The STS route to technological literacy is not merely the addition of a few new courses in engineering required of liberal arts students. It is indeed in the best sense a paradigm shift in the approach to their education. To put the case starkly I have reduced it to a tabular form.

The Present Paradigm

- Science leads to technology (= prosperity!!).
- We need science to do technology.
- Science equals physics ± chemistry ± biology (PCB).
- All (most?) citizens must have some PCB; the more the better for our economy. (The present science literacy approach which has led to the present science education crisis.)
- Abstract science is "superior" (more general, the real stuff) than applied science or technology.
- Specialization übber alles. Depth is what counts. Narrower the better.

The Emerging Changes

- Technology leads to science (from Galileo to A-bomb).
- Science is a minor and easily gotten component in successful technology.
- We are embedded in earth, materials, medical, "applied" science. These are the true basic-to-human sciences, encountered daily.

- Technology is met in the concrete reality of society that is the only "science" every citizen needs.

SCIENCE, TECHNOLOGY & SOCIETY (STS) is the Re-alization of the New Paradigm

- Puts humans and their personal and collective concerns at center.

- Is the re-creation of the uni-versity within the multi-versity.

- Stresses integration, (1) across disciplines, (2) knowledge and values, (3) being and doing.

- Restores technology and applied science to a central place in K-12 and the university.

- Invaluable for S/T professionals.

The New Pedagogic Content: STS - Technology - Science

It is the author's contention that having the entire student body exposed to STS will benefit them in several ways:

1. Students will be much more informed and aware of the most significant current issues in our society; which involve S/T in some way.

2. They will have been exposed to a method of critically analyzing such issues.

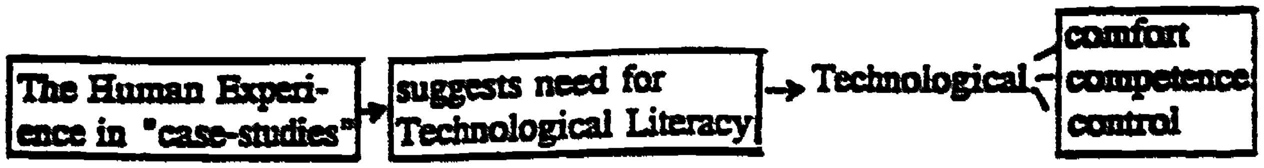
3. They will have been made aware of how technology affects their lives, and how they may interact with technology.

4. A higher percentage than at present may choose to enter engineering, some because they perceive it as a means of controlling their own futures.

5. A higher percentage will become interested in the scientific background behind the engineering, and this could result in more candidates for science degrees. But neither 4 nor 5 are goals of the STS movement.

Thus the STS approach to "science" education has two separate benefits; making better educated citizens and possibly increasing enrollments in science and engineering.

The STS route can be summarized thus:



<u>**The STS Strategy: Pedagogy from the Obvious, Instead of the Obscure**</u>

From time immemorial, communicating "techne" was the passing on from generation to generation of the most important stored up knowledge and wisdom about the most obvious, most common, most often encountered human contacts with those parts of reality which affect humans the most.

Each generation learned as much as possible about food, shelter, security, and so forth and passed it on to the next. For the last century, and rapidly increasingly over the last fifty years, school systems have attempted to teach all students about reality viewed from the particular formalism and stance of abstract science. This science is characterized by two key parameters: abstraction and mathematicization. These features are responsible for the power and rapid growth of science. They are at the same time responsible for its unintelligibility to, and lack of interest for, the vast majority of the population. Moreover, common sense and widespread human experience shows that the vast majority of citizens do not need much abstract science, and only modest quantification, to function very effectively, even in a highly technological society. The last President of the U.S., the chairpersons of most of our largest corporations, the leading playwrights, poets, and university presidents have very little knowledge of the level of science some now demand of all students.

A technology-focused curriculum would eschew abstraction for obviousness. Every citizen would be expected to know about those parts of contemporary human experience which are obvious to all, which affect all in daily living.

A simple algorithm to guide the choice of what to know, which can expand and deepen with advancing grade simply by going into greater detail, is to follow the activities of an average pupil through an average day. From the alarm clock, to the light switch, to the clothes worn, the rubber in the sneakers, to the stove heating water for coffee, to the car being driven to work, there is an infinite opportunity to use these objects and experiences for teaching technology and applied science, and derivatively basic science. This "applied science" must become the necessary core for all students, prior to being exposed to any abstract science. The beauty of using the same common human experience--eating, getting dressed, driving--is that they can be updated at each successive age level; and with increasing depth and sophistication, can form the connecting introduction to any part of physics, chemistry and biology. This is the technological literacy necessary for all citizens; it is also much better groundwork to make science more likely to be attractive to larger numbers.

Conclusion: Teaching Technology and Science in College Today

The integration of several subject matters or disciplines, including engineering disciplines, combined with the purposive nature of the work, elevates applied sciences and engineering over the scientific disciplines on a hierarchical ranking. Technology is not a subject alongside physics and chemistry. It includes science as one among many inputs (see Roy's Two tree theory in Shapley and Roy, 1983).

The idea that learning science is the necessary pre-cursor to learning technology is absurd. Most human history is proof. Indeed, the U.S. Department of Defense has shown that specific, even "high tech" tasks can be taught well, without any science. Figure 4 shows different routes which may be employed.

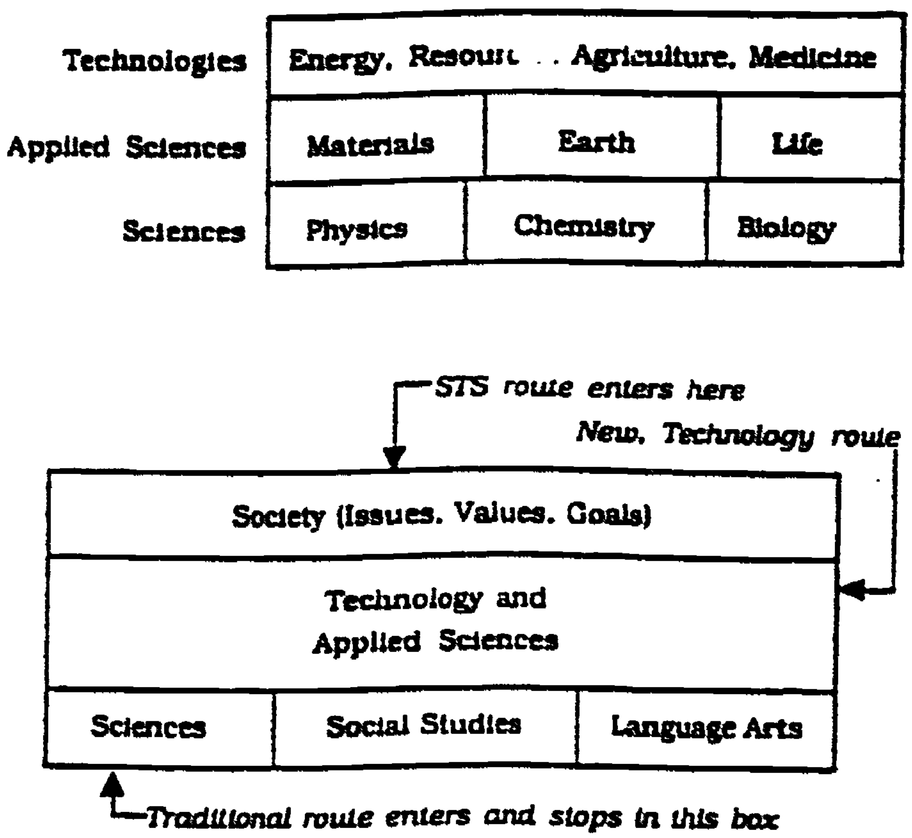


Figure 4. Possible STS and Technology Education Enphases in the New Sequence

For the median learner, we believe that the STS route--entering via the interest in the societal problem--is best. Moreover, it is the only innovation in content proposed for alleviation of the so called math/science crisis. For that reason alone we believe it is at least an essential component of the "science education" of the future. For a 10 percent minority of the population, entering via science (the present tradition in the U.S.) may be the most effective. But for a larger minority, the entry through hands-on technology may be the best. The U.S. has been losing out on the "brains in the fingertips" of the workers, the "techne-ologist," by overstressing the abstract conceptualization as the only way to learn the science which is related to technology, and technology itself.

In conclusion, my central thesis for college education in technology and science is as follows:

> Absolutely every <u>college</u> student <u>must</u> be introduced to the most significant issues facing our culture in a systematic way. Since a large percentage involve S/T, this requires that they encounter <u>technology</u>, in the larger context of STS, where they see it as a human tool to solve and/or create problems. Next, every student should have required courses in the <u>applied sciences and technologies</u> of every day living. Finally, some subset should be introduced to the beauty and power of abstract science.

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CURRENT EFFORTS IN TECHNOLOGICAL LITERACY

John G. Truxal
SUNY-Stony Brook

The speakers opening the workshop yesterday afternoon and the materials sent to you in advance of our meeting have indicated clearly that there is recognition within higher education that our graduates should be prepared for lifelong learning in the technology which increasingly dominates the environment of work and leisure, of personal and political decisions. While conferences of college faculty frequently include specific professors who emotionally question the importance of technological literacy, I will assume that this group is ready to accept the basic premise that we are living in a time when we can use technology to influence significantly the future. Education should prepare our students to participate in the social and political control of the evolution of that technology.

In the hope that we might agree implicitly on our interpretation of the term technological literacy, I would like to start with a specific example--in particular, an example from the area of HSGT, high speed ground transportation. This is a topic which is not (within my knowledge) the focus of any college course for general students, but it is a subject which motivates students and allows teaching of science and technology.

Interurban Trains

My senior senator, Pat Moynihan, has been urging the federal government to launch a project to build a magnetically levitated and propelled, 300-mile/hour train for passenger travel in the Northeast Corridor--initially from New York to Washington. While one might cynically view this as a way to ease Congressional travel between the two cities, Moynihan has even written for Scientific American (an article unusually readable for that magazine) and makes several persuasive arguments. For example,

1) The technology was invented in the U. S. (at Brookhaven National Laboratory), but this country has not made the technology transfer. Indeed, France, Germany, and Japan now lead, and we are unable to bid on the proposed Korean system. We have another example where the U.S. is not competitive.

2) The system would be a major contribution to our decreased dependence on oil for energy with the reduction in auto and air travel (about half of our petroleum use is for vehicles). Furthermore,

environmental effects would also be positive in both air quality and the greenhouse effect, and there would be lessened pressure for new airports and expensive improvements in air traffic control.

3) The project would represent a major economic boost for the region with the costs of construction, operation, and updating.

4) The project would be a showpiece of U.S. technological achievement--more dramatic than a manned mission to Mars.

These arguments are impressive, and it is easy to convince students that the government should move forward. To some extent, the technological imperative is at work. We know that the technology exists, so let's move ahead.

First, though, we should think of some of the problems.

1) The current Amtrak right-of-way will not be adequate. When the speed rises from 100 to 300 mph, allowable curvature is severely reduced. Furthermore, people will not ride in trains without windows. If the landscape moves by at 300 mph, riders suffer nausea unless there is a broad swath around the track, as we know from riding in a plane just before take-off. (One company proposed artificial windows with movies used to create the illusion the scenery was moving by at 50 mph.)

2) Safety is a critical constraint, as shown by the early accident with the BART subway system in the San Francisco area.

3) Economics must be considered. Relatively few people want to travel between the centers of Washington and New York City, so the train must accept and discharge passengers at intermediate spots (Trenton, Philadelphia, Wilmington, Baltimore, and others). With these stops total travel time versus maximum speed plots is shown in the figure below. With each stop we have to decelerate, load/unload, and accelerate, but the acceleration and jerk (rate of change of acceleration) are severely limited for rider comfort. Indeed, the train would probably reach maximum speed only on the Wilmington-Baltimore leg. (One company proposed a mini-train at Philadelphia, for example, running alongside the

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main train to allow passengers leaving to jump across, with the mini-train then returning to the Philadelphia station.)

4) There are other, major economic considerations. There are only 4 million travellers per year between New York and Washington, so the train would have to capture the large majority if fares were to be comparable to those for air travel. Success would require complete redesign of the areas around Penn Station in New York and Union Station in Washington to provide the facilities now available routinely at airports--hotels, conference centers, parking, car rentals, etc. This item as well as 3) above raise the specter of the project displacing large numbers of people; can we do this humanely and effectively?

When we consider both the opportunities and the problems, there is no clearly correct response to the Moynihan proposal. Perhaps other locations would be preferable (Los Angeles-Las Vegas, or Miami-Orlando-Tampa)? Perhaps we are fighting a losing battle in trying to move Americans away from the attachment to their automobiles (U.S. has 1.9 people per car, Japan 4.4)?

<u>Characteristics of Technological Literacy</u>

This example illustrates one characteristic we hope that technological literacy encompasses--the avoidance of the always attractive, simplistic answers to questions. Bob Wheeler, originator of the Yale program, simply states that he wants his students to become "nonsense detectors," able to recognize that policy questions are rarely black or white, that each of us must weigh both sides of the argument.

Technological literacy goes beyond this, as the previous speakers have indicated, to include:

a) Recognition that modern technology is inherently simple and understandable (it was designed by human beings). A television picture is just

300,000 dots each with appropriate amounts of the primary colors red, green, and blue.

b) Recognition that technology is closely allied to science and mathematics, but it is inevitably multidisciplinary. In our HSGT example, we can teach kinematics, dynamics, electricity and magnetism, but evaluation must include ergonomics, economics, political science, and values.

c) Self-confidence that we can learn enough about any technological subject to be at least somewhat informed in decision-making.

While these may be features of technological literacy, I believe there is no consensus on how it can be measured (any more than we are happy with attempts to measure scientific or economic literacy). A question such as "Do you know how the telephone works?" may actually yield counter-intuitive results--a "yes" response indicating that a simplistic explanation is accepted. If the U.S. is to meet the goal of the President and Governors to achieve U.S. leadership in mathematics and science by the end of the decade, we must either clarify the definitions or (as a sad alternative) find specific measures in which the U.S. does excel.

With this very cursory consideration of the definition of technological literacy, I would urge that in this workshop we accept two premises:

1) Technological literacy is essential for "concerned citizens," those involved with public decisions and the state of our society. We all like to think we are teaching concerned citizens of the future. (Actually, the estimate has been made that only 10% of adults are "concerned citizens." Since 50% go on to higher education, some of us must be teaching the future "unconcerned.")

2) Undergraduate education is an important arena for technological literacy. In the long term, pre-college education may have responsibility for this area, but for the foreseeable future higher education must respond to the needs.

<u>Constraints</u>

As we discuss how to encourage education for technological literacy, we should keep in mind the lessons from the past decade of efforts in those colleges and universities which have successful programs. Educational change faces constraints in four primary areas:

I. **Curriculum**

In liberal education the curriculum is already crowded, and most faculty members feel that their academic field is the most important. In the preface of a recent anthology on technology studies, there appears the statement: "However, the readings are not all written by professional philosophers. Some of the more seminal, if less careful, thinking has been done by those outside the discipline of philosophy." We all tend to characterize thinking in other disciplines as somewhat sloppy.

There are opportunities within the curriculum. The general education requirements may include technology studies, but almost always include science and mathematics which, one can argue, are most effectively taught through technology. STS courses often involve substantive technology. Finally, almost every major includes at least some free electives, and we should be delighted to compete here for student interest.

While a very few universities have established departments focussing on such themes as technology studies or technology/public policy areas, the most common way to ensure that technology studies has a lasting place in the curriculum is for the technology courses to be adopted as regular offerings by existing departments.

II. **Students**

The technology courses must be matched to student interests and backgrounds. Indeed, curriculum design is similar to engineering design: we have a given input (today's students at our institution) and a desired output (technologically literate graduates). Our task is to design the best possible system to change the input to the output.

In the past decade, experiences at many colleges have clearly demonstrated that students respond with remarkable enthusiasm to technology courses designed in these terms. Students enjoy learning about familiar and future technology, and they perceive that such studies will be important in their careers. As just one example, nearly all students will voluntarily elect computer courses even in the absence of requirements--and even at colleges where English and Modern Languages are very popular majors.

The experiences of the 1980's have shown that very popular courses can be offered on such themes as:

Reproductive technology	Communications
Forensic technology	Space
Structures	Environmental studies
Electronic circuits	Ergonomics

Furthermore, such courses inevitably include significant segments of science and mathematics--topics that students find challenging and interesting in this framework.

There is one other characteristic of student response. These technology courses seem to appeal to women almost as much as men. At my own university, for example, the undergraduate student body is 54% women, and we have about 46% women in the technology courses we offer for general students. We still have not reached parity, but we are much closer than engineering and physical sciences.

Finally, our experience with the national minorities-in-engineering program since 1975 indicates that minority secondary-school students are strongly attracted by technology and can be effectively drawn into the study of the related science. My colleagues developed twenty-four technology modules (about two weeks each) to be used in secondary science, math, and English classes, with over 800,000 modules delivered to schools with strong minority populations. One of the most popular was a unit on urban home fires, with students working with family or neighbors to evaluate their personal risk, and then determining why there are sections of East New York where the mean time between major home fires is five years.

III. Faculty

While the student constraint can be handled readily by the choice of appropriate course themes, the constraint imposed by faculty attitudes and behavior is much more difficult. The 1990 Sigma Xi report is just one of the many indictments of introductory science (and mathematics) courses. The National Science Foundation has also placed primary emphasis on these basic courses.

In spite of these stirrings and, indeed, the indications that mathematics teaching may be promising major changes, there are several problems for those of us interested in technological literacy:

1) Many teachers are quite satisfied with the introductory courses. Calculus 1 or Physics 1 are pretty much the same courses they took, and the U.S. has had excellent scientists. The high attrition rate simply indicates that the later courses are not filled with incompetent students. (The fact that so many students choose their major by a sequence of failures does not seem to bother these faculty.)

2) Many teachers are really not interested in teaching, especially lower-division students. This emphasis on research and publication appears not only in the research universities; even some of the four-year, liberal arts colleges seem to base tenure and promotion on "scholarly" publications more than teaching.

3) Many faculty are unaware of the recent work in learning and cognitive science; and do not realize that students learn in very different ways.

4) Many faculty have greater allegiance to their scientific/professional fields than to their institution.

Fortunately, these problems have a positive side. The fact that so many faculty have these characteristics opens the way for others who are interested in students, in teaching/learning, and in educational innovation.

Finally, many of the STS and technology-studies courses involve team teaching--often a professor in science coupled with one in humanities or social sciences. Experience with such an approach varies from college to college. In our setting at Stony Brook, we have found it preferable to have a single professor in charge of the course so that students have one individual to turn to for advice, even though we use visiting lecturers/discussers and we depend on consultation with faculty from other departments.

IV Costs

The last constraint on educational innovation is economic. In today's academic environment (at least, in our institution), funds for experimentation are severely limited, and faculty frequently defend their turf and enrollment. As a result, laboratory work for a new course in technology must utilize existing equipment or involve inexpensive measurements on the real world. Graduate teaching assistants are usually not available, so we have used no-cost, undergraduate teaching assistants (students who have previously excelled in the course), who receive credit for working for the faculty member in advising, overseeing lab work, and the like.

The Future

In view of these constraints, how can we move forward, building on the past accomplishments in Science/Technology/Society programs, the New Liberal Arts, and the current NSF interests? Hopefully, the above comments indicate that there are several ways we can find a place in the curriculum. The optimum approach depends strongly on the particular institution--its academic environment, faculty, curriculum, and students.

Two particularly promising approaches are:

1) Involvement of a small number of senior, excellent engineering teachers in the development of courses in technology for general students. For the faculty, the incentive is the very rewarding feedback from such teaching; for the engineering college, the new role within the academic environment and the significant teaching workload can buffer against oscillations in engineering enrollment.

2) Modification of courses satisfying core requirements in science. This approach is described further in the brief appendix.

Regardless of the particular approach appropriate for a specific institution, we are at an unusually exciting point in the evolution of U.S. higher education. Confluent forces are moving us strongly toward acceptance of technology studies as an important element for all students of higher education.

Appendix

An Introductory Science Course From the NLA

Recent national reports on science education have emphasized that introductory, college science courses for all students are not satisfactory. They often cover a large number of basic concepts in an encyclopedic fashion, they are frequently poorly taught, and they are not matched to either the backgrounds or the interests of many students.

The NLA Program has generated a set of outstandingly successful courses in this introductory science area. These courses possess certain common characteristics:

(1) While they come under the aegis of the traditional science departments, they include material drawn from science offerings at several levels (not just the usual coverage of the first course).

(2) Most topics are introduced through significant, real-world examples and problems. The science concepts are introduced as needed for the students to understand the model and problem. In this sense, a "just-in-time" approach is used (e.g., the concept of energy appears when it is needed).

(3) The only mathematics prerequisite is algebra, and the math is taught as needed.

(4) Emphasis is placed on problem and model formulation by the students.

These NLA courses, however, are usually not useful directly at other colleges for three reasons:

(1) The courses strongly reflect the interests of the professor, who in many cases has devoted a major effort to learning in the area covered by the course.

(2) The courses from the prestigious liberal arts colleges are designed for relatively small classes.

(3) The courses require major faculty commitments of time, so are inappropriate when teaching loads are heavy.

Widespread adoption of these new approaches requires an additional step in educational development -- the "educational transfer" analogous to the process of "technology transfer." With the lessons learned from the "research" stage, we now need to develop courses tailored to the constraints of the larger institutions -- the comprehensive and the research universities which serve over 85% of the students in four-year colleges.

Thus, if we are to capitalize on the numerous curricular innovations of the NLA Program, we need the additional effort of converting these materials to match the market.

Plan

We propose development of five modules, with a suitable one-semester course based upon the instructor's selection of the three modules best matched to his/her own interest (or, in some cases, two modules plus one developed independently by the instructor).*

If this experiment proved successful, the next step would be a second set of modules to allow a full-year course.

Professor

Our plan is to develop course materials which can be offered by an engineering or technology professor (an outreach from the engineering school to non-majors), or by a physical science professor (probably physics or earth science) with a strong interest in applications.

The course should also appeal to pre-service education students, especially in light of the on-going changes in pre-college science.

Desirable Course Coverage

The course would teach science through technology and would address problems of scientific, technological, and quantitative literacies. We anticipate the course would satisfy core-curriculum science (and technology, where relevant) requirements. Each module would include appropriate laboratory work, although a significant fraction of that should be outside the conventional laboratory setting (that is, in the real world with, for example, measurements of distance travelled by inertial navigation using a carpenter's level, of building accessibility for the handicapped, and of noise environment).

Work in the regular science laboratory rooms would be restricted to equipment normally available.

Desirable Characteristics for Teachability

(1) Each case study is introduced via a clearly relevant problem, but one leading to science in the form familiar to the physics teacher so that course coverage is not threatening. For example, first-year physics typically includes units on

> *General laws of motion* -- here inertial navigation by both artifacts and physiological sensors could be used. The space program obviously provides an attractive case study. The approach of using a TV camera as basic instrumentation allows analysis of elevator performance or sports and ballet activities (as demonstrated by Ted Ducas of Wellesley).
>
> *Electricity and magnetism* -- here we have the existing work by Jeffrey on heart pacing and the work by Copp/Zanella on electrification of Los Angeles. This unit would lead naturally into the logic and electronic circuits used so effectively by Barrett Hazeltine and others.
>
> *Wave motion* -- here sound and audio systems provide an attractive vehicle. The inexpensive Radio Shack sound-level meter allows students to make measurements in real environments and leads naturally into federal

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* This format would also allow offering a course in the pattern developed by Bob Wheeler at Yale, where six one-credit units are offered

> *A and B the first third of the semester*
> *C and D the second third*
> *E and F the last third*

and students can elect any three for credit for the full course.

regulations to protect worker health. Audiometry equipment is often available on loan from health centers.

Energy -- the model of U.S. and global energy use emphasizes the importance and potential of conservation (this study can include a personal audit of energy use). New sources of electrical energy point out the critical importance of amortized costs.

(2) Most of the class time is spent working problems using algebra or discussing very basic concepts. This is the normal situation in introductory science courses, it requires modest preparation for the instructor, and it leads to attractively straightforward measurement of student performance. While we might hope that the new science courses would lead to very different teaching styles, changes have to be gradual and evolutionary in light of the constraints within institutions.

(3) Economic, ethical, historical, and psychological aspects are included in student readings, so the instructor is free to consider in class these aspects only to the extent that he/she is comfortable. When we ultimately seek inclusion of such topics centrally within the course, there again must be the opportunity for gradual change.

(4) Classroom activities, demonstrations, movies or tapes, and slides must be readily available to the instructor.

(5) Additional materials are made available for enriched learning by some students, or for individual study projects.

Questions

We need to meet with key instructors from a few comprehensive universities to investigate several questions before such course development is initiated:

(1) Would such a course be attractive to your faculty colleagues in engineering, technology, or science? (The NLA experience seems to indicate strongly that student interest will be high.) Clearly all teaching materials would have to be available before the course was offered.

(2) Would your academic environment allow approval of such a course to satisfy a requirement in general education?

(3) Would you have one or two colleagues interested in working within such course development?

The answers to such questions are not simple. For example, the common yearlong physics covers nine or ten major topics; the proposed course would be more limited in coverage. Would physics faculty feel the loss to be catastrophic?

INVITED PERSPECTIVES

TECHNOLOGICAL LITERACY: VIEWS FROM A LIBERAL ARTS COLLEGE

Thomas Wasow
Stanford University

Need

The division between what C.P. Snow labeled "the two cultures"--that is, between the technical scientific disciplines and the humanistic fields of study--is deeply ingrained in our society. This is indicated by the variety of colloquialisms used to make the distinction: "techie" vs. "fuzzy", "hard" vs. "soft", "neat" vs. "scruffy", etc. Many students classify themselves at quite an early age--often well before college--as belonging to one or the other of these cultures. All too often, such students concentrate their studies as heavily as possible in one culture, taking as light a load as they can get away with from the other culture.

I find this situation distressing. I majored in mathematics as an undergraduate, switched to linguistics for graduate school, and have a joint appointment in departments of linguistics and philosophy. My research and teaching overlap, on the one side, with philosophical issues in metaphysics and epistemology, and on the other, with artificial intelligence and formal language theory. On the more applied side, I have been actively involved in the development of software for natural language processing. In short, my interests have always spanned the two cultures, and I firmly believe that a genuinely educated person must know something about both.

Quite apart from my own predilections, there are practical reasons for encouraging students to learn about both cultures. As technology comes to play an ever greater role in our daily lives--through the revolutionary developments of the last few decades in electronics, physics, chemistry, biology, and medicine--it becomes increasingly important for informed citizens to have some basic understanding of science and technology. We cannot maintain a democratic form of government if we surrender to the experts all authority over such vital issues as environmental policy, product safety, computer privacy, appropriate choices of military technology, etc. While the opinions of the professionals must carry special weight, the final decisions should be made by a wider public. But this is only possible if that public is technologically literate. And if this is an unrealistically optimistic goal, then it is especially important that students at institutions which produce a large share of society's leaders become technologically literate.

It is, of course, equally important that all of our students attain what we might call humanistic literacy. We have learned from experience that technological advances almost always entail social and ethical consequences. Scientists and engineers must have more than mere technical expertise. Otherwise, we end up with, as Martin Luther King put it, "guided missiles and misguided men." But, as has often been observed, there is an asymmetry: humanities students avoid the quantitative disciplines to a far greater extent than the students in those disciplines avoid the humanities.

Courses in history, literature, philosophy, and art are regarded by science students as pleasurable diversions, so no special efforts are needed (at Stanford anyway) to get them to do coursework in these subjects. Moreover, while it is regarded as socially acceptable for humanists to be technologically illiterate, no educated person admits to humanistic illiteracy. My former colleague in the dean's office, Brad Efron, a distinguished statistician, has developed a pat answer to express his annoyance with people (of whom there are many) who tell him how much difficulty they had with statistics in college. He asks them, "Would you brag about flunking English?" This, in a nutshell, epitomizes the asymmetry between the two cultures.

The asymmetry manifests itself in the curriculum. While most colleges offer courses of the "Physics for Poets" ilk, none that I know of offers "Poetry for Physicists." Science and engineering students are expected to study humanistic subjects in the same classes with all other students, but special science courses are provided for humanities students.

One reason for this (though by no means the only one) is that the scientific disciplines are vertically structured, in the sense that topics build on one another in such a way as to define a relatively fixed sequence in which courses must be taken. It is not possible, say, for an English major to take as his one natural science course a quantum mechanics class designed for science students. In contrast, a physics major can take as her one literature course a Shakespeare class designed for humanities students.

One alternative to courses like "Physics for Poets" is to have every student take the entry level course in one of the sciences--the first term of physics or chemistry, for example. Many students take this option; at Stanford, for example, most students satisfy their mathematics requirement with the first term of calculus. But these entry level courses for science majors are not generally very good one-shot introductions to science. Courses designed for the student who will not go on in science can do a better job, though their instructors must guard against the tendency to oversimplify to the point where the students are not challenged.

In the remainder of my remarks, I want to tell you a bit about what we do at Stanford to induce our non-science students to learn something about mathematics, science, and technology.

Requirements

First, we have a system of distribution requirements designed to guarantee breadth of study. It includes three requirements whose objective is, at least in part, to enhance the technological literacy of our students. Every undergraduate must take at least one approved course in each of the following three areas: Mathematical Sciences, Natural Sciences, and Technology and Applied Sciences. The last of these is clearly the most directly relevant to the topic of this workshop, so I will quote in full the criteria a course must fulfill in order to satisfy this requirement:

> Courses that satisfy the Distribution Requirement in Technology and Applied Sciences normally must:
>
> a) give students an appreciation for typical intellectual techniques and styles used in technology and applied science,
>
> b) give students an appreciation for some of the capabilities and limitations of technology and applied science,
>
> c) give students an understanding of the fundamental theory, history, social or environmental impact of the discipline[1],
>
> d) be *in* technology and applied science rather than *about* it,
>
> e) have an appreciable quantitative content, at an appropriate mathematical and scientific level,
>
> f) be taught by practitioners,
>
> g) be reasonably accessible to people outside the major.

[1]There has been some discussion of late as to whether the phrase "fundamental theory" should be deleted, to strengthen the commitment to making courses satisfying this requirement socially relevant.

This academic year, twenty-six courses have been certified to fulfill this requirement. Sixteen are from the School of Engineering, six from the School of Earth Sciences, three from the School of Humanities and Sciences, and one is cross-listed in Engineering and H&S. Topics are wide-ranging, including "Management of Geologic Hazards," "Programming Methodology," Applied Mechanics-Statics," "Models and Applications or Operations Research in Society," and "Technology and Musical Aesthetics." Some are courses that are part of the normal sequence to satisfy a technical major; others are intended for science and engineering students but are not part of any major; and a few are designed for students who will take only one course in the general area of applied science.

The courses in this latter category are not merely watered-down versions of what engineering students take. Rather, faculty have sought out topics in applied science that can be treated in a substantive way with minimal technical background. An example is a course called "Automobile Technology" that deals with how cars work, why they are designed the way they are, how they affect air pollution, and aspects of engine design for improving exhaust emissions.

The most widely taken course to satisfy the requirement is Computer Science 105A, "Introduction to Computers," which is described as follows:

> For non-technical majors to develop a working knowledge of computers as utilized in our society. Two major components: programming and issues. Karel and Robot and Pascal are used to expose students to the concepts of structured programming. Topics: artificial intelligence, databases, spreadsheets, graphics, security and privacy, computer systems, human factors, hardware, and networks. 105A requires considerable interaction between student and computer, but is oriented toward students without strong math and/or technical background, and assumes no previous computer experience.

About a third of our undergraduates take this course, and in many cases it leads them to do more course work in computer science.

Probably the most interesting means we offer for fulfilling the applied science and technology requirement is a year-long course sequence entitled, "The Nature of Technology, Mathematics, and Science," which also satisfies the mathematics and natural science requirements. Co-taught by a mathematician, a physicist, and an engineer, this sequence introduces students to a wide range of topics falling under the following general headings:

- Numbers
- Radio Astronomy
- Energy and Engines
- Relativity & Non-Euclidean Geometry
- The Computer and the CT Scan
- Physics - Quantum theory, Elementary Particles, and Cosmology
- Engineering Design

The treatment of this final topic includes dividing the class into groups of five for a final project consisting of designing a specified device (such as an electric 3-wheeled vehicle). The design teams must develop precise specifications for the device and research the availability and price of the necessary component, though they do not actually build it. Students complain about how demanding this assignment is, but take great pride in their accomplishment when it is completed.

As wonderful as "The Nature of Technology, Mathematics, and Science" is, it is not without its problems. It requires an enormous investment of time on the part of the three instructors, since they attend each other's lectures and work together to integrate them. When one instructor goes on leave or takes on some conflicting obligations, it is extremely difficult to staff the course. This year, it is not being offered because one crucial professor is on leave. Next year, it is being divided into three more discrete courses, in order to reduce the time required of the three teachers; I do not know whether this will be a permanent change.

The science requirements are not the only ones that we use to try to instill some degree of technological literacy. One especially innovative effort is "Technology and Culture," one of the eight year-long courses designed to satisfy Stanford's freshman requirement known as "Cultures, Ideas, and Values" (or CIV for short). The other CIV courses deal almost entirely with the history of politics, philosophy, literature, and art, largely in Europe, but with some attention to the influences of other cultural traditions. Technology and Culture, on the other hand, gives special attention to the manner in which science and technology shape, and are shaped by, the other aspects of culture. It deals not only with the development of science and technology in Europe, but also with the influence of Islamic and Chinese ideas on European scientific progress. The latter part of the course deals with some of the major challenges facing today's world that have a technological component, such as nuclear weapons, the environment, and recombinant DNA.

This year, for the first time, students in Technology and Culture will be divided into groups to design a final project. They must research and recreate a significant technological artifact from the period covered in the first two-thirds of the course (pre-18th century), writing a paper describing the research and construction of the artifact.

Technology and Culture is the most requested of the CIV courses, though staffing problems make it impossible for us to accommodate all of the students who request it.

Interdisciplinary Curriculum

General education requirements serve the function of motivating students to do coursework in particular areas of study. They are, however, a rather brute-force source of motivation; other, more subtle, means are also available. At Stanford, a particularly effective mechanism for encouraging students to explore new intellectual terrain is the interdisciplinary program. Almost a quarter of our undergraduates select interdisciplinary majors, many of them in programs that integrate material from the humanities, the social sciences, the natural sciences, and engineering.

The largest and oldest of these programs is Human Biology. With the participation of faculty from at least ten departments, it gives students the opportunity to study human beings as natural, evolutionary, and social organisms, and to explore human issues from the perspectives of anthropology, biology, psychology, and sociology. Another well established interdisciplinary program is Values, Technology, Science, and Society (VTSS), which draws on faculty from the Schools of Engineering and Humanities & Sciences to explore the social implications of scientific and technological development. This is the Stanford program that has been identified several times at this workshop as being an STS program. It is the institutional home for two courses described above, namely, "The Nature of Technology, Mathematics, and Science" and "Technology and Culture." Aside from these two courses, however, VTSS's curriculum is not directed at the issue of technological literacy. Rather, it is concerned with educating engineering students about the societal impact of technology. The School of Engineering requires each of its students to take at least one course in VTSS.

Two additional programs that cross the boundary between science and the humanities have recently been added to the Stanford curriculum. The program in the History of Science investigates the social, political, and intellectual contexts in which scientific progress has occurred, revealing the profound connections between the two cultures. Last, but not least, Symbolic Systems is the newest of our interdisciplinary programs. It brings together philosophers, linguists, psychologists, and computer scientists to investigate fundamental questions about the nature of information, intelligence, and communication--questions combining traditional epistemological issues with new conceptual and technical problems raised by the computer revolution. Symbolic Systems has been especially successful at involving researchers from nearby industrial research labs (especially the Xerox Palo Alto Research Center and SRI International) in the teaching of undergraduates. This has led to the placement of many Symbolic Systems students in jobs in these labs. For those students who come to the major with primarily humanistic interests, this constitutes an especially effective way of drawing them into the world of technology.

Yet another interdisciplinary program is currently under development. Earth Systems will bring together earth scientists, engineers, biologists, and economists to provide undergraduates with a rigorous introduction to issues of environment. This program, even more than any of the others, seems likely to draw students from the humanities and social sciences into some depth in the natural and applied sciences. Given the strong interest in the environment among Stanford undergraduates, I expect this major to be quite popular, its daunting list of requirements notwithstanding.

Each of these programs promotes technological literacy by motivating the study of science and technology on the basis of political, philosophical, or historical concerns. Students who may not derive intrinsic pleasure from studying quantitative disciplines are led to gain some knowledge of technical fields through their desire for a better understanding of certain societal or ethical issues.

Conclusion

I hope I have made clear that Stanford takes a many-faceted approach to the problem of providing our students with technological literacy.

We are aided in our curric... efforts by our location in the heart of the R&D portion of Silicon Valley, for the influence of technology is even more obvious there than elsewhere in the society. Computers are in evidence everywhere on campus (thanks, in part, to generous donations from a number of corporations in the neighborhood). Most undergraduate dormitories are equipped with microcomputer clusters linked to a campus-wide network, giving students easy access to an array of facilities (e.g., the library's card catalog, on-line databases, and electronic mail).

Increasing numbers of faculty make use of courseware in their teaching, which requires students to gain the minimal computer literacy needed to do their assignments in those classes. Among the courses that have begun integrating the use of computers into their syllabi is Freshman English, which is a degree requirement for undergraduates. Other subjects using courseware include thermodynamics, logic, French history, and

French language. It is now consequently virtually impossible for a Stanford undergraduate to avoid some hands-on experience with computers. This is an extremely useful step in breaking down technological illiteracy. Further steps are provided by requirements, courses, and programs like those I described earlier.

There is, nevertheless, considerable room for improvement. Too many of our seniors still graduate with the conviction that they have no ability or interest in science and technology. I fear that some will, like Brad Efron's pet peeves, boast of the difficulty they experienced in satisfying our science distribution requirements. I am eager to do more to promote technological literacy at Stanford and am grateful for the opportunity to learn from leading experts in this field.

VIEWS FROM THE ENGINEERING COLLEGE: ENGINEERING FOR NON-ENGINEERS

Curtis J. Tompkins
West Virginia University

First of all, the title of my presentation, "Views from the Engineering College," is obviously presumptuous and naive. The engineering college implies a singularity that must be put aside immediately. In my eleven years as dean of engineering at a comprehensive, state land-grant university, six years of service as an officer of the Engineering Deans Council and five years on the Engineering Accreditation Commission, and currently as President of the American Society for Engineering Education, I have gained an appreciation and understanding of the diversity and independent-minded nature of engineering educators and engineering schools in our country and, indeed, in many other countries around the world.

And yet, I will presumptuously and possibly naively go right ahead and pontificate on the subject assigned to me this afternoon. In doing so, I am reminded of the old story about the man who drowned in the great flood in Johnstown, Pennsylvania. Upon approaching the pearly gates, the man was told by St. Peter that each new resident of heaven was required to be initiated and introduced to the incumbent residents by giving a formal address on the most significant and noteworthy event of his or her life. The man enthusiastically replied that he would tell the audience about his experience in the Johnstown flood, only to discover, sitting in the center of the front row, of the audience, a long-time resident by the name of Noah.

Now that man had it relatively easy, because there was only one Noah. In the case of today's participants I can only ask in advance for charity on the parts of the veterans, the "old pros," such as John Truxal, Rustum Roy, David Billington, and the great majority of you who have toiled in the vineyards of technological literacy for many, many years.

The mission statement of the American Society for Engineering Education (ASEE) states that "ASEE should foster the technological education of society." We have not done much of that during the 98-year history of ASEE. A few of our engineering schools have placed some emphasis on providing engineering courses for non-engineering students, but we can count the number of schools which have made sustained and substantial efforts on our fingers. A few faculty leaders, many of whom are here today, have been articulating a vision for engineering and science faculty to provide more opportunities for non-science and non-engineering majors to learn about science and engineering. More than 95 percent of our faculty have been preoccupied with the education of those majoring in engineering or engineering technology.

Our nation appears to be at a significant crossroads in shifting the paradigm of mathematics and science education for non-scientists and non-engineers. President Bush and Secretary of Education Alexander have impressed many of us with what I want to believe is a very real and sincere commitment to improving K through 12 education in our country.

As we approach this crossroads, what are some of the roles, realities, and responsibilities of our engineering schools in improving technological literacy of non-engineers? While a few pioneering institutions and individuals have been working diligently on this challenge for several years, and should be applauded, as a nation, we have not made satisfactory progress in improving technological literacy when measured against the unfilled needs in this regard. How do and should our engineering and engineering technology schools fit into the enhancement of science and engineering awareness and knowledge of the general citizenry?

Consider the following five statements:

1. Less than 15 percent of the 3300 colleges and universities in the United States have accredited engineering or engineering technology programs.

2. I believe that a large majority of the deans and faculty of our nation's engineering and engineering technology schools agree that a technologically literate society is important, and probably essential, to U.S. competitiveness in the global economy as well as to an individual's ability to make decisions--public policy, corporate policy, and personal decisions.

3. I further expect that most engineering technology and engineering deans and faculty members would say, in the ideal, that each and every one of our nation's engineering and engineering technology schools should make significant contributions to the technological literacy of our citizens, particularly of those students enrolled in non-engineering programs at their institutions.

4. However, I am very confident that nearly every engineering and engineering technology dean would be quick to point out that virtually every school of engineering or engineering technology is saturated with demands upon its faculty to teach undergraduate, and in many cases graduate, students majoring in engineering or engineering technology, to conduct research, and, in many

cases, to provide continuing education and other outreach services. The enrollment of majors in engineering or engineering technology has generally been sufficient to occupy our faculty; that is, engineering and engineering technology faculty have not felt compelled to seek non-majors to populate our courses. Indeed, many, if not most, engineering schools have limited, that is to say, controlled, their enrollments.

5. Very, very few deans or faculty of humanities and social sciences schools want their majors to take courses in engineering or technology.

Putting these five statements together, a summary of the opening portion of a conversation with engineering and engineering technology deans on my assigned topic, might be as follows:

"While we recognize and support the need for improving technological literacy in the U.S., our plates are full. It is just not realistic to expect us to do much in this area. Besides, we only exist at a small percentage of our nation's colleges and universities. Even if we did a bang-up job at our institutions, more than 85 percent of the colleges and universities would not be served. And the faculty of humanities and social sciences don't want more technological content for liberal arts students."

In fact, such a conversation would probably parallel in many ways a conversation about improving K-12 education. Everyone is for it or at least recognizes the need, but not many engineering or engineering technology schools are doing much about it. And apparently we have not been expected to do much about it.

I wrote to some of my fellow deans of engineering recently and asked them the following questions:

1. What is being done or is being planned at your institution pertaining to the technological literacy of non-engineering and non-science students?

2. Should ASEE make this a high priority item?

Fifty-three engineering deans responded; most of them wrote long, thoughtful letters. I view the responding schools to be representative and a statistically significant sample of our nation's engineering schools.

I want to share with you specific comments from some of the responding deans as well as a summary of my findings from this survey. First, I found that more than 90 percent of the deans were positive and encouraging about ASEE playing a leadership role in improving technological literacy in the United States. Many of them suggested that ASEE coordinate closely with the various technical and professional societies as well as with other organizations interested in this subject.

Second, most deans, even those whose schools have been providing engineering courses for non-engineers, felt that their schools would not have much impact on technological literacy on their own campuses. By the way, twenty-six of the fifty-three responding schools planned to offer or did offer some coursework for non-engineering students. "Some" in most cases translates to "three or less" courses; enrollment in most of those courses at most schools was small--less than fifteen students per section.

Permit me to share some direct quotes from a few of the letters I received:

1. "Generally, I believe very strongly that my College of Engineering and indeed any college within a university should play some reasonable role in providing for the general education of all university students." (Bob Snyder, University of North Carolina at Charlotte)

2. "It is interesting that our non-engineering colleagues on campus are very concerned about our engineering students receiving a well-rounded education including a number of courses in social humanistic areas, but they are not concerned about non-engineering students learning about and developing an appreciation for technology." (Win Phillips, University of Florida)

3. "My discussions with the dean of the College of Business and Economics indicates that the faculty of that college feel a lack of technology literacy in their program, and they are planning to introduce requirements in both science and technology literacy that exceed the ones they have now." (Alan Pense, Lehigh University)

4. "There would have to be significant changes in the support by our central administration (both morally and financially) and by the faculty outside of engineering before we could substantially increase our effort in these areas." (Carl Erdman, Executive Associate Dean, Texas A & M)

5. "It is obvious that ASEE won't be able to make any inroads by itself, and will have to work with other educational organizations that represent the non-science and non-engineering degree students." (James O. Wilkes, Assistant Dean, University of Michigan)

6. "Princeton has recently initiated a university-wide effort to expand and strengthen the "Science for Non-Science Majors," and the faculty at the School of Engineering are actively involved in revising and creating new courses." (Hisashi Kobayashi, Princeton University)

7. "There is no real reward or incentive for faculty (especially young faculty) to get involved and there is often criticism of older (and more highly paid) faculty teaching small classes to non-engineering students." (Paul Hartman, Professor, University of Central Florida)

8. "I am not satisfied with the courses that are called technology since they are too few in order to introduce any significant numbers of our students to the real world of technology." (Otis Sproul, University of New Hampshire)

9. "A significant fraction of the liberal arts students have not taken the high school courses in mathematics, chemistry and physics that could serve as a basis for developing meaningful courses." (Jim Malone, Emeritus Professor, University of Kansas)

10. "I believe that we have established an image of inscrutability, impossibility, and insensitivity which has now come to haunt us. We frighten other college students; we myopic nerds with pocket protectors and wing-tip shoes have created an unfortunate monster and in order to sell our stuff, we must first rebuild our image and even our credibility as concerned citizens." (Jim Cross, Old Dominion University)

11. "A position statement or policy from ASEE would be beneficial for drawing attention to a serious concern that faces the nation." (Eric Soulsby, Associate Dean, University of Connecticut)

12. "As you know, engineering education progresses through the phases of science, engineering science, analysis, and design. Although these can be integrated somewhat, each phase basically builds upon that which has preceded it. We have been unable to develop an alternative that we consider meaningful. Without such an alternative, too much time in the non-engineering curricula must be devoted to this to be accepted in such curricula. This, we believe, is the fundamental issue. If this can be solved, then we believe progress could be made." (Paul DeRusso, Associate Dean, Rensselaer Polytechnic Institute)

At a recent annual Engineering Deans Institute, I had a conversation with several of my fellow deans on this subject. Here are some of the questions raised and comments made by those engineering deans:

- "I haven't had the dean of arts and sciences ask for engineering courses for liberal arts students."

- "Yeah, and our university faculty senate wants more humanities and social sciences to be taken by engineering students, not more technological content for the liberal arts students."

- "Even if we wanted to provide more engineering courses for non-engineering students, I don't believe our central administration would reallocate resources to support such an activity. And anyway, if we did receive more resources, I have several higher priority activities in which I would invest them."

- "What do we mean by technological literacy? Is it possible to provide sufficient technological course work in a non-engineering degree program to be able to claim that a student is technologically literate? When is enough, enough?"

- "Are science courses prerequisite for engineering courses for non-engineering students? If not, wouldn't our engineering faculty have to teach science background as well as engineering? What should the content of engineering courses be for non-engineering students? Can we get our faculty to agree?"

- "Is a little knowledge dangerous?"

- "Is a person with a Ph.D. in science or engineering technologically literate if he or she doesn't know about or understand environmental or computer or manufacturing or life sciences issues?"

- "And besides, what do most of the schools of medicine, law, dentistry and nursing do for non-majors? Very little or nothing, that's what. So why should we feel guilty about not doing more for non-majors?"

I will not go on quoting from that part of the conversation because I expect that you have an adequate flavor. Let me hasten to a much more constructive, hopeful and upbeat portion of our conversation. (Deans, by the way, like many people, tend to get a few things off their chests, at least when they are with fellow deans, especially if they feel someone may be thinking about imposing something unreasonable on their faculty.)

I am pleased to report that we arrived at several fundamental concepts on which most of us could agree:

a. We need to distinguish between someone who is motivated and prepared to learn on his or her own about technological matters and someone who is not. Our primary goal should be to increase substantially the number of individuals, particularly young people, who are motivated, inspired, and prepared to learn on their own on a continuing basis about technological matters.

b. The ways many science, mathematics and engineering courses are taught would not be particularly stimulating to students who are not majoring in science, mathematics or engineering.

c. More students will be interested in finding out about real world problems and opportunities than about the details of the underlying science, mathematics or engineering. For example, liberal arts students may be motivated to learn about solid waste disposal, acid rain, global warming, international competitiveness, applications of advanced materials, alternative fuels, applications of artificial intelligence, transportation problems, applications of autonomous robots and dozens of other technological challenges and opportunities. On the other hand, fewer students would be immediately desirous of learning about free body diagrams, material balances, energy balances, fluid mechanics, thermodynamics (at least the way it is usually taught for engineering students), and many of the other engineering science subjects required of engineering majors.

d. Once motivated by an interest in a problem (such as, for example, acid rain), the student should be provided information on basic principles that pertain to the problem, realizing that the objective is to increase awareness of the important basic principles and knowledge about where and how to find out more if the student is so inclined.

e. This a different perspective than most engineering faculty have employed in teaching engineering majors, although it might be a good perspective for doing that too. Some faculty would be very good at this; some probably would not.

f. The United States should have a citizenry with a high degree of technological understanding and capability. This ideal is achievable if we make a high priority commitment to assure that it becomes reality.

g. Like many ideals yet to be accomplished, widespread, adequate technological literacy in our nation will not be realized unless sufficient commitments are made and kept. We need to define what we mean by the terms "adequate technological literacy" and "sufficient commitments" in this context. And we should specify who needs to make those commitments.

h. We need a widely shared vision, and we need to make a commitment to that vision. Absent such a unifying vision, we may never accomplish satisfactory technological literacy in our nation, at least not in the next dozen generations.

i. We also must be realistic about the impediments, barriers and hindrances to the achievement of the shared vision--not to be preoccupied with those impediments--but to be aware of what stands in the way of accomplishing our ideals.

j. Engineering and science faculty should be involved in designing undergraduate courses which prepare and stimulate students to continue to learn about technological matters.

k. Our schools of engineering, the National Science Foundation, the American Society for Engineering Education and the Accreditation Board for Engineering and Technology should work together with other interested parties, including state and federal government, to make significant contributions toward improving the technological literacy of our citizens.

l. We need a national strategy for accomplishing widespread technological literacy, and we must have coordinated local, state, and regional activities to make it happen.

At a fairly practical level, I believe that we should focus on the primary goal of increasing substantially the number of individuals, particularly young people, who are motivated and prepared to learn on their own on a continuing basis about technological matters.

The relevance of the subject matter will provide significant stimulation, and, therefore, we must stress relevance. And there are two other factors that I view as equally important: the approach that is taken (i.e. good pedagogy) and the teaching skills of the faculty. These three factors--relevance, pedagogy, and teaching skills--are so obvious that they may be taken for granted. I believe strongly that they must not be assumed; they must be assured. These three legs are important if the table we are talking about building is to stand the real test. That test is simply whether individuals will be stimulated and motivated to want to continue to learn about science and engineering. In summary, assurance of widespread technological literacy depends on assurance of perceived relevance, interesting methods of learning, and the skills and enthusiasm of those who provide the subject matter.

Working together, we can overcome impediments and accelerate achievement of our shared goal to have a citizenry with a continually improving technological understanding. Our nation will benefit greatly from accomplishment of this goal.

As suggested by several of my fellow deans, ASEE, ABET, and our engineering and engineering technology schools cannot "go it alone." We need to work with others who should be interested and whose influence and power are necessary to shifting the technological literacy paradigm. Perhaps a first step is to assess and then strengthen the interest of these other essential parties. And I expect that we need to be prepared for a long-term, ongoing campaign to induce appropriate change in the thinking and priorities of those who influence and decide the content of educational programs for non-engineers and non-scientists.

Having said all of that, I must hasten to add before closing, that ASEE has taken a very hard look at its priorities during the past twelve months and determined that there are five top priority strategic categories on which it should focus:

Vitality of engineering education through restructuring the future

Improving engineering education through innovations and total quality leadership

Globalization and internationalization of engineering education

Outreach to youth to encourage pursuit of engineering education

Research dimensions of ASEE to reflect the realities of modern engineering education and educators

As we restructure and innovate and improve our outreach to youth we should (and I want to say must) focus on that part of the ASEE mission statement which I quoted at the outset of my presentation, namely, that "ASEE should foster the technological education of society." Given that the great majority of the engineering schools in our country are members of ASEE, I believe that there is a solid basis for being optimistic about prospects for the involvement of engineering colleges and engineering faculty in achieving this element of ASEE's stated mission. The guidance and impetus provided by this workshop could be instrumental in making this happen.

ENGINEERING AND THE LIBERAL ARTS

David P. Billington
Princeton University

This lecture seeks to present some general ideas, several definitions that help clarify the ideas, and a brief outline of two courses which illustrate how general ideas can be a framework for the teaching of engineering to liberal arts students.

General Ideas

First, the term "Technological Literacy" is so vague that any discussion of it needs a narrow focus to achieve any lasting results. Such a focus provides a discipline within which the teacher can present a broad integration of academic material. Second, the best teaching has always been done by individual teachers. While I know of some successful experiments in team teaching, they rarely survive economic pressures. Although not requiring team teaching, integrated instruction does require close collegial cooperation in which we instruct each other, read critically the lecture notes of each other, and even at times carry out joint scholarship. Third, teaching technological literacy requires the use of historical case studies based upon scholarship but written expressly for student use. Finally, until there is a strong tradition of widely used studies, the writing of new historical case studies needs to be done in collaboration with a network of teachers from a variety of schools in higher education. In this way, as the Sloan Program of the New Liberal Arts illustrates, the teaching materials will be disseminated quickly to other schools. But before any such teaching can have a national impact there needs to be a commonly understood definition of Technological Literacy.

Definitions

It is a widely accepted fact that the industrial revolution has radically transformed the rural, agrarian world of the early 18th century into an urban industrial one of the late 20th century. The prime mover in that transformation has been modern engineering, and it is that modern development which raised the issue of technological literacy. Therefore, the word technology in our present context is the same as modern engineering, but what is that? Here, as engineers we have an obligation to our society to present a simple credible and convincing definition. We have no business talking about technological literacy if we cannot define it in a way that the general public will see to be attractive, essential, and reasonable. This comes down to defining modern engineering, the product of 200 years of urbanization combined with industrialization--the unique outcome of the industrial revolution.

Two key events established that revolution (literally turning points): industrialized iron and the industrial steam engine. Symbolized by the 1779 Iron Bridge and the 1787 Rotary Steam Engine, these events began a transformation that led to the great structures of iron and the vehicles of steam that opened up the United States continent and laid the basis for a second pair of transforming events roughly one hundred years later: the production of electric power and the gasoline powered vehicles on roadways and in airways. In turn, these events led to a third pair of engineering turning points that we can identify in the late 20th century: the present dominance of information through high technology and the persistent deterioration of the infrastructure for low technology. Out of these central transformations come four defining ideas for engineering: structure, machine, network, and process. Each idea requires a treatise in itself, but in summary one can observe that each stands for one of the four main branches of modern engineering: civil, mechanical and aeronautical, electrical, and chemical. A close study of any one of these four will reveal in each one elements of all four ideas, but as defining symbols each catches one major aspect of modern engineering, and together they leave out very little. Examples of each would be the bridge, the car, the power grid, and the refinery; the first two ideas are embodied in separate objects, while the second two are systems. The structure is static, while the machine is dynamic; the network transmits, while the process transmutes.

Taking these ideas for a definition of technology as modern engineering, we next turn to the word "literacy" and ask what do we expect students to learn in order to be "literate" in modern engineering. It is best, of course, to ask what we mean ordinarily by literacy and the answer is simply: facility with words (vocabulary), word construction (rules of grammar), and writing (arguments, essay, reports, poems, and novels). There are, therefore, individual facts (defined words), connected facts (sentences and paragraphs), and finally meanings (stories). A literate person, we normally say, must have some minimum competence in reading and in writing, that is to say in the passive and the active sides of literacy.

Carrying over this argument into modern engineering requires us to identify or define the necessary facts, the rules for connecting those facts, and finally the meanings of sets of connected facts. Since we will use literacy metaphorically not literally, there is a freedom in how to translate these ideas into engineering. I shall take what seems to fit well with the four main ideas of engineering. The facts of engineering are expressed symbolically in formulas by which we predict performance; the rules by which we connect those facts come from the social context: politics, government regulation, economics and what is required to bring engineering works into being and to maintain them. Finally the meanings of engineering lie in how individual people respond to its works as characteristic of culture through aesthetics, ethics, and symbolism.

Each of these three components of literacy stand for one of the three liberal arts. The facts stand for natural science, the rules stand for patterns of group behavior typical of social science, and the meanings interpreted by artists, philosophers, historians, and critics represent the humanities. Therefore, in seeking technological literacy, we are really trying to show that modern engineering, being embedded in the liberal arts, is a defining feature of modern life and that liberal arts students can make sense out of it by seeing its place in their own fields of study. But what specifically should be taught in the name of technological literacy?

Content and Technological Literacy

The formulas which embody the facts of modern engineering are simple, involve no college-level mathematics, and contain ideas that cannot be easily expressed any other way. We begin with the steamboat, America's first major contribution to modern engineering. Its motion came from a reciprocating steam engine whose power we define as

$$H_p = \frac{PLAN}{33{,}000}$$

where
- P = steam pressure in pounds per square inch
- L = stroke (length of movement of the piston in the cylinder) in feet
- A = area of the piston head in square inches
- N = number of power strokes per minute

and the number 33,000 represents James Watt's estimate of the ability of one horse, one horsepower (H_p) being equivalent to 33,000 foot-pounds of work per minute. To get greater speed for the boat, the engineer must either increase the steam pressure (P), the cylinder size (L x A), or the engine speed (N). But each increase has its price. Greater steam pressure requires a larger boiler, greater cylinder size means a heavier engine to be carried by the boat, and greater speed means quicker wearing out of the moving parts and more vibration of the boat's structure.

Each of these terms can in turn be explored in more detail. For example, horsepower can also be expressed as

$$H_p = \frac{TV}{375}$$

where T = thrust of the paddle wheels against the water in pounds
V = velocity of the boat in miles per hour

and the number 375 simply converts miles-pounds per hour into horsepower units. The power of the engine must be transmitted to the paddle wheels and thrust must overcome the drag, or the resistance to motion caused by the water. This study will lead us quickly into fluid mechanics as well as into ideas related to power transmission.

One further study, of central significance to steamboat history and to present-day problem is boiler safety, expressed by the ring stress equation

$$f = \frac{Pr}{t}$$

where f = the stress in pounds per square inch in the boiler wall that can lead to straight longitudinal cracks in the cylinder.
P = steam pressure in pounds per square inch
r = radius of the boiler cylinder in inches
t = thickness of the boiler shell wall in inches

It is easy to realize that greater velocity (V) requires greater power (H_p) which can be achieved by higher steam pressure (P). It also requires more steam (used up more rapidly as N increases, thus a greater boiler volume (usually high r). On the other hand the cost of the expensive boiler can be decreased by using less material (smaller t). Each of these desirable changes (higher P, greater r, smaller t) increase both the useful power and the danger of boiler overstress contributing to boiler explosions.

Such analyses lead directly to the social issues surrounding modern engineering: public safety, private enterprise in competition, economy of operation and in the cost of fabrication, and public acceptance of new facilities. The goal of these scientific studies is to carry over into the social context some reasonably precise ideas about the potentials and the physical limitations of modern engineering so that the potential and economic debates can be better informed. Historically these equations explain the origin of government regulations for private enterprise, and for the late 20th century they provide a starting point for any intelligent discussion of modern vehicles and future possibilities. Power generation and transmission, thrust and drag, drag and velocity, pressure and stress, economy, and safety are all issues central to the present and future decisions about modern engineering.

It is of course possible to discuss such things without formulas and numbers, but that is not technological literacy. We must not claim that all discussion needs to begin in formulas. Rather the new dimension to be added to the old discussion is the quantitative one, and that is central to the literacy of modern engineering.

BROAD ISSUES IN SCIENCE, TECHNOLOGY & SOCIETY

George Bugliarello
Polytechnic University

Science and Technology and Related Literacies

Each one of us may have a different view of why we do science or why we do technology, indeed a different view as to what is science and what is technology. Let me simply suggest that science is about knowing nature--including ourselves--whereas technology in its broadest sense is about modifying nature. As such it includes not only engineering, but also art, medicine, surgery and, what is perhaps the most complex of all modifications of nature, education.

The most powerful intellectual instrument of science is verification--the insistence on verifiable truths. Hence the great importance of science literacy. It provides us as citizens with a concept and at least some rudimentary tools that can help us separate the wheat from the chaff in the myriad of issues to which we are exposed each day and about which we need to develop an opinion and make a decision. If nothing else, scientific literacy enables us to ask: how do I know that what I hear is true?

What we have come to call technology literacy is actually, to a considerable extent, engineering literacy, and what differentiates engineering from other activities that modify nature is a specific set of methodologies. The importance of technology literacy stems from the fact that modifications of nature by technology are acts of immense daring by our species and thus require intelligent directions and controls, lest they become acts of hubris and destroy the very nature they are intended to utilize, safeguard, improve or correct. They also require that an understanding of the key tenets of technology become an essential part of the intellectual core of the University.

Let me not belabor these fundamental points, other than stressing that the understanding of why we do science or technology is fundamental to education and educational reform. Rather, in the short confines of this paper, let me address derivative issues.

Science and Technology in Society

A number of issues stem from the fundamental importance of science and technology in our lives and underscore it. Some of these issues are universal, the same the world over, while other issues, like the maintenance of our competitive industrial position or the need to improve science education, are more specific to our country. I will be able to touch only upon a few; thus, I shall not be able to discuss, in spite of their importance, issues like the environment, natural resources, population growth, or privacy.

It is obvious that, in the past few decades in particular, science and technology--from medicine to energy to telecommunications--have had great impact on our lives. Perhaps less recognized is that some of the major problems or issues of today's society occur at the interface of science and technology with the rest of society. They are, generally, challenges to traditional values (as in the birth control controversy), problems of society's inability to take advantage of science and technology, and problems of our misuse of science and technology.

I shall not dwell on the challenges to traditional values, because these are constantly and widely discussed, throughout our society, in schools, in colleges, in business, in the media, and in families. Rather, let me talk about the other two sets of problems: in the first place, the fact that, in spite of our technological prowess in building, in generating power, in transmitting and manipulating information, and so on, we are still facing, the world over, immense problems of poverty, health care, education, and of real as well as functional and scientific or technological illiteracy. And, secondly, the fact that we are also facing a series of problems such as environmental degradation or congestion that stem directly from our technical and economic success.

Health Care, Education, Poverty, and Employment

Take health care, for instance. The problem is both cost and access. Technology has a big part in both. In terms of cost, in the U.S. health care uses more that 12% of our GNP--a figure projected to exceed 16% by 1996. Although this outrageously large slice of our GNP is due to several causes, a considerable part is associated with technology--a technology focused on the high cost or repair end of health care, rather than on prevention and maintenance (Bugliarello, 1984). As to access, some forty million Americans are today without direct access to health care, because of cost.

Technology, in effect, has provided technological fixes for a system for the delivery of health care that needs, instead, to be fundamentally restructured. Engineers, it seems, are usually much more comfortable working within a social system and accepting the status quo, rather than challenging it and proposing change.

The same situation prevails in education, where, in spite of all our technology, our system of education is performing miserably. Again, technology, rather than challenging the system, has operated within its confines in piecemeal fashion, without pressing for reform--for an intelligent integration of teaching and technological capabilities.

Poverty is another example of society's inability to take advantage of technology. We certainly have the technical means to produce enough food and shelter and education for all the poor in our country, but there is a major imbalance between our productive capacity and our ability to use that capacity. The problem of poverty, of course, is not only American. It is a massive global problem. Unless it is solved, the whole globe is at risk, with the potential for major disasters and destructive social instabilities.

There are no easy solutions to the problem of poverty, which is perhaps the most complex and baffling of all social problems, as the world has learned from the massive failure of seventy years of the communist experiment. But any solution has as a necessary condition the wide understanding of the productive potential of science and technology.

Poverty is tied to health and to education--and hence again to technology. It is also tied to hunger and nutrition. One of today's great tragedies is that in some parts of the world over half of the harvest rots for lack of storage or timely distribution that is an inefficient interface between social systems and technology.

The problem of poverty is also tied to employment. We have seen, in the U.S., the loss of a great deal of our manufacturing capacity, particularly in sectors that offered employment to the less educated, who have now sunk below the poverty line. The competitive success of the Japanese industry has truly become a matter of life and death for our economy. A key element of that success has been, as we well know, quality. The problem we face is that we tend to look at quality only as a technique--as an issue exclusively for our engineering schools and our industry--rather than something that needs to become widely embedded in our culture. This is what makes the Japanese challenge so serious for us, and this is where the challenge of technological literacy goes far beyond the providing of knowledge about technology or science; technological literacy is also about the development of habits of precision, and reliability among all the citizens.

Generating or retaining industrial jobs requires a careful industrial policy--another complex issue that a technologically illiterate citizenry is ill-equipped to address.

The Cities

Many of the major social problems in our country and abroad--poverty, disease, unemployment, and crime come together in the cities. And so do many of our opportunities. The question of cities is another of the complex and crucial issues in which science and technology have a major role to play.

I recently had the privilege of chairing the New York City Mayor's Commission on Science and Technology. The Commission undertook a systematic study of the role of science and technology in the future of the city. The conclusions were basically two:

> In the first place, an intelligent use of science and technology has much to offer to virtually every aspect of the city's operation--traffic, housing, waste disposal, competitiveness, and employment, etc. The city is a complex socio-technological system, but few in the management of a city have a sense of system and a sense--a clear and guiding sense--of complexity.
>
> The second basic conclusion is that the cities represent a huge market, hungry for new technologies. Think, for example, of the need to provide the handicapped with means to climb steps, or of the possibility of having far more informative "active" street signs, or of the electronic augmentation of highway capacity as an alternative to more cement. Or, think of new urban vehicles. It is important that in the U.S. we do not lose the opportunity this immense new market offers and do not repeat what lost us consumer electronics, or a substantial portion of our automotive industry.

Globalization

Globalization affects virtually every aspect of our society and has been made possible by science and technology--by transportation and telecommunications in the first place. It is a compelling demonstration of the power of science and technology advances to leap-frog obsolete political and social ways of thinking and of functioning--to leap-frog political boundaries, academic philosophies, or industrial organizations and to force change.

Paradoxically, the slowest institutions to truly espouse globalization have been the very citadels of science and technology--the universities that still continue to operate as islands wedded to one place. Teaching at a distance is just beginning to emerge, and it is still far from representing a truly globally integrated operation, with worldwide teams of teachers, worldwide assemblies of students, worldwide access to laboratories for experiments at a distance, and worldwide real time interactions among researchers. This is far beyond McCluhan's global village--truly the era of what I call hyperintelligence.

Infrastructure, the Environment, International Security

Infrastructure, the environment, and international security are three further aspects of a globalizing world which depends on science and technology and draws some of its greatest dangers from science and technology.

A weak, inadequate infrastructure not only makes life miserable, but it also has a major impact on employment and economic development, as business now can locate wherever it finds the most favorable and pleasant environment. Our limited and ill-guided national investment in infrastructure--both the physical infrastructure and the infrastructure of services such as schools or advanced university laboratories--puts us at a disadvantage in the international competition for jobs.

The environment is becoming a major preoccupation and point of contention between developed and less developed countries. What should be the levels of environmental protection investments? What are the responsibilities of different countries? (We should not forget, for instance, that this country is by far the major single consumer of the environment in the world.) What should be the timing of environmental protection actions (e.g. by when should we stop all noxious car emissions)? These are all major social and technological problems. They place unprecedented demands on the judgement of all citizens and on a science and technology community that is far more comfortable and knowledgeable with regard to scientific research than to policy formulation--particularly policy formulation with the potential for immense costs or social dislocations.

Lastly, international security, always a major science and technology arena, has become far more complex than during the cold war as a result of the development of cheap weapons of mass destruction--whether nuclear, chemical or biological--that are relatively accessible to smaller countries. Again, this presents major science and technology challenges not only in counteracting those weapons, but also--and far more essential in the long range--in finding ways through science and technology to enhance economic and social development and hence stability in regions such as the Middle East or Central America.

Biotechnology

This brief and spotty overview of the new challenges to science and technology with relation to society cannot overlook biotechnology, because of its fundamental revolutionary potential to change our own biology and to drastically transform the way we go about producing things--whether drugs, plants, or new highway pavements. But each of these revolutionary potentials must deal with the fact that technical and scientific prowess has far overrun society's ability to transform itself by accepting new ideas and new paradigms.

Some Generalizations

In terms of the kind of broad social problems that I have so briefly touched upon, the specific questions for the community of those concerned with science and technology, whether they come from the science and engineering or from the humanities side, are basically two: What do these problems have in common? How can the science and technology community best contribute to their solution?

Let me start with the question of commonalities. These are typically issues or problems in which science and technology are not sufficient for the solution, but are involved together with many other factors such as economics or politics that often have a dominant role. For instance, in education, in the U.S. it is essential to consider the role of school boards, PTA's, and state and federal governments. Similarly, in the case of the infrastructure, questions of sociology, politics, financing, jurisdiction, urban planning, or population policies flank and actually overshadow the purely technical issues--even though the infrastructure is a technical set of structures and devices.

As a correlate of the previous point, these are all problems that require a systemic view which is hard to come by. Consider, for instance, the reconstruction of a major airport like J.F. Kennedy. While billions of dollars are being spent on greatly increasing its capacity, little attention is being paid to the highways that connect it to the city, let alone to the building of rail links. Or, consider the manned space station program. It needed two components to achieve its objectives--a vehicle for reaching orbit and an orbiting station. The cost for both components first proposed to President Nixon was so great that it was decided to build first the vehicle--the very costly shuttle. But we are now facing a lopsided situation with an old shuttle and grave doubts that a manned space station will be built--hardly an ideal system!

A systemic view is even more important in dealing with the far more complex problems of the cities, or of poverty, education or health care. These are all problems for which technology fixes can go only so far and actually at a certain point become counterproductive and exacerbate the problem. For instance, as we have discussed in the case of health care, technology has helped drive costs sky high, supporting a system that is wasteful, uncoordinated and inefficient.

Finally, many problems, such as the cities, education, or health care, offer major opportunities for new technologies and new industries, if we know how to identify these opportunities and develop systems for commercializing them.

These are all problems for which a new vision cannot be developed without a technologically educated public, not in the sense of understanding in detail the nuts and bolts of technology, but the choices and possibilities that technology offers and the implications of scientific discoveries for our lives. We need a public capable of making decisions about those choices and of supporting those decisions through political action.

Let us now consider the second general question: what do we need to do? How can our society better use science and technology in the solutions of its major problems?

I would like to suggest, first of all, that the science and technology community must develop its own sense that it is legitimate and, indeed, that its duty is to take a leading role in addressing societal issues. It must not be satisfied only with developing new scientific knowledge and technical systems. It must also become active in seeing to it that they are applied with intelligence and wisdom.

Secondly, the science and technology community must better prepare itself through education. This will require the rethinking of curricula. We need to create more courses on socio-technology, so as to better understand the social environment in which science and technology operate. We also need to develop more courses on the philosophy of technology, to parallel those on the philosophy of science, so as to acquire a clearer view of why we do technology and of the role of science and technology as instruments for the extension of our human abilities.

Thirdly, engineers and scientists must learn to become far more involved than they are today in the political process, so as to have a say in policies about the use of science and technology to address broad social issues. We always remark about the very few scientists and engineers in the U.S. Congress, but thus far the science and technology community has done nothing to redress the balance--as it must be if we are going to have an industrial policy, or a policy for the cities, or for the other great social problems.

Scientists and engineers also need to become more involved in management--but not of the MBA kind, where the connection with technology is generally ignored. They need to become involved in the management of technology, in the study and practice of how to better manage and direct technological enterprises and technological processes, from energy to information, but also from hospitals to schools.

Lastly, and most directly tied to the theme of this conference, the science and technology community must become deeply involved in the development of technological and scientific literacy. It is not enough to preach the need for it. We need to make a coordinated effort (because there are today too many subcritical and overlapping initiatives) to reach and educate the entire population.

There is, indeed, a better way to address many urgent and difficult problems of our society. But that way requires a scientifically and technologically literate citizenry and a science and technology community willing and able to lead, not only by knowledge, but also by action.

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DISCUSSION ON SPECIFIC ISSUES

SUMMARY OF BREAKOUT SESSIONS

This section presents a summary of each of the eight breakout sessions held during the Technological Literacy Workshop. The first four sessions were devoted to specific issues in current technological literacy education. Joseph Johnston chaired the session on generation of issues to be addressed in each of the four categories under the headings curriculum development, courseware available, attraction of students, and faculty issues/logistics. The second set of four sessions were focused on specific elements of an agenda on what needs to be done in the future for technological literacy. David Reyes-Guerra chaired the session to identify issues to be addressed. These were grouped under courseware needed, consortium approach, funding directions, and stimulation of programs.

Curriculum Development

Curriculum development has been a central focus of the technological literacy movement. However, after two decades of serious efforts, several issues pertaining to curriculum development are still unresolved. Some of the major issues discussed at the Workshop were:

- What is technological literacy?

- What are appropriate objectives for technological literacy programs? What measures should be used to evaluate them against such objectives?

- What are the essential curriculum elements of an appropriate technological literacy program on a given campus? What instructional formats are most effective?

The curriculum development group discussed the issue of technological literacy as a design problem. As with many design problems, it is easier to recognize failures than success. Technological illiteracy is more easily described than technological literacy. The group also agreed that a technological literacy curriculum requirement for liberal arts students should, at a minimum, serve a parallel function to the ABET requirement of humanities and social sciences for engineering students. One of the objectives of any technological literacy curriculum would thus be to increase knowledge and understanding of engineering among non-engineering students. As far as the difference between technological literacy and engineering literacy is concerned, there was animated discussion with some people arguing the importance of understanding technology in a broader sense, one that includes but is not limited to engineering, while others argued the importance of not diluting the thrust of technological literacy by including too much. In the discussion group itself there was an implicit assumption that technological literacy was equivalent to engineering literacy or literacy about engineering. There was also a general consensus that the communication of process was more important in any technological literacy curriculum than any particular content.

Courseware Available

Availability of courseware is one of the key factors for the success of any technological literacy program. This is evident from the Sloan Foundation's materials development which was based on the belief that success of the New Liberal Arts Program depends on the availability of written materials to serve as curriculum materials for new courses. Major questions discussed in this session were:

- What materials are available to provide background to faculty members starting to work in this area?

- What materials are currently available for use in courses and laboratories in this area?

- What institutions now have courses and/or programs that might be considered models?

The discussion group identified design process, critical thinking, and problem solving as the three major aspects of technological literacy course content but believed that these are not helpful in defining it. The discussion on forms of teaching materials focused on historical case studies (like NLA Program monographs), and business school decision making units and concluded that such case studies should include numerical calculations, social contexts, and aesthetic, ethical, or symbolic meanings. The engineering-oriented teaching materials so far published in the New Liberal Arts Program are an essential starting point for the planning of any new courses in technological literacy.

Attraction of Students

Several studies now indicate that the student enrollments in technological literacy courses are relatively small when compared to total number of students. Furthermore, students of different academic backgrounds select technological literacy courses at random, leading to several implications. Within this context, the discussion group focused on the following questions and issues:

- How can students be attracted to such programs? What target populations should be pursued?

- How to reach out to selected groups of students (e.g. those preparing to be pre-college teachers).

- What preparation should students have? How can we ensure that they have it?

The group began by focusing its discussion on the differences between engineering and Science-Technology-Society (STS) courses. The group believed that at present there are courses on how technical things work, but no course specifically identified as technological literacy. This makes it difficult for students to identify and select technological literacy courses. Furthermore, STS courses offered at various colleges are tailored to the local environment, hence liberal arts students generally have difficulty accessing them. Engineering students enroll in humanities and social science courses because they find some relief in them. The reverse is not as true for liberal arts students. The group also agreed that more courses at the 100 level are needed since more students enroll in them. To attract the students, the group believed that course content should be aimed at specific target populations and needs to be linked with social environment.

<u>Faculty Issues/Logistics</u>

Currently there is little recognition for faculty development of technological literacy programs by universities and colleges. Faculty have problems sharing their time between literacy curricula and departmental obligations. Furthermore, faculty members are under pressure from their departments to maintain research and publications. In most of the colleges, technological literacy courses have been added to a list of elective course offerings, rather than integrated into degree programs. This session focused on the following issues:

- How to stimulate collaboration between liberal arts and engineering units on a given campus re technological literacy offerings.

- How to stimulate/reward faculty participation in the technological literacy area. How to prepare faculty members or teams to work effectively in this area.

- How are logistics best handled: organizational structure, faculty appointments, funding...?

- How to assure availability of appropriate books, case studies and other courseware.

- How can necessary funding be obtained for such technological literacy programs?

The discussion group felt that for colleges with an engineering unit, it is necessary that the engineering faculty be involved with the development and teaching of technological literacy courses to have a successful program. The projected decline in engineering enrollment through the mid 1990's was considered as a favorable environment for offering technological literacy courses to satisfy faculty teaching loads.

In most colleges and universities, the faculty reward system is based upon research publications and funding and teaching courses for majors. It was pointed out that this is especially true in a small liberal arts college where the number of faculty in an engineering and/or science department is small. Many of the participants recommended not getting young faculty involved in the technological literacy movement as it was a perfect way to torpedo a young faculty member's career and to make tenure unlikely. Experienced senior faculty members with established research careers are good candidates for offering technological literacy courses, perhaps especially if they are interested in a career change. Selected retired industrial engineers could also become involved. These individuals would bring a wealth of experience and knowledge into the classroom.

There were limited discussions on the availability of funding for technological literacy programs and on the available curriculum material. It was pointed out that the National Science Foundation (NSF) funded the Workshop and had several representatives in attendance. NSF funding is available for curriculum development and laboratory equipment for technological literacy courses. During the past decade there has been a wealth of curriculum material for technological literacy courses. The Sloan Foundation's New Liberal Arts Program has developed a monograph series and book series which can be used as text material for technological literacy courses. Reports from the Office of Technology Assessment and the National Academy of Engineering have been used as text material in many courses.

<u>Courseware Needed</u>

In most of the programs, courses are based on an individual instructor's area of science/technological interest. This leads to narrowly focused courses with wide gaps in the range of issues discussed or materials produced. Within this context the group focused on:

- Gaps in presently available materials, which should be filled.

- New types of coverage needed, or new combinations/formulations.

- Multiple formats (books, monographs, expanded syllabi, slide sets, video tapes, computer software,...).

- Information clearinghouse needed.

The group felt that well done, book-length case studies would provide all the complexity of: technical needs; social, economic, and political constraints; and cultural reception. The ideal teaching arrangement, in a technological literacy course or program using complete case studies, would be interdisciplinary. An engineering faculty member would be the best sort of person to convey to typically naive students the technical demands of an engineering or other technological project. For the rest, to present issues of cultural, social, and political complexity, not just any humanist or social scientist or manager will work out well. It probably should be someone accustomed to team-teaching and preferably accustomed to teaching in a team that involves scientists, engineers, or other technically-trained people. One member felt that both positive and negative case studies are needed, and liberal arts students can learn a great deal about the complexities of engineering and technological development from either sort.

Also the group recognized the importance of films, videos, remote-site TV presentations, and computer software. In a sense, a well done film, television series, or video on technology is a case study. A more important caveat has to do with the quality of the production of visual presentations of engineering and technology ventures. It is extremely important that the production be in the hands of competent professionals. But it is also extremely important that the producers, actors, etc., really know engineering and technological work.

Another new approach that has been considered is the transmission of a successful classroom experience from one location to another where technological literacy education is not otherwise feasible. It has been suggested, for example, that one of David Billington's presentations might be made available on tape or by interactive TV to classes at schools across the country.

<u>Consortium Approach</u>

The breakout group assigned to discuss possible mechanisms for enhancing technological literacy, including the idea of consortia focused on the following issues:

- How can institutions with current efforts in technological literacy work more effectively together--in support of current efforts, and in stimulation of new ones?

- What organizations and structures are currently available for collaborative work between institutions in technological literacy? How effective are they at present? What can we learn from their efforts?

- Are new structures or mechanisms needed? If so, what characteristics should they have?

The group began by agreeing that it was important "not to reinvent the wheel." The group also agreed, however, that the wheel needed to be "trued up" somewhat and the current impact of technological literacy multiplied. As the discussion developed, individual suggestions and ideas fell into three main areas--the identification of organizations currently active in technological literacy, suggestions for groups that should be encouraged to become involved in promoting technological literacy, and proposals for actual mechanisms and activities for encouraging technological literacy.

After singling out those organizations already involved at one level or another, the group focused its attention on identifying target groups which might be encouraged to become active or perhaps more extensively involved in the technological literacy area. Among those organizations that might assist in promoting technological literacy are the National Association of State Universities and Land Grant Colleges (NASULGC), the American Council for Academic Deans (ACAD), the Council of Colleges of Arts and Sciences (CCAS), the National Conference of Academic Deans (NCAD), state government education departments, and the National Governors Association (NGA). The Public Broadcasting System (PBS) was also identified as a potentially important vehicle for spreading technological literacy awareness through programming focused on engineering and technology. The discussion on suggestions for mechanisms both for promoting technological literacy and for actually incorporating it into the curriculum focused on common core curriculum requirements, top down CEO approach, state and regional consortia, press coverage and public outreach. Following the identification of the above wide-ranging ideas, the group concluded its discussion by suggesting three short-term action items:

1. 1993 should be declared the year of technological literacy and that technological literacy should be a major theme for all professional society annual meetings.

2. ABET, NSPE and other appropriate engineering societies should promote technological literacy as a worthwhile activity by 1) encouraging engineering deans to have faculty develop and offer appropriate technological

literacy courses and 2) working to make technological literacy a general education requirement for all undergraduate programs.

3. A short 1-2 page executive summary of the conference should be sent with an appropriate cover letter to the heads of all appropriate engineering and academic societies and organizations. In addition, the report should be circulated to all appropriate university administrators, including presidents and provosts and both engineering and liberal arts deans.

Funding Directions

Many programs depend upon external funding, and if funds are withdrawn, these programs most likely will be canceled. One recent study indicates that the major universities do not have relatively large budgets for technological literacy related programs, and if external funding is withdrawn these programs suffer significantly. The breakout session on funding directions focused on the following:

- What funding programs have been at work on technological literacy, and what have been their strengths and weaknesses?
- What funding mechanisms are currently available for support of technological literacy?
- Are new funding efforts needed? If so, what characteristics should they have?

With respect to funding sources, the group identified four main categories: 1) government, 2) private foundations, 3) industry, and 4) colleges and universities.

The leading player under the government funding sources is the National Science Foundation. Within the NSF Directorate of Education and Human Resources, Division of Undergraduate Science, Engineering and Mathematics Education (USEME), there are two programs particularly relevant. Undergraduate Curriculum and Course Development; and Undergraduate Faculty Enhancement. The former supports improvements in introductory courses and includes a concern for scientific and technological literacy of the nonspecialist student and the general public. The latter emphasizes short courses, workshops, and other hands-on experiences for participants.

After identifying the role of the Sloan Foundation, the group also discussed small local private foundations, and technology-based companies and their associated foundations. The group felt that the leadership of engineering colleges is crucial in any project emerging from the workshop.

<u>Stimulation of Programs</u>

The group focused on the following issues:

- Are additional programs in technological literacy needed?

- If so, what national level stimulation would assist in their initiation and growth?

- How can the technical and liberal arts faculty on a given campus be encouraged to work together to generate such programs?

After agreeing that additional programs are needed, the group focused its attention on ways to stimulate the initiation and growth of additional programs. The various issues discussed include holding annual conferences, publishing articles in journals/magazines such as the <u>Chronicle</u> and <u>Liberal Learning</u>, approaching funding agencies, arranging meetings with engineering deans and the Council of Colleges of Arts and Sciences to discuss issues of technological literacy, and creating an exciting video series on technological literacy, the history of technology, and engineering, to be shown on PBS.

The group also discussed the possibility of arts and science faculty fellowships in engineering colleges, retraining liberal arts faculty to teach technological literacy courses based on their areas of specialization and initiating a program of faculty development to persuade engineers to become involved in technological literacy courses.

CLOSING REMARKS

MAJOR FINDINGS

The Technological Literacy Workshop successfully identified the major issues in technological literacy for non-engineers, and clearly established the critical dimensions of those issues. In addition, a thorough review of current programs was particularly helpful in identifying the progress made so far in technological literacy education and in setting promising directions for the future. Some of the findings discussed below are clearly basic ones surrounding the initiation of any new field of study, but others are more specific to the field of technological literacy education.

As a result of the Workshop and the studies done in preparation for it, it is clear that sufficient ground work on which to build effectively has already been done by some individuals and institutions. At the individual level, distinguished contributions have been made by Professor John Truxal of SUNY Stony Brook and Professor Rustum Roy of Pennsylvania State University. At the institutional level, efforts of the Sloan Foundation and the NLA Center at SUNY Stony Brook are most commendable. In addition, valuable efforts have been made by several individuals with wide ranging backgrounds at various institutions in the country.

In spite of these previous and current efforts, however, an examination of key issues clearly indicates that much more needs to be done. One major finding of this Workshop is that more effort is needed in several critical areas of technological literacy education.

Currently there are only a few institutions offering courses that can be identified as clearly dedicated to technological literacy for non-engineers. Even though technological literacy is considered as part of the "Science, Technology and Society" (STS) field by some individuals, it is becoming increasingly difficult to identify the technological literacy component in many STS programs. Hence, there is a need for more programs and courses with sharp focus in the technological literacy field.

The Workshop discussions clearly indicate that enough materials are available for the program administrators and faculty members to initiate or start new programs and courses in technological literacy. However, current efforts in courseware development are fragmented and incomplete, and, hence, there are gaps in the areas of technology covered in the curriculum materials developed so far. For example, as pointed out by Professor Truxal, areas such as energy, environment, and transportation are not yet major themes of courseware development. For balanced technological literacy education, curriculum materials encompassing all major areas of technology need to be developed.

Currently, there are only few engineering faculty members involved in technological literacy education. This is evident from our survey of the faculty involvement at various institutions and the curriculum materials developed so far. It is one of the major issues that received serious attention from the Workshop participants. They clearly established the need for engineering school leadership in initiating and supporting technological literacy programs, in addition to courseware development.

RECOMMENDATIONS FROM THE BREAKOUT SESSIONS

Specific recommendations were made by each of the breakout session groups, relevant to their assigned discussion topics. Common elements from these sets of recommendations have been included in the previous Major Findings section. Full reports from the breakout sessions are contained in the Appendix.

Curriculum Development

- A technological literacy curriculum requirement for liberal arts students should, at a minimum, serve a parallel function to the ABET requirement of Humanities and Social Sciences for engineering students.
- In any technological literacy curriculum, communication of process should be given more importance than any particular content.
- More 100 level courses are needed on technological literacy.

Courseware Available

- Course content for technological literacy should include exposure that will help develop student pleasure in engineering along with some ability to solve simplified engineering problems and to think critically about engineering objects and systems.
- Case studies should include numerical calculations, social contexts and aesthetic, ethical, or symbolic meanings.
- The engineering-oriented teaching materials so far published in the New Liberal Arts Program are an essential starting point for any planning of new course materials that wishes to focus on technological literacy.

Attraction of Students

- Technological literacy should not be part of the traditional "turf battle" over too much material concentrated into too little time. Instead, technological literacy can become a "binding force" that helps to unify the entire curriculum.
- Teaching technological literacy in the classroom can be enhanced by a practical, emphasis on "the way things work," particularly for the non-science and non-engineering student.

- There is an urgent need for data on why students find some courses and subjects more attractive and others less so. An outcomes assessment is essential to identify how successful we are in creating technological literacy in the classroom.

Faculty Issues/Logistics

- For colleges with an engineering unit, it is necessary that the engineering faculty be involved with the development of and the teaching of technological literacy courses to have a successful technological literacy program.
- Predicted decline in engineering enrollments in the mid 1990's may be a favorable environment for offering technological literacy courses to satisfy faculty teaching load.
- Experienced senior faculty members with established research careers are good candidates for offering technological literacy courses. Selected retired industrial engineers could also become involved. Because of career problems, young faculty members should not be asked to be involved in the technological literacy movement.
- The Sloan Foundation's NLA Program materials can be used as text material for technological literacy courses. Reports from the Office of Technology Assessment and the National Academy of Engineering can also be used.

Courseware Needed

- Technological literacy courses using case studies need to be team taught.
- Case studies should include positive as well as negative aspects of technology. Proper balance is needed to convey the complexities of technological development.
- Film and video presentations are more useful than classroom-oriented materials in presenting the scope and complexity of engineering, especially to out-of-school adults.

Consortium Approach

- Recommendations for mechanisms both for promoting technological literacy and for actually incorporating it into the curriculum include a common core curriculum requirement, "top down" CEO approach, state and regional consortia, and press coverage and public outreach.

- The year 1993 should be declared as the year of Technological Literacy, and it should be a major theme for all professional society annual meetings.

- ABET, NSPE, and other appropriate engineering societies should promote technological literacy as a worthwhile activity by 1) encouraging engineering deans to have faculty develop and offer appropriate technological literacy courses and 2) working to make technological literacy a general education requirement for all undergraduate programs.

Funding Directions

- Any proposal for funding needs to be fairly sharply focused and should have support from the highest levels within the university.

- The leadership of engineering colleges is crucial in any project emerging from the Workshop, and there should be some means of demonstrating the serious commitment of colleges and universities to its aims.

- To maintain momentum and keep the interest of the many constituencies represented in the Workshop, it would be well to plan for continued consortial activities including development of a resource center for the gathering and dissemination of relevant information. Periodic meetings, workshops, and conferences to help the network of interested and informed participants grow would also likely be part of such long-term arrangements.

- Engineering colleges in a few major universities should join with other colleges in their campuses to develop a campus-wide technological literacy program for students. This should be a major short-term project.

Stimulation of Programs

- Additional programs in technological literacy are needed, but it is not clear that every undergraduate should be exposed.

- National level efforts are needed to stimulate the initiation and growth of technological literacy programs (e.g. specialty conferences, journal and news articles, sessions at appropriate society meetings, television programs, etc.).

- Technical and liberal arts faculty must be encouraged to work together on technological literacy programs, with specific mechanisms such as faculty development funding utilized as motivation.
- Special incentives are needed to encourage faculty and students to become involved in technological literacy programs (e.g. core curriculum requirements).
- Support of college and university CEO's should be enlisted, to stimulate technological literacy programs on their campuses.

NEXT STEPS FOR THE TECHNOLOGICAL LITERACY PROJECT

All of the above findings lead to two major conclusions, which were presented at the end of the Workshop. In order to coordinate the currently fragmented efforts of individuals and various institutions involved in technological literacy, we need a technological literacy center with national visibility to serve as a clearing house for technological literacy information and materials, building upon the base already developed. Furthermore, a demonstration project to initiate the growth of new programs at liberal arts colleges with engineering schools on their campuses, by utilizing experts from current programs as consultants, and providing necessary start-up funding is needed.

It is suggested a national technological literacy center might be developed at the headquarters of the Accreditation Board for Engineering and Technology (ABET) in New York City. Activities of such a center, funded by grants and contracts, might include the following:

- Information clearing house (database on programs, people, books, courseware, etc.)
- Newsletter
- Umbrella proposal generation and funding for projects, such as:
  - Courseware/curriculum development,
  - Faculty development,
  - Conferences/workshops.
- Promotion of technological literacy efforts and activities, such as:
  - General education component on college campuses,
  - Teacher preparation for pre-college positions,
  - Programs for K-12 education,
  - Generation of support for technological literacy efforts among several key constituencies, including government, industry, education, and private foundations.

As a major next step beyond the 1991 Workshop, it is further suggested that significant funding be sought for a Technological Literacy Demonstration Project. Such a project would be aimed at the stimulation of new technological literacy programs at several colleges and universities, perhaps ten, with umbrella grant funding provided as an incentive. The grant funding would support campus based efforts at faculty development and course/curriculum development, and would provide consultants from currently successful programs to guide each campus effort. Activities of this project would include:

- Stimulate interest in development of technological literacy programs at colleges/universities,
- Conduct competition to select demonstration program institutions (approximately 10),
- Obtain consultants to work with selected schools,
- Conduct workshops
  - -- bidders conference
  - -- selected institutions
  - -- progress reports
  - -- final results report to broad audience (at end of 3 years).
- Manage the grant
  - -- interface to schools
  - -- interface to sponsor

The final workshop at the end of the three year demonstration project would be aimed at attracting many more schools into technological literacy efforts.

Outline proposals for these two follow-up projects are contained in the Appendix of this proceedings volume. The sponsors and leaders of the Technological Literacy Workshop are pursuing these directions.

A P P E N D I X

Final Agenda

TECHNOLOGICAL LITERACY WORKSHOP

6-8 May 1991
Georgetown University Conference Center
Washington, DC

Monday evening, May 6

4:00 p.m.	Registration, check-in
5:00 p.m.	Introduction to Technological Literacy Project, Charge to Workshop *(Russel Jones)* Greetings from sponsors: ABET - *Leslie Benmark* AAC - *Paula Brownlee* NSF - *Wilbur Meier*
5:30 p.m.	Review of past efforts in technological literacy *(Rustum Roy and Barrett Hazeltine)*
6:30 p.m.	Reception
7:30 p.m.	Buffet dinner/ open discussion

Tuesday, May 7

7:30 a.m.	Continental breakfast
8:30 a.m.	Review of ongoing efforts in technological literacy *(John Truxal)*
9:30 a.m.	Generation of issues to be addressed *(Joseph Johnston and Russel Jones)*
10:30 a.m.	Coffee break
10:45 a.m.	Breakout sessions on specific issues Curriculum - *Carl Mitchum* Courseware available - *David Billington* Attraction of students - *John Opie* Faculty issues/logistics - *Marian Visich*
12:00 noon	Buffet lunch/break
1:15 p.m.	Plenary session, reports back from Breakout sessions *(Russel Jones)*
2:15 p.m.	Views from the Liberal Arts College *(Thomas Wasow)*
3:15 p.m.	Break

Tuesday, May 7 (continued)

3:30 p.m.	**Views from the Engineering College** *(Curtis Tompkins)*
4:30 p.m.	**Engineering and the Liberal Arts** *(David P. Billington)*
6:30 p.m.	**Reception**
7:30 p.m.	**Banquet**
8:30 p.m.	**Speaker on broader issues in Science, Technology, and Society** - *(George Bugliarello)*

Wednesday, May 8

7:30 a.m.	**Continental breakfast**
8:30 a.m.	**Development of agenda for what needs to be done in technological literacy** - *(David Reyes-Guerra)*
9:30 a.m.	**Breakout sessions on specific elements of agenda** Courseware needed - *Paul Durbin* Consortium approach - *Stephen Cutcliffe* Funding directions - *Samuel Goldberg* Stimulation of programs - *Bethany Oberst*
10:30 a.m.	**Coffee break**
10:45 a.m.	**Plenary session, reports back from Breakout sessions** *(Wilbur Meier)*
12:00 noon	**Buffett lunch/break**
1:30 p.m.	**Final plenary session: Development of Plan for Next Steps in Technological Literacy Project** - *(Russel Jones)*
3:30 p.m.	**Workshop adjourns**

TECHNOLOGICAL LITERACY WORKSHOP PARTICIPANTS
May 6-8, 1991

Benmark, Leslie F., President
Accreditation Board for Engineering and Technology
c/o E. I. du Pont de Nemours & Co.
2141 Hickory Run, CRP
Box 80723
Wilmington, DE 19880-0723
302/999-4919

Billington, David P.
Department of Civil Engineering
Operations Research
School of Engineering/Applied Science
Princeton University
Princeton, NJ 08544
609/258-4613

Brownlee, Paula, President
Association of American Colleges
1818 R Street, N.W.
Washington, D.C. 20009
202/387-3760

Bugliarello, George, President
Polytechnic University
333 Jay Street
Brooklyn, NY 11201
718/260-3500

Cherno, Melvin
Vaughan Prof. of Humanities
University of Virginia
223-A Thornton Hall
Charlottesville, VA 22903
804/924-6093

Cutcliffe, Stephen H., Director
Science, Technology & Society Program
327 Maginnes Hall #9
Lehigh University
Bethlehem, PA 18015
215/758-3350

DeLoatch, Eugene, Dean
School of Engineering
Morgan State University
Cold Spring & Hillen Road
Carter Grant Wilson Building
Room 318
Baltimore, MD 21239
301/444-3231

Devon, Richard F.
Associate Program Manager
National Space Grant College and Fellowship Program
National Aeronautics and Space Administration
University Programs Branch
NASA Headquarters Code XEU
Washington, D.C. 20546
202/453-8344

Durbin, Paul T., Professor
Philosophy Department
University of Delaware
Room 303 Philosophy Building
Newark, DE 19716
302/451-8208

Dustin, Jack, Research Associate
Urban and Public Affairs
Wright State University
062 Rike Hall
Dayton, OH 45435-0001
513/873-2382

Fallon, Daniel, Dean
Liberal Arts College
Texas A & M University
College Station, TX 77843-1246
409/845-5141

Feisel, Lyle, D., Dean
College of Engineering
SUNY at Binghamton
Vestal Parkway
Box 6000
Binghamton, NY 13902-6000
607/777-2871

Gianniny, O. Allan, Jr.
Professor of Humanities
School of Engineering & Applied Sciences
University of Virginia
A218 Thornton Hall
Charlottesville, VA 22903
804/924-6115

Goldberg, Samuel, Program Officer
Alfred P. Sloan Foundation
630 Fifth Avenue
Suite 2550
New York, NY 10011
216/774-8081

Gorenstein, Shirley, Professor/Chair
Dept. of Science & Technology Studies
School of Humanities & Social Sciences
Rensselaer Polytechnic Institute
5508 Sage Lab
Troy, NY 12180-3590
518/276-6574

Hazeltine, Barrett, Associate Dean
College of Engineering
Brown University
182 Hope Street
Providence, RI 02912
401/863-2673

Herkert, Joseph
Asst. Professor of Civil Engineering
Lafayette College
Easton, PA 18042
215/250-5427

Hickman, Charles
Director of Projects & Services
American Assembly of Collegiate
Schools of Business
605 Old Ballas Road, Suite 220
St. Louis, MO 63141
314/872-8481

Hutchinson, Charles, E., Dean
Thayer School of Engineering
Dartmouth College
Hanover, NH 03755
603/646-2238

Jennett, J. Charles, Dean
College of Engineering
Clemson University
109 Riggs Hall
Clemson, SC 29634-0901
803/656-3202

Johnston, Joseph
Vice President for Programs
Association of American Colleges
1818 R Street, N.W.
Washington, D.C. 20009
202/387-3760

Jones, Russel C.
University Research Professor
University of Delaware
205 McDowell Hall
Newark, DE 19716
302/451-6074

Kline, Stephen Jay, Professor
Department of Mechanical Engineering
Room 500K, Building 500
Stanford University
Stanford, CA 94305-3030
415/723-2176

Kulacki, Francis, Dean
College of Engineering
Colorado State University
111 Engineering Building
Fort Collins, CO 80523
303/491-6603

Kumar, Thulasi, Research Associate
University of Delaware
260 Elkton Road, D-7
Newark, DE 19711
302/454-7422

Liebman, Judith S.
Vice Chancellor for Research and
Dean of the Graduate College
University of Illinois at Urbana-Champaign
601 East John Street
420 Swanlund Administration Building
Champaign, IL 61820
217/333-0034

McGee, Henry, Director
Chemical and Thermal Sciences Division
National Science Foundation
1800 G Street, N.W., Room 1228
Washington, D.C. 20550
202/357-9606

McGinnis Kay, Carol
Dean of Humanities & Social Sciences
University of South Carolina-Columbia
Columbia, SC 29208
803/777-7161

Meier, Wilbur L., Dean
College of Engineering
North Carolina State University
Box 7901
Raleigh, NC 27695-7901
919/515-2311

Mitcham, Carl, Interim Director
STS Program
The Pennsylvania State University
133 Willard Building
University Park, PA 16802-2800
814/865-9951

Morgan, John Derald, Dean
College of Engineering
New Mexico State University
P. O. Box 30001 - Dept. 3449
Las Cruces, NM 88003
505/526-6758

Oberst, Bethany S.
Vice President for Academic Affairs
James Madison University
Harrisonburg, VA 22807
703/568-6616

Opie, John, Director
Science, Technology & Society Program
Center for Technology Studies
New Jersey Institute of Technology
University Heights
Room 501M
Newark, NJ 07102
201/596-3270

Rathbone, Donald E., Dean
College of Engineering
Kansas State University
146 Durland Hall
Manhattan, KS 66506
913/532-5590

Reyes-Guerra, David R., Director
Accreditation Board for Engineering
and Technology
345 East 47th Street
New York, NY 10017-2397
212/705-7176

Roy, Rustum, Director
Science, Technology & Society Program
Evan Pugh Professor
133 Willard Building
Pennsylvania State University
University Park, PA 16802
814/865-3041

Saul, William E.
Professor and Chairperson
Michigan State University
Dept. of Civil and
Environmental Engineering
A349 Engineering Building
East Lansing, MI 48824-1226
517/355-5107

Scholz, Charles B., Research Associate
University of Delaware
56 Welsh Tract Road, #212
Newark, DE 19713
302/456-9891

Tompkins, Curtis J., President
Michigan Technological University
1400 Townsend Drive
Houghton, MI 49931-1295
906/487-2267

Truxal, John G.
Distinguished Teaching Professor
Department of Technology and Society
College of Engineering & Applied Sciences
SUNY at Stony Brook
Stony Brook, NY 11794-2250
516/632-8760

Viets, Hermann, Dean
College of Engineering
University of Rhode Island
Bliss Hall
Kingston, RI 02881-0805
401/792-2186

Visich, Marian Associate Dean
College of Engineering & Applied Sciences
Department of Technology & Society
SUNY at Stony Brook
Stony Brook, NY 11794-2200
516/632-8380

Walker, M. Lucius, Dean
School of Engineering
Howard University
2300 6th Street, N.W.
Washington, D.C. 20059
202/806-6565

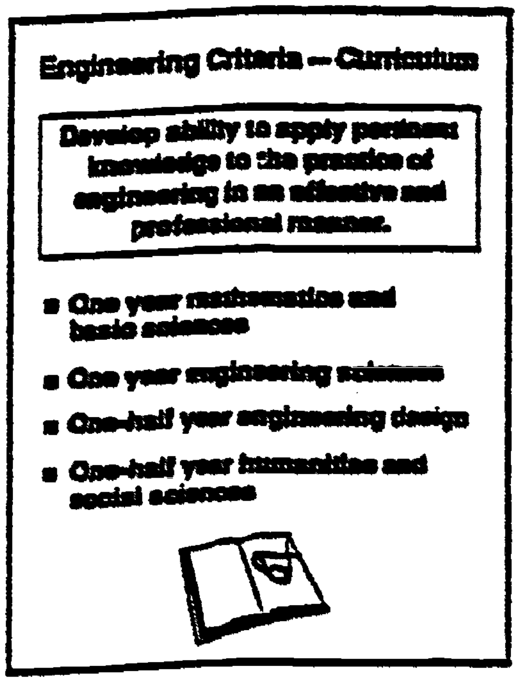
Wasow, Thomas A., Dean
Undergraduate Studies
Stanford University
Building One
Stanford, CA 94305-2070
415/723-9786

GREETINGS FROM SPONSORS

WELCOMING REMARKS

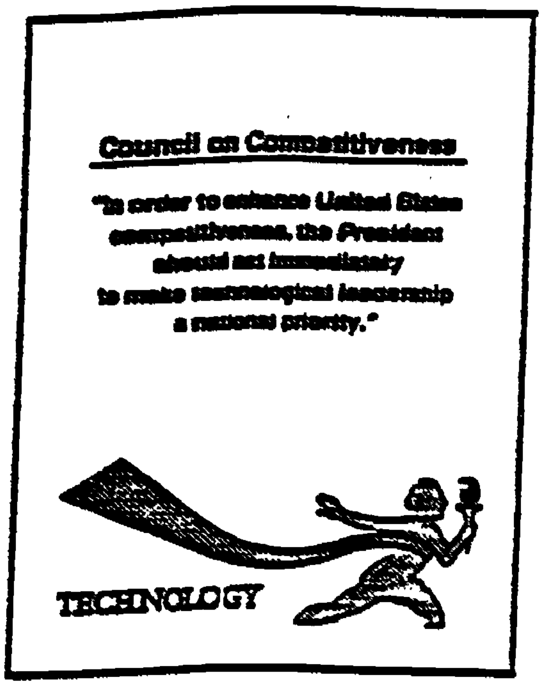
Leslie Benmark
Accreditation Board for Engineering and Technology

ABET is pleased to be a co-sponsor of the Technological Literacy Workshop along with the Association of American Colleges and the National Science Foundation. Technological literacy in today's society is a must. A vast majority of the critical decisions which affect each person's daily life is based on some form of technology.



For many years, ABET has maintained a curricula requirement in the engineering criteria of one-half year of humanities and social sciences. The exponential growth of needed technical subject matter to cover the requirements of entry into the engineering profession has not diminished ABET's emphasis in humanities and social sciences.

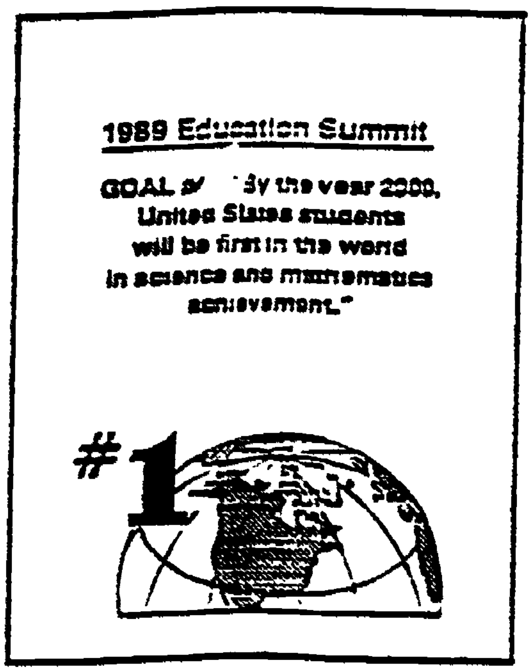
ABET is not only conscious of the need for technically educated persons to be <u>whole</u> persons with a broad education beyond technical subjects but is also keenly aware of the need for technological literacy for all persons.



The first key recommendation of the Council on Competitiveness, a private, non-profit, non-partisan organization of chief executives from business, higher education, and organized labor, was

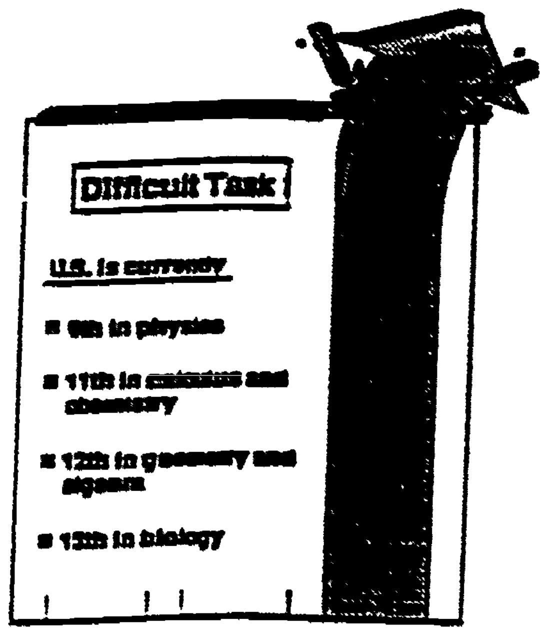
> In order to enhance United States competitiveness, the President should act immediately to make technological leadership a national priority.

A crucial component of this technological leadership is the broadening of the education of all students by creating a better understanding of technological subjects.



Following the 1989 Education Summit, the President ar 'he Governors established six national goals for improving edu.-cion in the United States. Perhaps no goal is more critical to America's future in international competitiveness than Goal #4.

> By the year 2000, United States students will be first in the world in science and mathematics achievement.



Achieving this goal during the next decade is no minor task. A recent education study examined the mathematics and science skills of thirteen year old students in thirteen industrialized nations. The United States students ranked ninth in physics, eleventh in calculus and chemistry, twelfth in geometry and algebra and last in biology.

Building on this significant strengthening of mathematics and science in the early grades, technological literacy for all students during their post-secondary education would help to increase their recognition of competitiveness issues and improve the position of the United States as we compete on a global basis.

The Technological Literacy Workshop can make a significant step toward making the United States "first in the world in science and mathematics achievement." ABET is pleased to be part of this endeavor and looks forward to the results achieved by leveraging the efforts of engineering and liberal arts colleges on various campuses so that movement toward the goal of a technologically literate public can be achieved.

WELCOMING REMARKS

Paula P. Brownlee
Association of American Colleges

It is such a pleasure to bring you greetings from AAC, our association whose 630 members take pride in commitment to liberal learning in all its manifestations--and they are myriad.

At AAC we are in the midst of a study concerning the undergraduate major in conjunction with twelve learned societies; these include mathematics, physics, and biology. Interestingly, the very nature of the major has not really been researched and pondered, and at AAC we find ourselves in the midst of a fascinating discussion. The importance of study-in-depth and sequential learning in certain majors is of great significance. Other majors are showing us that there is another aspect of learning--that of connectedness, to other disciplines and other methodologies, that should be intentionally developed also.

I am reminded, as I speak, of a lovely mobile sculpture that we have in our home, the result of two persons' work--an artist and a physicist. Entitled "Tumbleweed," it is made up of an intricate series of cogs, wheels, and pulleys--beautifully crafted in wood. It is both kinesthetically and aesthetically lovely. In it, two ways of thinking and creating are combined to come up with something quite new. Each artist alone simply could not have produced this imaginative creation.

At Union College, where I arrived in 1976 as Dean of Faculty (and engineering), I was delighted to work directly with our Engineering Division to design a new curriculum, incorporating a technology course requirement for <u>all</u> students. I believe, still, that the conversation of students from all majors, with each other and with their faculty, is a vital part of their education. In combination of the perspectives that the separate disciplines confer on us can come new understandings and new knowledge.

This is a large part of the mission of AAC--to further and to develop strong liberal learning on our campuses. The centrality of technology and the work of engineers in our contemporary society, and in fact in history, compels us to address the issues this workshop raises. Even with an overcrowded undergraduate curriculum, we must be sure that students engage in the kind of interdisciplinary study that includes technological literacy education. This particular connectedness is essential to a truly liberal education.

I will end with an anecdote of something that happened to me yesterday. I do it to illustrate just how narrowly educated we perceive each other to be! I was giving a commencement address in which I quoted some lines of poetry. After the address a trustee of the college expressed amazement that "a chemist would actually dare to quote some poetry." It seems to me that therein lies the challenge: to educate our students in many fields of endeavor, and certainly including technology. Thus endowed, they may become wise and creative professionals and citizens of our society.

WELCOMING REMARKS

Wilbur L. Meier
National Science Foundation

It is indeed a pleasure to be here and to have an opportunity to welcome you to this meeting. It is also quite a challenge to be third welcomer in a session sandwiched between the organizer of the conference and two pre-billed scintillating speakers. One immediately knows, from the organizer's comments, that the welcomers are the minor speakers because he talked about the major speakers, and one also knows that these are the non-scintillating speakers because he also talked about the scintillating speakers who are to come later. It is, in fact, a challenge to welcome you to a meeting like this. But, undaunted I will plunge on and welcome you nonetheless.

We are, in fact, pleased to have an opportunity in the National Science Foundation to be a supporter of this workshop, and it is, in fact, supported by both the Engineering Directorate and the Directorate for Education and Human Resources.

When we think about the topic of literacy, to begin with, I think we have all been saddened to see the sad state of literacy in this country in the broad sense. Twenty to thirty percent of our people are functionally illiterate and, in fact, this is one of the more serious issues that American industry faces in terms of fielding their team in trying to be competitive.

But even more serious than that, I believe, is that when one looks at the general population one finds the great majority of our citizens to be illiterate technically. When one looks at the longitudinal studies that the Department of Education has done, and looks at the champagne glass curve that describes education starting with sophomores in high school and seeing those who finally get degrees in either science or engineering, one is concerned even more about the part of the curve that is outside those fields. For the most part, that group is technologically illiterate.

That issue is what this conference is to address. That is the critical issue, and in fact, is the second major issue that U.S. industry must deal with in trying to be competitive in this world. So this is a critically important workshop. It is one the National Science Foundation is delighted to support, and I am delighted to welcome you here.

BREAKOUT SESSION REPORTS

Joseph S. Johnston
Association of American Colleges

Like a number of others in the room, I am here as a learner, both personally and professionally. Personally, I cannot have other pretensions. The first article I picked out from the background reading was Rustum Roy's. I found there two words I had never seen before--"fissiparous" and "negencentric." These were not part of my supposedly liberal education. Professionally, I represent the Association of American Colleges which has worked closely and well with ABET in the past. We are in a sense friendly listeners to this conversation on technological literacy, and we are weighing whether we should join in any project the conversation might produce. A major national project to promote technological literacy? Clearly, a worthy goal. But on what terms, and to what ends? Driven by what educational philosophy? God, as they say, is in the details.

Since I have questions like these, it is appropriate, I suppose, that Russel Jones has asked me to help him set out some of the issues that would be raised by any technological literacy initiative. Russel and I have talked, and he has grouped some of the likely questions into four categories under the headings "curriculum," "courseware," "faculty issues/logistics," and "attraction of students." What I will try to do here is briefly comment on a number of the questions that fall within each category.

Curriculum

- What is technological literacy?

- What are appropriate objectives for technological literacy programs? What measures should be used to evaluate them against such objectives?

- What are the essential curricular elements of an appropriate technological literacy program on a given campus?

- How does the study of technological literacy differ from study of engineering?

- What claim does it have to be a part of general education?

- How do we ensure that the study of technology advances to liberal education?

- How do we integrate technological literacy offerings into undergraduate liberal arts programs?

- What have previous efforts accomplished? What have we learned from them?

The first of these questions are definitional. What is technological literacy? There is more to this innocent question than an outsider might think. There are a number of perspectives on that question represented in this room. The three questions that follow remind us that at least three different kinds of definitions are possible. The first of these asks about the purposes of technological literacy programs. The second asks about the essence of the thing--the essential curricular elements. Are there core methods and concepts? To pose a question much heard in teacher education these days, is there a "knowledge base" that is distinctive? The third of these questions tries to define technological literacy by distinguishing it from engineering. How does what we mean by technological literacy differ from the intended product of study within Science, Technology and Society programs, or New Liberal Arts programs.

If these are questions that disinterested faculty and administrators can be expected to ask of any initiative to introduce technological literacy into the curriculum so too, is the next question: what claim does technological literacy have to be part of a general education? Is this thing, too, really essential, one can hear them asking? General education is already crowded, and there are many claimants to more time and attention within it. There are, of course, many who are urging a greater attention on the part of all students to values and to international and multi-cultural concerns and to mathematics and science. The accrediting agencies, engineering among them, continue to limit the amount of time available to general studies. John Truxal is certainly correct in pointing out in the conclusion of his article, "Technology in the NLA," that "to address the issues which technology raises is a step which is only possible if we learn the basic concepts, capabilities and limitations of that technology." Rustum Roy is also right when he refers to the lack of technological literacy studies in the curriculum as "mind-boggling." But it is similarly strange to many that we do not have other professional areas represented there, as well. Some would say that business and economics should, at some level, be a part of everyone's college experience. Others would even argue that all should have some exposure to the study of education. After all, they point out, everyone at the university is involved in the enterprise of education, and all should be more self-conscious about it. Virtually everyone who graduates will go on, if not to further study, to life as a school-supporting taxpayer. Most will, as mothers and fathers, have children in the schools. Most will, as voters, elect those who will make policy about public education.

The next question seems to be a critical one. How do we ensure that the study of technology advances liberal education? A liberal education is defined less by the subjects that are studied than by the spirit of the inquiry--the kinds of questions we ask. There is no reason why the study of technology cannot provide an appropriate, a very rich and strong liberal education. However, like the dry, specialized history course that is taught illiberally, the technological literacy course can fail to advance liberal education.

The question of how one would integrate technological literacy offerings into an undergraduate liberal arts program is not an easy one either. It is a substantive as well as a strategic question. How does the study of technology relate to other fields? I am reminded of the old definition of a scholarly center on a university campus as an entity that is by definition on the periphery. How can we integrate technological literacy so that it is not peripheral? My sense is that we are approaching a point where those students and faculty who might have been predicted to be interested in technological literacy have been, and that substantial progress from here--the claiming of a place in the center, versus on the periphery--may be difficult to achieve. Are we at a kind of natural limit?

I might at this point have introduced an additional question: Where should technological literacy be introduced into the curriculum? Should it be general education, and if so required general education? Should it be an elective sequence? Is it a major? Should it take any of the above forms--perhaps several on the same campus--depending on local circumstances?

The final question in this first set, asking what previous efforts have accomplished and what we have learned from them, is timely. I think I have reached professional middle age--that point at which one begins to see a fair amount of repetition. I recently saw that in 1982 a report on technological literacy urging the importance of technological literacy emerged from a Wingspread conference held under the auspices of . . . the Association of American Colleges. We need to do better. We need to capture what we know. We need to keep it alive. We need to make sure that we learn from what we have already been able to discover. There are many fine programs whose experience can be shared. Of course we need imagination. We need fresh thinking. But we need not re-invent the wheel.

Courseware Available

- What institutions now have courses and/or programs that might be considered models?

- What materials are available to provide background to faculty members starting to work in this area?

- What materials are currently available for use in courses and laboratories in this area?

The name of this category provides proof-positive that Russel Jones prepared these slides. "Courseware" is not a term that has much currency within the arts and sciences. A few there would even consider it a barbarism. The term itself is an example of the little discontinuities that would need to be negotiated to get an impartial hearing for technological literacy among many liberal arts faculty.

The bibliographical work that Russ and his colleagues have done in preparation for this conference should be a big help in answering all three of these questions. We all need to bear in mind, however, that we cannot simply give people their materials and wait for ignition. If substantial numbers of faculty and institutions are to embrace technological literacy as a central subject, it will be as the result of a comprehensive effort in which "courseware" is only one element.

Faculty Issues/Logistics

- How do we stimulate collaboration between liberal arts and engineering units on a given campus re: technological literacy offerings?

- How do we stimulate/reward faculty participation in the technological literacy area. How do we prepare faculty members or teams to work effectively in this area?

- How are logistics best handled: organizational structure, faculty appointments, funding...?

- How do we assure availability of appropriate books, case studies, and other courseware?

- How can necessary funding be obtained for such technological literacy programs?

A few years back AAC published a report entitled Integrity in the College Curriculum. It pointed out how few incentives faculty have to work outside their specialties especially as teachers. It contained the memorable observation that the faculty speak of teaching "loads" and research "opportunities." It is against the background of this reality that we need to consider the first two questions here, having to do with stimulating collaboration around the teaching of technological literacy. My colleague Alan Gianniny is right in pointing out that the success of AAC's and ABET's joint efforts to improve the humanities and social sciences component of engineering education has had everything to do with "firm encouragement"--to use Alan's nice phrase. ABET promoted these efforts by glowering over AAC's shoulder in a way that was visible to the engineering deans. Is it possible to stimulate cooperation between liberal arts and engineering units without this kind of help? Certainly a clear conclusion of our jointly sponsored study was that much of the best engineering-liberal arts collaboration is in those humanities and social sciences departments that are "captive,"--that is to say, that are contained within technological institutes, unlike, say, French and philosophy and political science departments in multi-purpose universities. These departments do their work within an over-arching institutional mission and structure of authority that ensures their consciousness of and attention to the needs of engineering students. Technological literacy programs, however, need to operate outside of technological institutes--where one might not be sanguine with the possibility of lasting progress on a purely voluntary basis. Since unfortunately AAC has no power comparable to ABET's, cooperation will be in large part left up to the good will of educational priorities of faculty and administrators in liberal arts.

These facts give some appeal to a strategy (to use a phrase from another of the background papers) of "infiltration." To refer again to the AAC/ABET study, we found the best examples of innovative, imaginative, and effective programming in the humanities and the social sciences for engineers in two kinds of settings. I have already mentioned one--the technological institute. The other kind of setting was that in which some individual faculty member had taken it as his or her personal responsibility, and sometimes life's work, to create this kind of program. It was not clear in these latter cases that there was a broad institutional base of support for what was done, though typically enrollments were high, as was student enthusiasm. It was not clear that the particular offerings would outlive the faculty members. Nonetheless, for a period of time great things can be achieved by the eccentric faculty member who decides to accomplish something. It may be that continuing to encourage those who have an interest and expertise in technological literacy to take it, missionary-like, to those who could profit from it is and will remain one of our best strategies. Those who do this "infiltrating" need to remember the words of the Tammany Hall ward heeler, George Washington Plunkett: "I seen my opportunities and I took 'em."

The other questions here deal with logistics and funding. With respect to the first, we really need to take a hard look at what is effective and what is not. Team teaching comes to mind, for instance, but so does Harland Cleveland's definition of it as "that favorite academic device for avoiding interdisciplinary thought." How can we really ensure that the arrangements by which it operates not only enable a program to be offered but to be educationally effective for the students in it.

The great lesson, I gather, of some previous Sloan Foundation efforts and certainly of the Ford MAT program has been that change can be rented, but it can not be bought. It is often extremely difficult, that is, to sustain the changes that funding makes possible once that funding disappears. So the question asked here about funding really needs to be expanded: how, we should ask, can these programs be funded and institutionalized?

<u>Attraction of Students</u>

- How to reach out to selected groups of students (e.g. those preparing to be pre-college teachers).
- How can students be attracted to such programs? What target populations should be pursued.
- What preparation should students have? How can we ensure that they have it?

We have heard this morning from John Truxal about the infectious enthusiasm of students who were well taught about technological literacy. John is a gifted teacher. But I get mixed reports on the general quality of teaching in engineering schools, as indeed in business and liberal arts programs. The interest of the subject is never enough to ensure the interest of the course. And indeed, in talking about technological literacy for liberal arts students, it is important to remember a set of issues that have been receiving more and more attention lately having to do with the intellectual accessibility of certain kinds of subject matter for certain kinds of students. We are getting more sophisticated now about the contextual relativity of good teaching. What is very effective instruction for engineering students may not be for certain humanities or social sciences students, and <u>vice versa</u>. Some of the most interesting work on this issue has been done recently by Sheila Tobias, author of a series of studies on math anxiety, peer observations on teaching, and most recently a book entitled, <u>They're Not Dumb, They're Different</u>.

The issue is raised of reaching out to particular groups of students. Doing so successfully may depend to a great deal on reaching out to their faculty, who in turn advise those students and decide their program requirements and recommend cognate courses to their majors. The particular instance of pre-college teachers is given, and I think wisely. John Truxal has referred to triage by ability level as one principle of selection for technological literacy students. Another might be leverage. What groups of undergraduates would we choose to target for technological literacy education if we wanted to ensure that through them technological literacy would reach the largest number of others? Surely by the measure of leverage pre-college teachers would be our choice. They will go into the schools, and what they know or do not know about technology will have an impact on what their students learn or do not learn about it.

One final observation on the question of how students can be attracted to such programs. I am not sure we have done as much as we can to articulate the usefulness of technological literacy to a variety of careers. Today's students are motivated by career concerns, and subject matter that is congruent with their career needs can engage them. At the same time we should be responsible in making the case for technological literacy. It is much more than an asset in one's career. It is an essential part of a broad foundation for informed citizenship in a rapidly changing world.

In his piece on the "New Liberal Arts" John Truxal suggests the engineers' central function is to break a complex problem into a large number of simple problems. My fear this morning is that we have only managed to break a complex problem into a large number of complex problems. But Russel Jones and I do hope that this parsing of some of the issues that we face, and the brief comments that we have offered here on them, will be helpful in setting up the sub-group discussions that follow.

CURRICULUM DEVELOPMENT

Carl Mitcham
Pennsylvania State University

The curriculum discussion group began by noticing that the issue of technological literacy was a design problem. As with many design problems, it is easier to recognize failure than success. Technological illiteracy is more easily described than technological literacy.

Technology is also easier to define than technological literacy. Technology, according to one participant, includes hardware or artifacts, socio-technical systems of manufacture, skills/processes/procedures for accomplishing tasks, and socio-technical systems of use. Another participant immediately noted how the acronym STS can stand for socio-technical systems, and that in this sense clearly technological literacy is part of STS.

As part of a preliminary attempt to define the objectives of technological literacy curricula, it was pointed out that engineers are required to take more humanities and social sciences courses than humanities and social science students are required to take engineering courses. A technological literacy curriculum requirement for liberal arts students should, at a minimum, serve a parallel function to the ABET requirement for engineering students. One of the objectives of any technological literacy curriculum would thus be to increase intelligence and understanding of engineering among non-engineering students.

In subsequent discussion a question was raised about the relation between technological literacy and engineering literacy. Are they the same or different? There was animated discussion on this issue with some people arguing the importance of understanding technology in a broad sense that includes but is not limited to engineering, while others argued the importance of not diluting the thrust of technological literacy by including too much.

In the discussion group itself there was an implicit assumption that technological literacy was equivalent to engineering literacy about engineering. One participant, for instance, pointed out the importance of visual thinking in engineering; another suggested problem solving as equally central. Any technological literacy curriculum should communicate an appreciation of both to liberal arts students. There was also a general consensus that the communication of process was more important in any technological literacy curriculum than any particular content. At the same time, process cannot be presented separate from content.

Following some disparaging comments about 100-level courses, one liberal arts dean ventured the opinion that he would love to see a few good 100-level courses on technological literacy. This should not be the end of a technological literacy curriculum--a curriculum includes more than one course--but it would be a good and necessary beginning.

There was also animated discussion about whether technological literacy courses require as prerequisites a certain degree of scientific and mathematical literacy. Some members of the group felt strongly that scientific and mathematical literacy could themselves be taught by means of technological literacy courses.

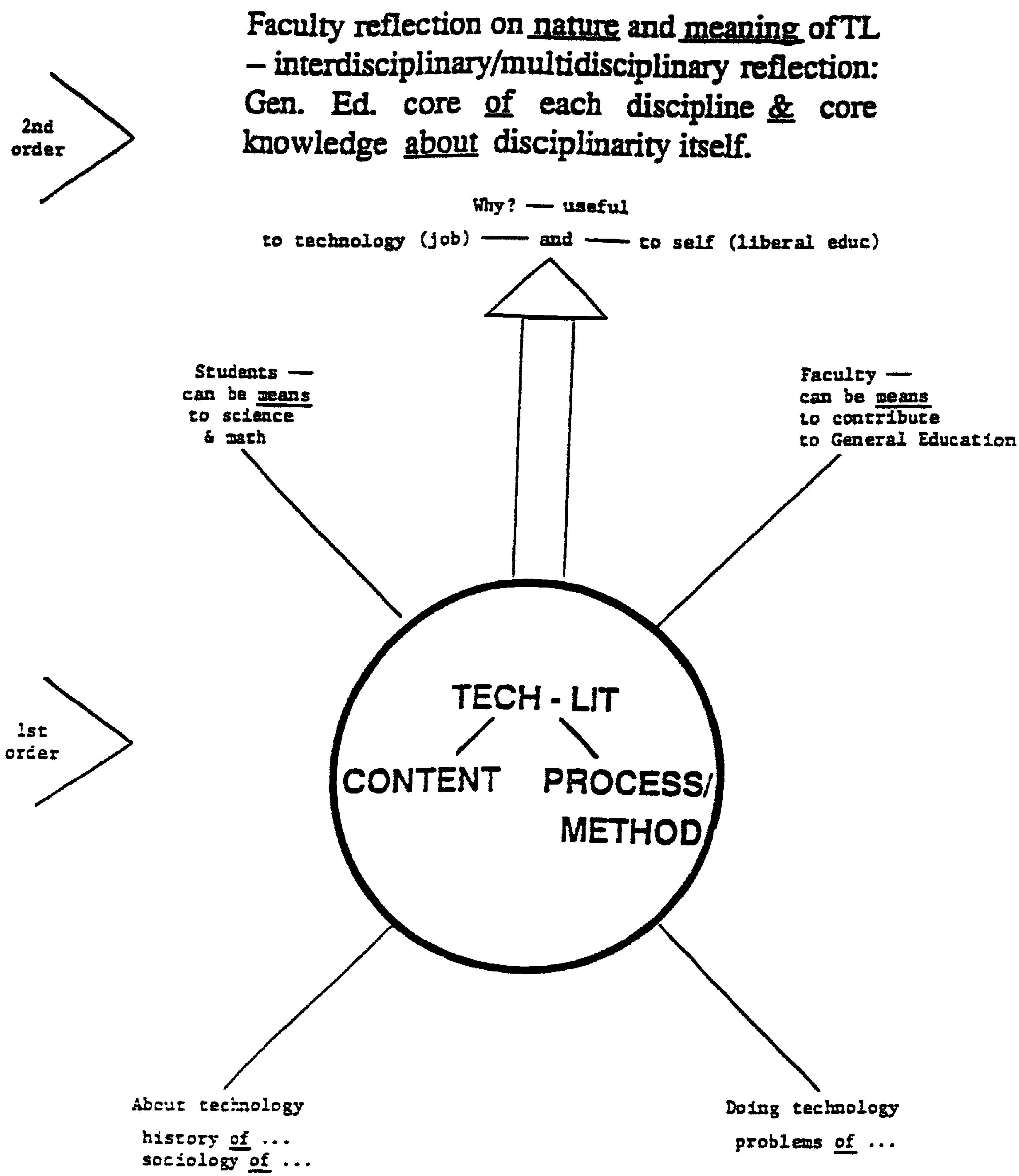
Returning to the issue of a technological literacy curriculum itself, the group distinguished two levels of curriculum analysis. Level one emphasizes the importance of both content and process or method. This content and process can be communicated _indirectly_ in courses _about_ technology, but more effectively and _directly_ by courses in which students actually _do_ technology, (meaning engineering problem solving and design). Courses about technology are typically entitled "The History _of_ Technology" or the "Sociology _of_ Technology," whereas courses in which students _do_ technology are typically entitled "_Problems_ of transportation/communication/etc." As part of this first level of analysis, it was also noted that for students technological literacy can be a _means_ to science and mathematical literacy. For faculty, especially engineering faculty, technological literacy can be a _means_ by which they contribute to general education.

At a second level of curriculum analysis, the question was raised about _why_ technological literacy should be promoted. There are two answers. First, it is useful to society, and can help students to get jobs. Second, it is personally useful, because it provides understanding and knowledge. Technological literacy contributes to a general or liberal education.

It was also argued in relation to this second level of analysis that the faculty in any institution of higher learning should come together to reflect on the nature and meaning of technological literacy. Such reflection should be interdisciplinary in character. For instance, it would be very useful for each department in the university to present what the faculty of that department thinks are the core concepts or ideas which all students should know if they are to be well educated generally. Each discipline should identify what part of itself should be included in a core, interdisciplinary, general education.

It is also necessary for a truly liberal education for members of all disciplines to reflect upon the strengths and weaknesses of disciplinarity itself. In relation to technological literacy, it is crucial for faculty and students at the senior level to become aware of the frameworks that engineers and scientists use in thinking about problems and the world. It is necessary, argued one member of the group, to recognize the need for multi-disciplinarity to deal with truly complex problems and complex systems. It is also necessary to recognize that any proposition is true only within some limited domain or system. It is reflection on such issues that makes interdisciplinary discourse possible, and this should be the capstone of technological literacy.

A summary of these two levels of analysis is provided in the following diagram.


Faculty reflection on nature and meaning of TL – interdisciplinary/multidisciplinary reflection: Gen. Ed. core of each discipline & core knowledge about disciplinarity itself.
2nd order
Why? — useful
to technology (job) — and — to self (liberal educ)
Students — can be means to science & math
Faculty — can be means to contribute to General Education
1st order
TECH - LIT
CONTENT
PROCESS/ METHOD
About technology
history of ...
sociology of ...
Doing technology
problems of ...

COURSEWARE AVAILABLE

David P. Billington
Princeton University

This session dealt with general views on course content, on the forms of teaching materials, and on the results obtained so far. The people attending were Benmark, Billington, Devon, Durbin, Dustin, Frair, Granning, Hutchinson, Liebman, Morgan, Tompkins. Some of the major issues discussed were:

General Views on Course Content

First, how do engineers think or what is the design process in engineering and what were the historical origins of present day engineering objects or systems. A second theme for content was embodied in critical thinking as an educational goal which includes technological assessment, the potentials, and the limitations of technology. A third idea was expressed by the tendency to define engineering through problem solving and thus to develop course content focused on ideas and examples from the solution of engineering problems. Parallel to problem solving is design as another prime characteristic of engineering; and along with both comes the joy and excitement of engineering--something which has been partially lost in the public mind in recent years. Also partly the emphasis on institutional forces as shaping technology has tended to make the activity of engineering seem less appealing. Some renewed stress on the role of individuals and their joy in engineering would help redress a loss of balance in the image of the profession. Another factor raised was the perception that engineers and scientists do not do well in teaching their own majors, let alone in teaching liberal arts students.

Aspects such as critical thinking, problem solving, and joy and excitement are all essential to good course content but they are no help in defining it. The engineering design process and the stories of individual engineers, on the other hand, are defining aspects as are the social (which include institutional) constraints peculiar to engineering work. This course content for technological literacy seems to require exposure to defining aspects as well as experience with them that will help develop student pleasure in engineering along with some ability to solve simplified engineering problems and to think critically about engineering objects and systems.

The Forms of Teaching Materials

Our discussion focused on case studies in engineering which can involve either historical content or other sorts. The historical case studies need to be based upon original scholarship and can thus be relatively permanent additions to the literature. The form for these studies can be full-length books (such as Networks of Power by Hughes), monographs (such as The Electrification of Los Angeles by Copp and Zanella), or shorter units (such as the Steamboat unit in the Episodes Monograph). Another sort of case study are the business school decision making units which can give students some experience with problem solving and critical thinking in a contemporary context. This context is also crucial for the historical studies; they should illustrate present day problems (such as containment vessels and government regulation for reactors). Whatever the length of these studies they should include numerical calculations, social contexts, and aesthetic, ethical, or symbolic meanings. Such studies are integrated in the sense of illustrating how engineering works must perform in the natural world, must come into being in the social world of politics and economics, and will change the perception of individuals.

Results Obtained So Far

Some general questions were raised about available materials and those that might be developed: are they integrated in a way to appeal to or make sense to liberal arts students? Can they be used at schools other than the ones at which they were developed? and will they be merely watered-down engineering? Here the Sloan results provide a basis for some reasonably firm conclusions. First, the New Liberal Arts Program put in a few engineering faculty into close contact with many liberal arts faculty to the benefit of both. Second, the program brought together faculty in research universities and those in liberal arts colleges; and third, it supported scholarly research aimed at producing teaching materials. The results to date show that integrated teaching units can interest liberal arts students, that units developed at one institution can be used at other places, and that historical case studies quite naturally use simplified mathematical formulations for difficult engineering designs because pioneering engineers often did just that themselves.

The engineering-oriented teaching materials so far published in the New Liberal Arts Program are an essential starting point for any planning of new course materials that wishes to focus on technological literacy.

ATTRACTION OF STUDENTS

John Opie
New Jersey Institute of Technology

As far as students are concerned, the group agreed that technological literacy belongs in a general or core curriculum required of all undergraduates. But technological literacy should not be part of the traditional "turf battle" over too much material concentrated into too little time. Instead, technological literacy can become a "binding force" that helps to unify the entire curriculum. That is, it can provide a thread throughout many core courses that can help students find coherence in their diverse courses, and to see the relevance of the courses for their careers and future lives. Technological literacy, after all, is not the "property" of one discipline or field alone, but is inherently cross-disciplinary. The group noted that such curriculum tracking is explored in the recent AAAS engineering student's guide on the humanities and social sciences.

Other important subjects were:

1) We must recognize that the "two cultures" debate over differences between the humanities and the sciences is still commonplace among students and their courses. Students who are comfortable with math often feel inadequate in verbal skills, and vice versa. This polarization is unacceptable and unnecessary, but not unusual. Technological literacy is a particularly effective means to overcome the two cultures division. One attempt to resolve the conflict exists in the Sloan Foundation's New Liberal Arts programs.

2) Teaching technological literacy in the classroom can be enhanced by a practical emphasis on "the way things work," particularly for the non-science and non-engineering student. There is often too much emphasis upon abstract principles, e.g., "nuclear energy," and not enough about the ways in which science/technology impacts daily life, e.g., nuclear energy powerplants.

3) Technological literacy ought also to emphasize how scientists and engineers solve problems, particularly (a) the effectiveness of scientific reductionism to break down large problems into more manageable smaller parts, and (b) the emphasis engineers place on pragmatic problem solving, rather than the intellectual debates of the humanities.

4) One important observation was that scientists and engineering students tend generally to be optimistic about the future. Social criticism and reform movements tend more to come from the humanities and social sciences, while engineers are more likely to believe that specific problems can have successful specific solutions when enough time and effort is put to them. The implications of this observation were not explored but the subject seems to have potential.

5) Technological literacy is a particularly good point of entry into other major core educational subjects, notably globalism and multiculturalism. Today's world is bound together primarily through a scientific and technological culture that is becoming universal. As technological literacy makes students aware of the power of technology in their lives, they can also better understand the place in global and diverse world for their nation, their culture, their communities and themselves.

The group also agreed that there is an urgent need for data on why students find some courses and subjects more attractive and others less so. And outcomes assessment is essential to identify how successful we are in creating technological literacy in the classroom. More data is essential.

FACULTY ISSUES/LOGISTICS

Marian Visich, Jr.
SUNY-Stony Brook

The breakout session on faculty issues and logistics discussed the problems associated with getting faculty interested in teaching courses in technological literacy and the logistics of introducing technological literacy courses into the curriculum on a given campus.

For colleges with an engineering unit, it is necessary that the engineering faculty be involved with the development of and the teaching of technological literacy courses to have a successful program. The technological literacy programs at Brown, Penn, Stanford, Stony Brook, and Yale were initiated in the engineering colleges in the early 1970's when engineering enrollments declined. This provided the engineering college the opportunity to teach non-engineering students and to increase the student FTE taught by the engineering faculty. In the late 1970's and early 1980's, engineering enrollments increased dramatically, resulting in large class sizes and increased work load for the faculty. Engineering enrollments peaked in 1983-84 and have declined since then. It is projected that engineering enrollments will decline through the mid 1990's. This may once again lead to a favorable environment for offering technological literacy courses to satisfy faculty teaching load. It was pointed out by several Deans of Arts and Sciences that it was difficult to get cooperation from their engineering deans, at the present time, to develop technological literacy courses to satisfy general education requirements. The problems of stimulating cooperation between departments in the typical College of Arts and Sciences were also discussed.

In most colleges and universities, the faculty reward system is based upon research publications and funding, and teaching courses for majors. It was pointed out that this is especially true in a small liberal arts college where the number of faculty in an engineering and/or science department is small. Many of the participants recommended not getting young faculty involved in the technological literacy movement as it was a perfect way to torpedo a young faculty member's career and to make him unemployable. Experienced senior faculty members with established research careers are good candidates for offering technological literacy courses if they are interested in a career change. Selected retired industrial engineers could also become involved. These individuals would bring a wealth of experience and knowledge into the classroom.

Two of the critical factors in developing the technological literacy course for liberal art students are that the faculty member is interested in the subject matter of the course and that the material be presented at a level to match the background of the students. Based upon the professional background of the individual faculty member, successful courses have been developed in communications technology, biomedical engineering, microelectronics, bridges and structures, and the exploration of space. Many of the courses were initially team taught to reduce the course development time. Yale University has a unique scheme for teaching technology literacy courses. Time is scheduled for a three-credit course in the morning and for one in the afternoon. The semester is divided into three parts and a total of six one-credit courses are offered during the available time slots. This has attracted many junior and senior faculty members to participate as their time commitment is for only 1/3 of the semester. A student is required to take any three of the one-credit courses to get credit for the course.

There were limited discussions on the availability of funding for technological literacy programs and on the available curriculum material. It was pointed out that the National Science Foundation funded the workshop and had several representatives at it. NSF funding is available for curriculum development and laboratory equipment for technological literacy courses. Williams College was successful in receiving NSF funding for Larry Kaplan's course on forensic science for the development of curriculum materials and laboratory equipment.

During the past decade there has been a wealth of curriculum material for technological literacy courses. The Sloan Foundation's New Liberal Arts Program has developed a monograph series and book series which can be used as text material for technological literacy courses. Reports from the Office of Technology assessment and the National Academy of Engineering have been used as text material in many courses.

REFLECTIONS ON TECHNOLOGICAL LITERACY

David R. Reyes-Guerra
Accreditation Board for Engineering and Technology

The Accreditation Board for Engineering and Technology (ABET) and its predecessor, the Engineering Council for Professional Development (ECPD), have been concerned with "technological literacy" for many years. This topic did not have a high priority, however, because ABET concentrated its limited resources on matters that affected its main concern: accreditation. Under the leadership of Russel Jones, 1987-88 ABET president, ABET elevated the issue of technological literacy to its immediate priority list. Although this issue is ancillary to straight engineering practice, we consider it vital to the understanding of the engineering profession. Thanks to generous support from the National Science Foundation and the continued interest and dedicated leadership of Russel Jones we were able to hold this conference and provide an opportunity to investigate how best to serve the public and the engineering profession by increasing the technological literacy of everyone, especially those in higher education institutions who are pursuing programs that eventually impact on technology.

The engineering profession must be involved in the effort to increase technological literacy in this country. It is vital not only to the health of the profession but to our continuing national competitiveness, as well.

Let us be simultaneously cynical and truthful for a moment. Engineers work with facts; let us consider some of those facts. The engineering profession cannot take on the technological literacy campaign alone. We simply do not have the numbers of faculty or the funds to do a major public relations or advertising campaign. If only we had the resources of Ford or some of the beer manufacturers!!! All the engineering colleges, 325 at the latest count, 290 with accredited programs, account for 30,000 faculty members who run the full spectrum from instructors to tenured full professors. These men and women are already addressing a student population in the millions. How much time could they dedicate to this effort? There are more than 3,500 colleges and universities with millions of students. We are a very small force in the total spectrum of higher education.

We must find new ways of disseminating the information and materials already collected. The populations we would like to influence immediately are the liberal arts community and the non-technological populations in higher education. Later, we would like to focus on the National Science Teachers Association and the large number of students who are coming up through the high schools. We want to reach them! Our student population exceeds 40 million, and there are over 18,000 high schools. Think of the numbers we are talking about. How can we realistically handle this volume? How can we multiply ourselves to cover all concerned publics? How many of our colleagues could and would be interested in participating in helping to carry out a technological literacy campaign?

I would like to have David Billington's lecture given to a million high school students, and another million in college--not just one lecture but a series of lectures illuminating what we mean by technological literacy. Who can we get to sponsor such an event? How realistic is it to expect one issue, such as "structures" or "bridges," to represent the entire field of technology?

It is very difficult even to conceptualize the magnitude of the field we are trying to impact. That tells us that the self-imposed load on the engineering profession to address technological literacy is tremendous. Can we expect to handle this vital issue with our present resources? How can we impact the publics we need to relate to, and how prepared are they to give their own time and effort to become technologically literate?

Thanks to committed individuals like Dr. Goldberg and organizations like the Sloan Foundation, millions of dollars (a necessary, but proverbial grain of sand) have been infused into this project. A lot of people have given tremendously of their money, resources, commitment, and effort for technological literacy. Has the effort been successful? Where do we go from here?

Yes, the effort has been extremely successful in spite of the overwhelming odds. Humans, it is said, can move mountains, and some of you are moving the mountain of illiteracy.

Look at the reality of the numbers I mentioned to you. Then, envision the task of bringing the technological literacy issue to the general public and the project shows itself as a monumental, mind boggling effort. Do we have the funds, can we get the funds, do we have the people, can we get them to dedicate themselves to this enterprise? All these are questions we must pose. We have simply taken the first step; there are many more to take, but we cannot wait, we must follow. Some of you have shown the way and have taken that first step. It is up to the rest of us to move ahead and help you in furthering your scope of involvement.

For myself, I liken bringing the world technological literacy to a religious crusade. The zeal and commitment of a few, sometimes a handful, can change the world.

We must rely on others from other disciplines and professions to help you carry the message and assist with the work. You in the engineering education community may develop the courses, you may develop the material, but someone else with some other kind of vehicle must be found that is sufficient to carry the message to the vast numbers that must be reached. Let us be realistic about what we can do and what we are going to do. Let us set realistic goals. It is hoped that this workshop will set the tone, help delineate the problem, and set us on a path to positive accomplishments. I would give you the charge to really look at the total picture and how we can realistically influence the rest of the world to understand the technological outlook or point of view concerning the problems that beset humanity. Many of those problems have a technology base.

ABET recognizes the promotion of technological literacy as both the mandate and the duty of the profession. In ABET, twenty-six engineering societies come together to share common problems related to education. ABET's main responsibility is accreditation, and those of you in engineering colleges are very familiar with ABET through the accreditation process.

Our membership is the entire profession through the curricula-responsible engineering societies, and you, as educators, have a part in ABET through your membership in professional or technical engineering societies. We must awaken the engineering societies to their responsibility for carrying a public message not only about the value of their own disciplines but on the value of technological literacy itself. Our engineering societies are not really as involved as we would like to see them.

You, as educators who are working in the area of technological literacy, should call upon the technical and professional societies to enlist their commitment to technological literacy. Your own faculty is not enough. Look at the large numbers we must make aware of our new "religion"--technological literacy. The colleges add up to over 3,500, and that is one of the publics we must influence.

Can we imagine some way to multiply at least a hundredfold the effect of the efforts made by Steve Cutcliffe, Dave Billington, John Truxal, and so many others? How can we multiply the commitment and the activity of all of you? Perhaps we should declare a new world crisis, a global war, and get 24-hour coverage by CNN!!!

At today's session let us devise a way of working on these issues. Let us abandon the old way of doing things. Let us set the agenda for the future....

Let me call your attention to President Bush's message on education. It is a very comprehensive paper which addresses, among other things, technological literacy. Those of you in leadership positions in engineering education will find several concepts he expresses that will be useful to you during your conversations with state legislative bodies and other governmental agencies. I also recommend a paper, "Towards a US Technology Strategy," published by the NSF, Eric Bloch, the director of NSF, that describes what measures can be taken to develop a U.S. technology strategy. Many of the issues central to technological literacy can be discussed in terms of national competitive strategy, and you will find them in this paper.

Let us think in terms of what I said earlier. We have to imagine new methodologies, new ways of communication. ABET President Leslie F. Benmark, who spoke earlier, said that what we need in engineering is an "L.A. Law"--in reference to the appeal of TV and its great communications ability--and, of course, ECPD (the fore-runner of ABET) said that years ago. We need a television show that portrays engineering. Television is a powerful medium, and a good way of communicating. However, not everythone I know conveys a good image or communicates well on camera.

I know a very, very powerful and fascinating individual who addressed some of us a couple of days ago. I and others in the audience were enraptured. His colleagues subsequently told me that although he is a fantastic live lecturer, his videotapes are not as effective. He himself, agrees with that evaluation.

Perhaps instead of using professors in our videotapes, we should use trained actors to deliver our message. Instead of you speaking, use an expert who is really good at communications. He can read your script.

One of the best films I have seen recently that illustrates this situation is on Escalante, a high school mathematics teacher in South Los Angeles, California. He is from Bolivia and has worked miracles in his school mathematics program. I have met him and was very impressed with his approach to motivating young people to "like math." He was praised by the President, and named outstanding teacher in the United States. They made a film on his teaching. The actor selected was not Mr. Escalante but an actor, Edward James Olmos. Even though the film was biographical, Mr. Escalante could not play himself in his everyday activities. Why? He projects differently on film. How many cases do we know of others portraying the person being featured, even though that person is able to play himself?

After seeing the amount of work and research Russel Jones and some of you put into this conference (demonstrated by the large lists of reference material), I am certain we need a "clearinghouse." There is a vast amount of material that we must catalogue, review, and classify. We not only need a clearinghouse, we need to create a group that is able to look at the existing material and objectively evaluate and criticize the many items. We need a group to look at different parts of the entire bibliography we have available and decide which are most favorable and proper for helping with technological literacy. We must be able to catalogue based on age and education of intended audience . on area or field of coverage. We must look at gaps that must be addressed.

Many years ago a national effort with a high school course was developed, "The Man-Made World." This came from Bell Laboratories and AT&T. Dr. Ed Davis and Dr. John Truxal were the principal authors. This effort was followed by the series on the "World of Manufacturing" and the "World of Construction" from Ohio State University.

Neither of the above efforts, for one reason or another, ever accomplished its objectives. There is a move to generate some course material that can be given in the seventh or eighth grade that will substitute for the industrial arts (shop) or home economics course. This is intended to bring about a respect and understanding of technology in the students. We can call this an attempt to promote technological literacy. The other purpose of these courses is to develop a liking for science and mathematics study.

In New York we have done the same thing. We now have a mandated program in the seventh grade on technological literacy. All youngsters in the State must take this special course which has been put together by course specialists. I understand some engineering professors helped to develop this course. Although it is a mandated course, it has not been adopted by New York City.

We must identify instruments by which we can communicate with the world at large. Possibly the most difficult task is providing vehicles by which others--not necessarily we--can do the work. With high schools and other schools we must help by developing the material that others can use. Sufficient numbers of engineers are not available to do this work. We must prepare to have others deliver "our" message.

Consider the limitations I have been talking about all along. The numbers game controls our effectiveness. We cannot communicate with the entire world in the same way we customarily teach engineering in the classroom to our own students. We need new structures, new methods, new paradigms. Dr. Bugliarello reminded us last night of the health situation in this country. The numbers were staggering, and worst of all he was talking about life and death. He did a thorough job. He talked about the technology involved in the health field and the millions, if not billions of dollars and millions of people involved. Is technological literacy something we should push for the forty million Americans who cannot afford health insurance? Should we worry about technological literacy for the large retired segment of our population? Should we teach technological literacy to middle-aged students returning as adults to college?

When we talk about the NSF and Sloan, we are considering the current funding sources in this country for this vital concern. Should the Conference Board and other such organizations be forums in which we talk about what technological literacy means? The Conference Board is made up of the chief executive officers of leading manufacturing concerns in the U.S. Should General Electric, Chrysler, General Motors, IBM, Xerox, Lutron, or any of the others who have a lot of trouble with the level of technological literacy among their employees be interested in helping us help you to bring these ideas to fruition? We keep talking about the need to have a technologically literate workforce. Should we rely entirely on the valiant efforts made by the foundations that always help the engineering education effort? Should we not think in terms of letting the large corporations which rely on a technologically literate work force contribute financially to this effort? What you are doing is of great benefit to these companies. The results are not immediate, but they will show longstanding, permanent results after a generation of young people have gone through the experience of education for technological literacy.

Industry complains about our workforce. They do not simply mention the selfish work ethic of most employees (the proverbial "union" problem with innovation), but over and above that is the complaint that most workers are not able to do the work in an intelligent way simply because they do not understand the basic principles; they are not technologically literate.

The education of most members of the labor force is not geared to being in the skilled or semi-skilled workforce. Education from kindergarten through the senior high school level is oriented toward a liberal arts background. Even vocational/trade schools are not geared to answer the needs of industry, and, furthermore, there are very few of them relative to the "academic" or "comprehensive" schools. We eagerly copied the European model of education but failed to adopt their vocational/trade education. Workers in this country have to be reeducated in the major industrial concerns and other companies. Technological literacy would make the difference in all segments of our population as we freely compete with the rest of the globe in our technological world.

Good questions for you to answer in the next hour. These next points are very germane to what we are talking about.

How can the technical and liberal arts components on campus be encouraged to work cooperatively with you and together to generate appropriate programs in technological literacy? You must stress the fact that even though they do not realize or accept it, the liberal arts and sciences have a technological component.

One of the prompters to our involvement and why we sought the help of the NSF and leaders such as John White to support us and Russel Jones to take the leadership of this conference is the success ABET/ECPD had with getting the liberal arts and humanities to help engineering. We thought that that success could also be replicated with engineering influencing liberal arts, the humanities, and the social sciences.

The Association of American Colleges (AAC) undertook a major research program to determine "clusters" in the social sciences and humanities (SS&H) that would give the depth and breadth that the ABET engineering accreditation criteria demanded and satisfy the SS&H representatives. ABET was seeking guidance for the engineering programs with regard to the sixteen semester credit hours or the one-half year in SS&H that are specified in the criteria.

The SS&H experts that AAC brought together agreed to design various clusters. They all agreed to this exercise even though they felt that sixteen semester credit hours provided a very short window to attempt "breadth and depth." To them, twenty-four to thirty hours was a minimum.

Dr. Joseph S. Johnston, Jr. from AAC guided this work. Two publications came out, one entitled Unfinished Design and the other An Engineering Student's Guide to the Humanities & Social Sciences. The former is a comprehensive book containing all the research information, and the latter is a guide for general distribution among students. Over 70,000 copies of the Guide have been distributed and successfully utilized.

Based on the needs of society and of the world to answer the sense of national competitiveness, should not we in engineering and those in liberal arts and sciences urge the adoption of technological literacy as a requirement in their curricula?

The regional institutional accrediting agencies should also require that all undergraduate educational programs have a technological literacy component. We live in an era of technology, and our citizenry should be technologically literate. We are committed to prepare a more informed citizen to address congressional and political leaders at both federal and state governments on matters relating to everyday life. It would be helpful if those leaders were more technologically literate. We should make all necessary efforts to convince the people in liberal arts that they need to give their students some background in technology if they are to be properly prepared for the leadership positions of tomorrow. The college level is where most work needs to be done in technological literacy as the college graduate is geared to occupy positions of intellectual leadership.

I spoke a while ago with Stephen Cutcliffe, and I asked him if historians look down at him and at other historians who deal with technological literacy subjects such as history of technology. He said no, and that these areas are well respected. I wonder how the other faculties in a comprehensive university feel about their peers being interested in areas that reflect on technology.

How many philosophers, politicians, writers, artists, and sages from the past reflected upon technology and its effect on humanity? Research on this topic should be attractive to faculty members from a number or fields. Karl Marx and Sigmund Freud, to mention two opposites, dealt with technology in many of their writings.

The timeliness of courses and subjects is essential to a successful curriculum. The attractiveness of engineering should be manifest to all students, especially our own, if they receive a course in technological literacy early in their college careers. We should offer technological literacy material to our own students as they join the engineering college. Just-in-time education should involve this area and should be an incentive for the student to remain in our programs. The attrition rate in engineering, of highly qualified students in many cases, can often be attributed to the deception of their not being taught any engineering subjects for one or two years. The student, who is eager to become an engineer, wants to be exposed to engineering from the very beginning. An introduction through a technological literacy course would answer this real need.

We have a tremendous challenge ahead of us. Let us get together and pool our efforts to show the rest of academe that it is true that **HUMANS CAN MOVE MOUNTAINS** but that you need **TECHNOLOGICAL LITERACY** to get started.

COURSEWARE NEEDED

Paul T. Durbin
University of Delaware

This report assumes, and builds upon, a workshop on existing courseware. That earlier workshop, conducted by David Billington, put on display once again Billington's brilliance in elaborating the ideal for technological literacy courses. Elsewhere, Billington has spelled out the foundation for an excellent technological literacy course (or program):

> An engineering work, such as a bridge, must be designed in accordance with scientific principles, and the goal of such design is efficiency, the greatest safety with a minimum of materials. But a bridge makes no sense unless we see it also in terms of the society that caused it to be built. The social imperative of a bridge is economy, the greatest utility for the least cost. We need as well to see such works in terms of the humanistic impact as revealed by the responses of painters, poets, and social critics. Do these structures stir our imagination and give us a sense of wonder?[3]

A significant part of the workshop on existing courseware focused on the package put together by the New Liberal Arts group,[10,11,15] of which Billington has long been one of the most innovative and prolific members. Also mentioned, however, were NASTS publications,[4] the Lehigh curriculum newsletter, Science, Technology and Society,[13] and the Society for the History of Technology's published collections of syllabi.[12]

With so much already available in terms of technological literacy courseware, someone might wonder what we had to talk about in a second workshop on courseware needs. But as things turned out we had plenty to talk about--and not only complaints about existing courseware. In the remainder of this report, I give my personal impressions of some of the needs people like ourselves have been talking about.

More and Better Case Studies

A number of case studies exist that are useful in teaching technological literacy,[1,5,6,7,8,14] and there are even some tangentially-related case study textbooks,[2,9] but in my opinion there could never be too many good booklength case studies. If they are well done they provide all the complexity of technical needs, social, economic, and political constraints, and cultural reception that we saw David Billington hold up as the ideal, above.

The ideal teaching arrangement, in a technological literacy course or program using complete case studies, would be interdisciplinary. An engineering faculty member (or a working engineer, biomedical engineer, etc., as the case demands) would be the best sort of person to convey to typically naive students the technical demands of an engineering or other technological project. For the rest, to present issues of cultural, social, and political complexity, not just any humanist or social scientist or manager will work out well. It probably should be someone accustomed to team-teaching--and preferably accustomed to teaching in a team that involves scientists, engineers, or other technically-trained people.

Even in this ideal situation, there can still be problems with the utilizing of full-length case studies in a technological literacy course. There are tensions of all sorts: between humanities professors' interests and students' needs, between and among faculty members (or pre-college teachers) with different backgrounds, between students with varying career orientations and the "undeclared" who have not yet decided what to do with their lives, and between and among the various organizations and institutions which may end up employing the students or being influenced by their votes as citizens in the future.

One final note about the case studies that might be developed for teaching in this mode. Some advocates of technological literacy worry that case studies of technological catastrophes or of misuses of technology will give students the wrong impression. Most bridges do not fall down; most technological ventures are reasonably well managed (and some are even exemplary in ethics terms); and so on. In my view, both positive and negative case studies are needed, and liberal arts students can learn a great deal about the complexities of engineering and technological development from either sort. If negative impressions are conveyed to the student, it may be that that comes from the biases of the professors rather than from a well done case study.

Films and Videos

A few visual presentations of technological developments, engineering projects, technical disasters, and legally or ethically ambiguous cases involving engineers or other technical personnel are beginning to be produced and distributed--for example, in the Nova series (among others) on TV. Some members of the technological literacy movement feel strongly that our greatest need lies here--that film and video presentations will give non-engineering students a more effective picture of the scope and complexity of engineering in the modern world than anything else could.

I would not disagree with the need for such productions; in particular, they might be more useful than classroom-oriented materials in helping to achieve technological literacy among out-of-school adults. (The same is true for other visual or dynamic media presentations--for example, in the best science museums, which often do a better job of presenting technological processes and gadgets than of presenting complex scientific developments.) But I would propose two caveats, and the first is related to the case study approach dealt with above. In a sense, a well done film, television series, or video on technology is a case study. It is simply a matter of a different medium (possibly more effective for some audiences?).

A more important caveat has to do with the quality of the production of visual presentations of engineering and technology ventures. It is extremely important that the production be in the hands of competent (and preferably imaginative and creative) professionals. But it is also extremely important that the producers, actors, etc., really know engineering and technological work. Presenting stiff characters or caricatures in stylized, and unrealistic plots or situations or settings can do as much bad as good. In my view, the same standards should be held up for media presentations as for print case studies--and in both cases the standards should be professional, and they should be high.

Interactive and Remote-Site TV Presentations

Another new approach that has been considered is the transmission of a successful classroom experience from one location to another where technological literacy education is not otherwise feasible. It has been suggested, for example, that one of David Billington's presentations (even one of his courses or a similar course taught by someone else) might be made available on tape or by interactive TV to classes at schools across the country. Other similar suggestions have been put forward, especially to multiply the successful experiences of the small number of outstanding teachers (engineers and others) available for technological literacy courses.

This innovative idea has its problems, however. And the most obvious problem is the one that holds back innovations of this sort in other areas of education as well. That is the problem of loss of the intangibles involved in good teacher-student interaction in the classroom. Interactive TV and other ingenious technological gimmicks may partly make up for this loss, but outstanding teachers (including outstanding technological literacy teachers) have so far shown only limited interest in the distance-teaching idea (and especially in distance teaching without an excellent on-site assistant of some sort), presumably for this reason. Still, it is a possibility.

Computer Software

Finally, among this limited set of new ideas for technological courseware, there is the possibility of utilizing an increasing (?) base of computer skills among liberal arts students to improve technological literacy. One example, possibly far-fetched, might be to involve at least some non-engineering students in a computer-assisted-design course (probably one specially designed for them rather than a regular course already in the curriculum for engineering students). If feasible, such a course might give non-engineering students some idea of what engineering design is all about (if not of the complexities of the rest of modern engineering and technology). And imaginative engineering professors may come up with better examples of software useful for educating non-engineering students in technological literacy.

Conclusion

Some of the ideas discussed here may strike the reader as purely speculative as well as far-fetched. In any case, it is not up to a group of workshop participants at a technological literacy conference to come up with the materials that will be needed for successful technological literacy courses. In all probability, future innovations will come from innovative technological literacy teachers. That is what has happened, for instance in the New Liberal Arts experience as well as in the experience of those who have contributed syllabi to the Lehigh curriculum newsletter (and similar ventures). Good courseware is developed by good teachers. That is the way it has always been, and that is likely to be the way it will be in the technological literacy movement.

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CONSORTIUM APPROACH

Stephen H. Cutcliffe
Lehigh University

The breakout group assigned to discuss possible mechanisms for enhancing Technology Literacy, including the idea of consortia, began by agreeing that it was important "not to reinvent the wheel." The group also agreed, however, that the wheel needed to be "trued up" somewhat and the current impact of TL multiplied. As the discussion developed, individual suggestions and ideas fell into three main areas--the identification of organizations currently active in TL, suggestions for groups that should be encouraged to become involved in promoting TL, and proposals for actual mechanisms and activities for encouraging TL. The group concluded the breakout session with a proposal for a three-pronged action agenda.

Currently Active TL/STS Organizations

We began our discussion by identifying key organizations already involved in technology literacy and STS-type activities. Included were:

ABET	- Accreditation Board for Engineering and Technology
AAC	- American Association of Colleges
ASEE	- American Society for Engineering Education
NASTS	- National Association for Science, Technology & Society
NSPE	- National Society of Professional Engineers
NSTA	- National Science Teachers Association
CUTHA	- Council for the Understanding of Technology in Human Affairs
NLA	- New Liberal Arts Program (Sloan Foundation) Engineers for Education

Also included among the groups already involved in the Technology Literacy/STS area are those policy and historically oriented divisions of the professional societies, e.g. the Society for the Social Implications of Technology (SSIT) of the Institute of Electrical and Electronics Engineers, the Liberal Studies Division of the ASEE, and the Center for the History of Chemistry (CHOC) of the American Chemical Society and the American Institute of Chemical Engineers, Committee 120, History of Concrete of the American Concrete Institute, and the Historic Landmarks Program of the American Society of Civil Engineers.

Target TL Groups

After singling out those organizations already involved at one level or another, the group focused its attention on identifying target groups which might be encouraged to become active or perhaps more extensively involved in the technology literacy area. Among those organizations that might assist in promoting TL are the National Association of State Universities and Land Grant Colleges (NASULGC), the American Council for Academic Deans (ACAD), the Council of Colleges of Arts and Sciences (CCAS), the National Conference of Academic Deans (NCAD), and the state government education departments and the National Governors Association (NGA). Organizations that might be approached for financial support as well as promoting TL include the National Science Foundation (NSF), the National Endowment for the Humanities (NEH), and the Foundation for the Improvement of Post Secondary Education (FIPSE). The Public Broadcasting System (PBS) was also identified as a potentially important vehicle for spreading TL awareness through programming focused on engineering and technology.

Mechanisms

Following the identification of target groups for supporting and extending TL awareness, the discussion shifted to suggestions for mechanisms both for promoting TL and for actually incorporating it into the curriculum.

A. Common Core Curriculum Requirement.

One of the broadest based approaches would be including a TL requirement within the notion of a common core curriculum as suggested by the Boyer Report of the Carnegie Foundation.

B. "Top Down" CEO approach.

For an effective impact, the group also felt it was important to approach the problem from the "top down" as well as from the "bottom up" through individual faculty. If college and university presidents and provosts can be convinced of the importance of TL, this will facilitate its incorporation into the curriculum. For example, if ABET as part of its exit interview were to suggest to college/university presidents the importance of TL and to inquire what their engineering colleges were doing to promote TL among non-technical students, this would go a long way toward promoting TL activities.

C. State and Regional Consortia.

Another important area for concentrating attention is at the state and regional educational level. A number of states such as New Jersey already have focused programs often utilizing consortia arrangements in the TL/STS area. By working through the National Governors' Association and state education departments, it might be possible to expand this level of activity.

D. Press Coverage and Public Outreach.

For TL to become effectively understood, it will be important to expand educators' and the public's awareness through more extensive publicity. It would be helpful to have TL both promoted and covered at all major professional and educational meetings. Here organizations like the NSPE, through its publicity staff, would be particularly well suited to assist promoting and providing coverage of technology literacy-related sessions and events. Similarly at a more local level, individual college and university departments of journalism (perhaps especially science/technology writing programs) could assist in promoting awareness of technology literacy generally, as well as of specific activities and events.

Summary Resolutions

Following the identification of the above wide-ranging ideas, the group concluded its discussion by suggesting three short-term action items:

A. 1993 should be declared the year of Technology Literacy and that TL should be a major theme for all professional society annual meetings.

B. ABET, NSPE, and other appropriate engineering societies should promote TL as a worthwhile activity by 1) encouraging engineering deans to have faculty develop and offer appropriate TL courses and 2) working to make TL a general education requirement for all undergraduate programs.

C. A short 1-2 page executive summary of the conference should be sent with an appropriate cover letter to the heads of all appropriate engineering and academic societies and organizations. In addition, the report should be circulated to all appropriate university administrators, including presidents and provosts and both engineering and liberal arts deans.

FUNDING DIRECTIONS

Samuel Goldberg
The Sloan Foundation

Let me begin with some general issues raised during our session:

1. Before funding there has to be a decision made on what one wants to do. Our workshop discussions have covered a very large number of issues and possibilities for future activities. Any proposal for funding will need to be fairly sharply focused. There is much work yet to be done in answering the question: Funding for what?

2. Whatever is proposed, it should have support from the highest levels within the university. Engineering colleges and others, including funding agencies, need to be confident that the program being planned has the approval and support of key university administrators.

3. Decisions need to be made about who will do the work on a given campus. Are these projects, pedagogical and curricular in nature, appropriate for junior as well as senior faculty members? Here, as at other such gatherings, we have heard much about teaching and research, criteria for tenure, and the university reward system. A proposal will need to be realistic and not assume that there is likely to be a major shift in the way universities and colleges of engineering see their mission or conduct their business. Luckily, only relatively few committed and excellent faculty members are needed to get things started on campus and even to have a significant impact.

With respect to funding sources, the group identified four main categories:

Government
Private Foundations
Industry
Colleges and Universities

Government

The leading player here is the National Science Foundation. Within the NSF Directorate of Education and Human Resources, Division of Undergraduate Science, Engineering and Mathematics Education (USEME), there are two programs particularly relevant for our interests: Undergraduate Curriculum and Course Development; and Undergraduate Faculty Enhancement. The former supports improvements in introductory courses and includes a concern for scientific and technological literacy of the nonspecialist student and the general public. The latter emphasizes short courses, workshops, and other hands-on experiences for participants. From what we have heard, NSF is particularly interested in proposals that involve under-represented minorities and women, develop continuing cooperative relationships among universities, four- and two-year colleges, industry and other concerned groups, encourage research faculty to become engaged with K-12 issues in our schools, and pay attention to dissemination so that good ideas can be spread beyond the grantee institution.

The Department of Education and the National Endowment for the Humanities should also be approached. Governmental agencies, such as NASA and EPA, may be particularly interested in the development of courses on special topics, for example, space technology and waste management. Finally, mention was made of state and local governments. They do not have much money these days, but their interest in improving science, mathematics, and technology education in the public schools (and in the education of school teachers) may lead them to consider support or at least some level of cooperation in an appropriately targeted project.

Private Foundations

This gives me an opportunity to say a few words about the Sloan Foundation's New Liberal Arts (NLA) Program. Now almost ten years old, it has involved grants totaling about $22 million to thirty-six undergraduate colleges and a dozen universities. Faculty workshops, conferences, course development, writing projects, and many other activities have been supported, all designed to increase the attention paid in the undergraduate liberal arts curriculum to technology and quantitative reasoning. A Resource Center for the NLA Program, located at SUNY-Stony Brook and directed by John Truxal and Mike Visich, publishes and distributes a monthly newsletter, collects and disseminates syllabi, teaching modules, and other course materials, and serves to bring news of NLA activities to the wider public.

Given the technology thrust of the program and the fact that most undergraduate colleges do not have engineering departments, the involvement of dedicated university engineering faculty has been an important feature of the program. Four such persons who have contributed in major ways to the NLA program are participating in this workshop: John Truxal, Mike Visich, David Billington, and Barrett Hazeltine. Although not as many as we would like, there are nevertheless quite a few engineering faculty members interested in the pedagogical and curricular problems associated with bringing a knowledge of what engineers do and how they do it to undergraduate non-engineering students. The liberal arts colleges appear to be interested, although it is always difficult to get naw courses into an already crowded curriculum. Student interest is not a problem at all, and this should be an encouraging fact for those planning next steps following this workshop.

Grant-making in the NLA program has come to an end for the Sloan Foundation. We are now focusing on dissemination of results. In that connection, I want only to mention the value of establishing networks involving both engineering and liberal arts faculty members and the crucial importance of having effective written materials that can be put in the hands of those who would like to experiment and develop general education technology courses on their own.

Those of you who would like to learn more about the NLA program and NLA publications (syllabi, monographs, and books) are encouraged to write or call directly to John Truxal or Mike Visich at the SUNY-Stony Brook Resource Center.

It is our hope that what has been done within the New Liberal Arts program will prove useful as a foundation on which to build. There is much yet to be done and this workshop is an important step along the way.

There are, of course, many other foundations besides Sloan that are interested in science and technology and could well be approached once decisions are made about next steps. In our discussion, mention was made of the many small local foundations that could be helpful and therefore should not be forgotten.

Industry

That industry has a stake in technology education is clear. Imaginative projects promoting technological literacy may therefore attract some level of support from technology-based companies and their associated foundations. The group felt that this was a source of funding worth pursuing.

Colleges and Universities

Two main points were made during our discussion. First, it is necessary as this technological literacy project develops to find some means of demonstrating the serious commitment of colleges and universities to its aims. Tangible financial or other support is one way to do this. Second, the leadership of the engineering colleges is crucial in any project emerging from this workshop. However, the involvement of engineering faculty cannot be perceived merely as a temporary reaction to a dip in student enrollment, only to be abandoned as soon as the number of engineering applicants increases.

Let me take this opportunity to make one final remark about long-term arrangements and short-term action following this workshop. To maintain momentum and keep the interest of the many constituencies represented at this workshop, it would be well to plan for continued consortial activities. These could include development of a resource center for the gathering and dissemination of relevant information, perhaps via an electronic bulletin board. The sponsorship of writing projects for the preparation of new course materials could be an important activity. Periodic meetings, workshops, and conferences to help the network of interested and informed participants grow would also likely be part of such long-term arrangements.

Short-term action is also necessary. One possibility is for a few large universities to make commitments for a major project. The engineering college on each campus would not act alone, but would join with arts and sciences, medicine, nursing, business, education, and other parts of the university to develop a campus-wide technological literacy program for students. Two-year colleges and even the public schools in the region could be involved, especially if the university school of education were convinced that such a program would serve an important role in teacher training. The development and funding of at least one such project would serve as an important existence theorem for the entire community, showing that what we hope will turn out to be a wide-ranging national movement is feasible and worth the significant effort it will require.

STIMULATION OF PROGRAMS

Bethany S. Oberst
Southwest Missouri State University

The participants who attended this session were Cherno, DeLoatch, Feisel, Gorenstein, Jennett, Kulacki, Meier, Oberst, Scholz, and Wasow.

Charge to the Committee: Address the following Issues and Questions

Are additional programs in technological literacy needed?

If so, what national-level stimulation would assist in their initiation and growth?

How can the technical and liberal arts faculty on a given campus be encouraged to work together to generate such programs?

Are special incentives needed to encourage faculty/students to become involved?

How should we package what we are calling technological literacy so that the converted can sell it on their own campuses?

How can we reach the CEO's of various colleges and universities to enlist their support?

Five over-arching concerns emerged during the session:

1) We should all be aware that this project to encourage the study of technology in the undergraduate curriculum of colleges and universities is nothing less than an effort to change the cultural climate in the United States. While many people in this country are viewing technology with reservations and sometimes even hostility, we are suggesting that technology is an appropriate and critically important area which urgently needs to be addressed in the undergraduate curriculum.

2) In thinking about shaping activities designed to promote technological literacy we need to be aware that we are in fact working with three potentially distinct audiences: the general public; teachers and students in K-12 education; and the world of higher education.

3) When working to promote the study of technology on an individual campus, two strategies should be weighed in light of the general environment of the institution. One approach is to work to change general education requirements by the addition of courses in technological literacy, and the second is to promote grassroots efforts by even a small number of enthusiastic and dedicated faculty.

4) The first professional degree in engineering--unlike the other professions--is the baccalaureate. This unique pattern makes issues of parity and comparison between the engineering undergraduate curriculum and that of liberal arts majors problematic.

5) There is a lack of clear consensus about who should actually do the work of designing and teaching technological literacy courses: engineering faculty or arts and sciences faculty. A team approach may be the most effective in the long run.

Questions and Suggestions

1) Are additional programs in technological literacy needed?

- Yes.
- We must determine whether we can defend additional programs as a needed/required component of the undergraduate education of every student.

2) What national-level stimulation would assist in the initiation and growth of additional programs in technological literacy?

- Hold a yearly conference of approximately fifty invited guests to discuss central issues.
- Organize a nation-wide commemoration of an event related to technology. This would be in the mid to late 1990s and be used as a vehicle to raise public awareness of the role of technology in the United States, past, present, and future, and the need for greater technological literacy.
- Work hard to gain the backing of the Association of American Colleges. Other organizations whose endorsement would be useful are the Association of American Universities, the Council of Colleges of Arts and Sciences, the American Council on Education, the National Association of State Universities and Land-Grant Colleges, and the

American Association of State Colleges and Universities.

- Write an article for publication on the back page of The Chronicle or for the AAC's publication Liberal Learning.

- Write a monthly column for The Chronicle on "interdisciplinarity" in higher education.

- Arrange for the Council of Colleges of Arts and Sciences to invite the engineering deans to meet with them in a session organized around the issue of technological literacy.

- Approach the National Science Foundation (particularly the Social Science and the Education and Human Resources directorates) for funds to promote team approaches to technological literacy.

- Aim at finding a charismatic national leader who could stimulate change.

- Create an exciting video series on technological literacy, the history of technology, and engineering, to be shown on PBS.

- Develop the model of John Leehart's series of minute-long programs on PBS aimed at technological literacy.

3) How can the technical and liberal arts faculty on a given campus be encouraged to work together to generate programs in technological literacy?

   - Seek dollars for arts and sciences faculty fellowships in engineering colleges.

   - Encourage grassroots initiatives by individual faculty members interested in technological literacy.

   - Initiate a program of faculty development to persuade engineers to become involved in technological literacy courses.

   - Retrain liberal arts faculty so that they can teach technological literacy based on their areas of specialization.

   - Arrange for liberal arts faculty to be in more direct contact with engineering faculty.

- Deal directly with deans who can effect change on their level.

4) Are special incentives needed to encourage faculty/students to become involved in technological literacy?

   - Yes.

   - Make six-to-nine hours of coursework in technological literacy required for the baccalaureate degree.

   - Work through institutional committees to effect change.

   - Stress the art of engineering through professional associations.

   - Create two-to-four engineering fellows, recruited from arts and sciences faculty, to develop programs modeled on David Billington's program at Princeton.

5) How should we package what we are calling technological literacy so that the converted can sell it on their own campuses?

   - Consider changing the term "technological literacy" using value free language in order to make the concept more palatable across broad audiences on campus.

   - Be aware that the general public has growing concerns about the issue of sustainable technology.

6) How can we reach the CEO's of various colleges and universities to enlist their support?

   - Do a survey of presidents and provosts who are themselves engineers to find out what they have been able to accomplish in technological literacy on their own campuses.

   - Work through national associations where campus CEO's congregate.

   - Aim at getting the support of provosts through conferences.

RESOURCES AVAILABLE

CURRENT PROGRAMS SURVEY

Programs Survey Report

During the 1960s Americans recognized that they needed a better understanding of the impact science and technology had on society in order to protect the environment, to limit the discord caused by change, to sustain political and cultural values, and to insure the full participation of citizens in the economic and political system. In the following years, universities and colleges, foundations, professional and higher education organizations, and state and federal governments have engaged in a wide variety of innovative activities to improve the science and technological literacy of a broad range of individuals. At the academic level, these activities led to the introduction of new programs and courses at many colleges and universities. The growth of interest and actions to improve scientific and technological literacy can now be viewed as a national movement for educational reform.

Technological literacy involves an understanding of basic technological systems and processes, the mathematical and scientific foundations of technology, and the use of this knowledge to make intelligent, well-informed decisions and choices about technological issues. In particular, it includes an understanding of technology innovation; technology assessment and risk-benefit analysis; interaction between technology, science and industry; and related environmental, economic, social, agricultural, military, and international issues.

Thus far, the literacy programs that have been developed are diverse, often divergent, and normally focused on science. Technological literacy has not received the same emphasis, study, funding, or curriculum development as science literacy. Over the last five years, efforts to overcome this serious shortcoming have come from individuals and organizations loosely identified with "science, technology and society" (STS) curricula and programs. While credit should be given to those involved in STS, technological literacy continues to be a relatively unknown quantity in higher education curricula.

NEED FOR THE CURRENT STUDY

In the early part of the last two decades, a number of colleges and universities in the United States started new programs under the broad title "science, technology and society." Only a part of the STS programs were devoted to technological literacy aspects. The degrees offered, faculty and student involvement, and funding at various institutions varied greatly, based on the objectives of individual institutions.

Based on the various definitions and the institutional perspectives on technological literacy, it is clear that boundaries of the field are frizzy and there is no agreement on how to define the technological literacy and hence, to identify the institutions offering technological literacy to individuals. Ample evidence of this is the growth of diversified programs and the large volume of research and articles produced in the last decade under the title technological literacy, which can only be identified remotely with technological literacy objectives.

It can be argued that academic programs serve many purposes. But the aim of the technological literacy movement is to impart technological literacy to liberal arts or humanities majors. However, the STS movement focuses on enriching the education of engineering/science students with knowledge about the historical, social, and political dimensions of technology. The underlying assumptions of these programs may be that we cannot separate the technological literacy and social aspects of technology.

In spite of pedagogical activities over the last two decades, little has been done in a systematic way in the technological literacy field.

Furthermore, from a review of program experiences and observations made by faculty involved in technological literacy curricula, a number of serious problems can be identified that deserve further study and improvement. Some of the major issues are discussed below.

Science/technological literacy curriculum is unrelated to degree granting.

In most cases the courses have been added to a list of traditional course offerings, rather than integrated into a degree program. As such, science and technology courses for liberal arts majors depend upon attracting students with popular subjects and flexibility in degree requirements. Students select science and technology courses at random, and this has several implications: 1) the courses are poorly integrated, resulting in a survey of science, technology and society issues; 2) the courses can have little relation to the student's degree; 3) the courses stay on an introductory level, avoiding in depth investigation or thinking; 4) no specific number of courses are required, and therefore, evaluating literacy is impossible; 5) courses are based on an individual instructor's area of science/technology interest, and are thus often narrowly focused; 6) courses are unrelated to the students' standing, lower or upper level.

Science and technology programs for liberal arts majors are satellites in the institution's organizational structure.

If science and technology programs are not integrated into the organizational hierarchy, several consequences are possible: 1) the intellectual contribution of the program to the institution is marginal; 2) few take the program seriously; 3) the decision making process disregards the program and can undermine the legitimacy and purpose of science and technology courses for liberal arts students.

What it means to be interdisciplinary and what qualities instructors should have are poorly understood.

Faculty members often must be re-educated in order to effectively communicate with students from various degree tracks or their colleagues in the program. In addition, teaching materials must be processed to integrate the ideas, concepts, and skills necessary for science/technology curricula. Program faculty must learn to coordinate and communicate across disciplinary lines.

STUDY OBJECTIVES

In order to answer various issues raised about the status of technological literacy programs, this study, supported by the National Science Foundation has the following main objectives:

- To know the current status of technological literacy programs;
- To identify the principal objectives of these programs;
- To assess the extent to which these programs are training the students in the technological literacy field;
- To know about the enrollment of students and the faculty members involved in these programs;
- To know at what level technological literacy is imparted and;
- To identify the major problems faced and prospects for the future.

METHODOLOGY

Identifying the Programs

To explore the various issues involved a general literature survey of the STS programs, seminar and workshop activities, and the research materials published in the field was carried out.

Based on the literature survey, major institutions involved in the STS field were identified. These institutions were asked to send the information related to STS programs offered by them. From the information received and the earlier literature survey, an acceptable definition of technological literacy was formulated. This intensive library research was conducted to identify colleges and universities that offer major or minor programs, or at least a few courses in the field. To maintain a focus on the technological literacy component, this study did not consider programs that can be identified as policy or scientific literacy oriented. The main emphasis was also placed on colleges and universities that have both liberal arts and engineering schools on their campus. From the library research and information received from the colleges and universities, twenty-eight institutions involved in the technological literacy field were identified. Appendix 1 gives the list of the institutions and their major characteristics.

Data Collection

To collect the information about technological literacy related programs, a questionnaire was prepared requesting information about the objectives, degrees offered, fields of study, credits required, student's strength, faculty and their academic background, areas of research interest, funding issues, publications, and future plans of the program. Questionnaires were mailed to the program coordinators of the twenty-eight selected institutions. A sample copy of the program questionnaire is contained in Appendix 2. Of the twnety-eight programs, thirteen program heads completed and returned the questionnaire. Five program heads replied that either they had withdrawn their programs, or that they do not come under the scope of technological literacy programs.

Analysis

The information asked in the questionnaire was classified into various headings as follows: 1) Origin and organizational structure; 2) Program objectives; 3) Academic programs offered; 4) Student and faculty participation; 5) Funding issues and; 6) Areas of research concern. Since the collected data has a significant portion of descriptive information, the data were not coded and tabulations were done manually. The following discussion focuses on the analysis of the data by subject headings as discussed above.

Objectives of Programs

In spite of the diversity among the programs in organizational structure, courses offered, student and faculty involvement, and research conducted, there is considerable similarity among them in terms of their stated objectives.

However, some universities have broad based objectives like providing and/or examining social, economic, political, philosophical, and environmental aspects of technological developments, while some others have sharply focused objectives like providing quantitative, problem-solving, and technological literacy skills to its students. A critical examination of the various program objectives indicates three main overlapping objectives. They are:

- To study and examine the social, economic, and political implications of technological developments;
- To understand the ethical, and value dimensions and ideas involved in science, technology and society;
- To promote an understanding of concepts, processes, and products of technological developments and to enhance the quantitative and problem-solving capabilities to understand and evaluate the impacts of new technological developments.

At this stage it is important to recognize the fact that the last objective is considered to be the main focus of the technological literacy movement. However, most of the programs surveyed heavily emphasize the first two objectives, and some even do not include the third objective in their programs. Nonetheless, some of the liberal arts colleges, such as Grinnel College and Wellesley College that received large grants from the Sloan Foundation under the New Liberal Arts program have very sharply focused technological literacy objectives. The main objective of Sloan's New Liberal Arts program is to include some kind of study of technology and the technological process into liberal arts education.

Origin and Organizational Structure

It is interesting to note that the major universities have been the first to recognize the importance of science and technological literacy and also to establish programs broadly titled "science technology and society" (STS). Within the study group, Cornell University's program for studies of science and technology, established in the year 1969, was the first in the leading American universities. This was followed by Pennsylvania State University in 1970, Stanford University in 1971, SUNY in 1972, and Lehigh University in 1972. NJIT established a program as early as 1977, but later it was modified, and a new version was started in the year 1987. In addition, there were several liberal arts colleges that established science and technology studies programs in the early 1980s and later years. Unlike the major universities, most of the liberal arts colleges introduced technological literacy courses or programs with the help of major NLA program grants from the Sloan Foundation.

The organizational structure of the programs clearly indicates the broad scope and interdisciplinary nature of STS programs. Most of the programs established in the early 1970s are now independent programs/departments. However, STS programs at some colleges and universities are jointly offered by two or more traditional departments. Furthermore, some programs are housed in engineering departments (as in Lafayette College), while others are housed in history departments (as in Reed College). STS programs at most of the small colleges are part of the existing traditional departments and are headed by a faculty in the regular department.

<u>Academic Programs and Orientation</u>

With respect to the academic programs offered, there is a wide gap among the various institutions surveyed. Some of the universities offer the highest possible degree, that is the Ph.D., while some others have only a few courses listed under the program for students from other traditional departments. Based on the objectives of the individual programs, some offer social science degrees, some science, and some others even engineering degrees.

Irrespective of the above differences, a few institutions (for example, Rensselaer Polytechnic Institute) focuses on ethical and value issues in their programs. Most other programs emphasize the social, historical, and political aspects of technology, and only a few have courses that can be exclusively identified as technological literacy oriented. The majority of the courses offered at all levels have less technological literacy component in them. It may be surprising to note that some courses developed for liberal arts students are now enrolled in by engineering students. Some programs offer STS degrees for engineering majors. This may indicate the need for engineers with additional skills to deal with various aspects of new technology. Similarly, social science based programs may serve as a technical complement to the increasing influence of science and technology on all aspects of human life. However, the majority of the courses/programs were developed to cater to the increasing needs of liberal arts students.

Science and technology studies at Rensselaer Polytechnic Institute is the only program that offers degrees in STS from the baccalaureate to the doctoral level. However, this program is designed for students who have academic backgrounds in such broad areas like natural sciences, social sciences, engineering, humanities, or science and technology studies. Furthermore, as pointed out earlier, this program has a strong emphasis on the ethical, value, and political dimensions of technological development.

The STS program at Pennsylvania State University offers an undergraduate minor as well as a doctoral degree. Introduction of a bachelors degree in STS in the next two years is in the planning stages.

Other major universities, namely, Cornell University, Stanford University, Lehigh University and NJIT offer undergraduate degrees in the STS field. However, individual programs focus on diversified issues like biology and society, history and philosophical aspects, and human values in technological development. In addition to the above; Cornell has an undergraduate concentration in STS, Lehigh has an STS minor, Stanford has a Ph.D. degree offered through regular departments, and NJIT has an M.S. policy studies listed under its STS program.

SUNY offers an M.S. degree in Technological Systems Management and a minor in Technology and Society, as well as exclusive courses that can be identified as technological literacy oriented. SUNY's department of Technology and Society, through its NLA Center, devotes a significant portion of its academic activities to technological literacy curriculum development.

Other colleges, namely, Lafayette, Grinnel, and Colby College have minor programs in science and technology studies. Dartmouth and Wellesley Colleges offer only a few courses in STS as part of their undergraduate curriculum.

The total credits required at various institutes for bachelors degree varies from 72 to 124 with the average being 110 credits. An average of twenty-seven core credits are required for a bachelors degree. For minor programs at the undergraduate level, an average of eighteen credits are required in the various institutions surveyed. Most of the programs surveyed encourage their students to take courses in other departments to fulfill the degree requirements.

Student and Faculty Participation

Unlike the traditional programs, fewer students are enrolled in STS programs at various colleges and universities. Only SUNY, NJIT, Stanford, and Cornell universities have a relatively large number of students enrolled in major programs. During 1990, forty-seven students enrolled in the BA program at Cornell, twenty-four at NJIT, and twenty-five at Rennselaer Polytechnic Institute. SUNY had the highest number (120 students) enrolled in its Master's program in the year 1990. However, the total number of students enrolled in one or more of the technological literacy related courses is significant even when compared with the total university strength. For example, at Lehigh University, out of a total of 6,500 students, approximately 1,000 are enrolled in technological literacy related courses. At Rensselaer Polytechnic Institute, 2,000 out of 5,500 students are enrolled in these technological literacy related courses. Other small colleges like Lafayette and Grinnel have less than ten students in their programs.

Due to the interdisciplinary and interdepartmental nature of the STS programs, the total number of faculty involved in teaching and research is difficult to ascertain. However, from the analysis it is clear that no program has more than six full-time faculty members based in the program. SUNY has the largest number, followed by Stanford and Pennsylvania State University with faculty numbers six, five, and four respectively. In terms of total faculty (full-time + Joint), Pennsylvania State University has more than 54 faculty followed by Lehigh University with forty and Stanford University with twenty.

<u>Funding Issues</u>

Of all the programs surveyed, SUNY has the largest budget which is $1.5 million, followed by Cornell University with $0.75 million, and Pennsylvania State University with $0.5 million. NJIT, Wellesley, Grinnel and Colby Colleges have funding levels less than $150 thousand.

Except for Wellesley College (75%), most of the programs receive less than 50% of its grants from outside sources. SUNY receives 40% of its grants from non-profit organizations. It is interesting to note that most of the programs responded that it will be possible for the department/program to continue all essential activities even if the external funding sources are withdrawn. However, major programs like SUNY and Pennsylvania State University felt that it is not possible to continue all of their essential activities without external funding.

<u>Areas of Research Interest</u>

Research interests of the programs surveyed can be mainly classified into four different areas. They are: 1) Energy/environmental policy; 2) Historical/social aspects of science/technology; 3) Ethical and value issues in science/technology and; 4) Communications.

Cornell University, NJIT, and Lafayette College focuses on all of the above four identified areas. Most other colleges have research interests in historical/social aspects of science and technology. Besides the philosophical and policy aspects of technology, Pennsylvania State University focuses on technology literacy for citizens. Similarly SUNY is engaged in research activities leading to curriculum development in the technológical literacy field.

Conclusions

Today, the importance of technology in the daily lives of individuals and in society is growing at a rapid rate. In a world already reshaped over recent decades by nuclear weapons, new technologies of transportation and communication, and a host of innovations in agriculture, medicine, and many other fields, the pace of change gives no sign of slackening. The capabilities of our political, social, and economic institutions will be limited if a large portion of its citizenry are not aware of the implications of these changes.

After two decades of technological literacy activities, several colleges and universities are now offering teaching and research programs to a wide range of individuals. No course or program can boast success unless it fulfills the needs of its students in particular, and society in general. Even though there is no single institution that has technological literacy as its only objective, most of the programs' objectives overlap into this area. It is clear that the whole technological literacy field is embedded into loosely identified "science, technology and society" (STS) curricula and programs. This study was conducted with the hope that a critical examination of STS curricula and programs along with other related courses and programs at various universities in the United States will help to identify the progress made, problems ahead, and future prospects for technological literacy programs. The major findings of the study are summarized below.

This study clearly indicates the wide range of institutions involved and the diversity of science and technological literacy programs offered by them. Even though a broad title like "science, technology and society" (STS) does not place emphasis on any one area of concern, the individual programs surveyed have placed heavy emphasis on science literacy, as well as, on the social, historical, and political implications of technological developments. Though the importance of science and technology was equally recognized in the early 1970s and 1980s, even after two decades, technological literacy has not received the same emphasis as scientific literacy. If technological literacy involves an understanding of technological systems, processes to make well-informed decisions and choices about technological issues, than most of the programs surveyed, to a large extent, do not fulfill this objective. An understanding of social, historical, or philosophical aspects of technology w.thout an understanding of mathematical and scientific foundations of technology does not contribute to the technological literacy of an individual.

If technological literacy is mainly for liberal arts students, then most of the programs surveyed offer little opportunity in this direction. Because of the small number of students involved in these programs, it clearly indicates that there is a need to increase the number of courses and programs offered in this field. An examination of faculty involvement clearly indicates the need for greater participation by engineering faculty at all of the institutions surveyed. Although funding from external sources appears to be a problem, most of the programs depend on university or state funding.

Based on the present study, the following recommendations can be made:

- There is an urgent need to recognize technological literacy as a field and to clearly define its objectives.
- To enhance the quality and quantity of the technological literacy component, new courses and programs that have a very sharp focus may be developed.
- There is a need to restructure the existing programs that have broad and overlapping objectives.
- Technological literacy courses might best be introduced at the undergraduate level in the liberal arts program.
- As far as possible, technological literacy programs that have a sharp focus need to be housed in engineering schools. This not only helps to focus, but also encourages faculty participation from engineering schools.
- Wherever possible, faculty from engineering schools should actively participate in the interdisciplinary STS programs to have a greater impact on the technological literacy component.
- There is an immediate need to identify new areas of research along with differentiating the technological literacy areas of research from the current areas of research. This helps to identify and strengthen technological literacy as a field.
- External funding sources need to be explored in order to have practical implications of the technological literacy field.
- To encourage student participation, incentives in the form of assistantships at the graduate level or scholarships at the undergraduate level, need to be provided.

Table 1: Programs and their Major Characteristics

College/University	Department/ Program	Degrees Offered	Field	Areas of Research
1. Colby College	Science and technology studies	Minor	Science and tech. studies	1. Computer aided music 2. History of science 3. History of technology
2. Cornell University	STS	BA/BS	Biology and society	1. Agriculture and society 2. Ethical issues in science/technology 3. Risk mgnt. and communications 4. Science and technology policy 5. Social studies of science/technology
3. Dartmouth College	—	Few courses	—	—
4. Grinnell College	—	Minor		1. Technology transfer 2. Telecommunications
5. Lafayette College	Technology studies minor	Minor	Technology studies	1. Energy policy 2. Engineering ethics 3. Risk analysis and communications
6. Lehigh University	STS	BA minor	STS	1. History/ philosophy of science/tech. 2. Sociology/politics of science/tech.
7. NJIT	STS	BS MS	STS Policy studies	1. Communications 2. Environmental policy 3. Ethics 4. History of technology 5. Media and technology
8. Pennsylvania State University	STS	BA/BS Minor Ph.D	STS STS STS	1. Philosophy of technology 2. Technology literacy for citizens 3. Technology policy
9. Reed College	History department	Few courses	—	—
10. Rensselaer Polytechnic Institute	Science and technology studies	BS MA/MS Ph.D	STS STS STS	1. History of science and technology 2. Public policy 3. Politics of STS 4. Science policy 5. Values studies
11. Stanford University	Values, technology science and society	BA/BS	STS	1. History of technology 2. Philosophical and ethical issues 3. Technology and aesthetics 4. Technology and third world develop.
12. SUNY	Technology and Society	Minor MS	T and S Technological systems management	1. Curriculum development 2. Educational computing 3. Environmental and waste mgnt. 4. Technology assessment
13. Wellesley College	Technology studies	Few courses	—	—

UNIVERSITY OF DELAWARE
Newark, DE 19716

TECHNOLOGICAL LITERACY PROJECT

Questionnaire

I. Program Information: ____________________

1. Name of the university/college ____________________

2. Name of the department/program ____________________

3. Address of the program ____________________

____

____

4. Name of the department/program head ____________________

5. Name of the person completing this questionnaire ____________________

6. When was the department/program started ____________________

7. What are the goals and objectives of your program?

8. What degrees does your program offer?

Degree	Field	Total Credits Required	Total Credits Required in Technology Literacy Related Courses	Credits of Required Core Courses If Any	Year the Program Was Started
BA/BS					
MA/MS					
Ph.D.					
Others (Please Specify)					

9. How many technological literacy related courses are listed in your department/program? (Including core, electives)

10. What are the admission requirements of your program?

Degree	Required Degree	Field	GPA	Other Requirements If Any
BA/BS				
MA/MS				
Ph.D.				
Others (Please Specify)				

11. What are the future plans of your department/program? (Please indicate the new courses planned, programs proposed, and changes in the existing programs.)

II. Student Information:

1. What was the approximate total enrollment of the university during the academic year 1988-89?

BA/BS ______________ Ph.D. ______________

MA/MS ______________ Other Courses ______________

2. How many students are enrolled in your program?

Year	BA/BS		MA/MS		Ph.D.		Other Courses	
	F.T.	P.T.	F.T.	P.T.	F.T.	P.T.	F.T.	P.T.

F.T.: Full-time P.T.: Part-time

3. What percentage of applicants for your degree programs are generally accepted for admission?

Year	% Accepted
1989	________
1988	________
1987	________

4. Please indicate the number of students with undergraduate degrees in the following fields:

Field	MA/MS	Ph.D.
Humanities		
Social Sciences		
Natural Sciences		
Physical Sciences		
Engineering		
Others		

III. Faculty Information:

1. What was the number of faculty at the beginning of the program?

Full-time ____________ Research faculty ____________

Joint faculty ____________ Others ____________

2. Please indicate the number and discipline of the faculty involved in the program during the 1989-90 academic year.

Qualification	Full-time		Joint-faculty		Research faculty		Others	
	Engr.	Non-Engr.	Engr.	Non-Engr.	Engr.	Non-Engr.	Engr.	Non-Engr.
Masters								
Doctorate								

IV. Grants/Funds:

1. What is the current budget of the department/program? ______

2. What percentage comes from outside grants/contracts? ______

3. Please indicate the percentage of external funds from each of the following sources:

State ______ Profit Organization ______ Other ______

(Please Specify) ______

Federal ______ Non-profit Organization ______

4. Will it be possible for the department/program to continue all essential activities if the external funding sources are withdrawn?

Yes ______ No ______

5. Please indicate the total number of students financially supported by your program during the academic year 1989-90.

Type of Support	BA/BS	MA/MS	Ph.D.
Full assistance			
Partial assistance (Tuition Support)			
No assistance			

6. Do you expect there to be a significant increase in student financial support in the following years?

Yes ______ No ______

V. Research Activities:

1. Please indicate the number of faculty involved in technological literacy related research activities.

Full-time ______ Research faculty ______

Joint-faculty ______ Others ______

2. Please list the major areas of research interest in the department/program.

1. ______
2. ______
3. ______
4. ______
5. ______

3. What was the total amount spent on research activities during the year 1988-89?

4. Do you expect a substantial increase in the research funds in the following years?

Yes __________ No __________

5. Please list the major research grants received during the academic year 1989-90.

VI. Publication:

1. Please list the faculty publications during the 1989-90 academic year in the technological literacy field. (Attach additional sheets if necessary)

Title	Faculty (Author)	Source of Publication (Journal, publisher etc.)

2. Does your program have any regular publications such as newsletters, magazines, etc.?

Yes __________ No __________

If yes, please list them by title.

____

____

____

____

3. Does your program maintain any special collections, libraries or other resources relating to these fields of study? (Please describe).

TECHNOLOGICAL LITERACY CURRICULUM MATERIALS

NLA WRITTEN MATERIALS

The New Liberal Arts (NLA) Program of the Alfred P. Sloan Foundation has the goal of assisting in the introduction of quantitative reasoning and concepts of modern technology within liberal education. The program is based on the conviction that college graduates should have been introduced to both areas if they are to live in the social mainstream and participate in the resolution of policy issues.

The Sloan Foundation made major grants under the NLA Program to thirty-six colleges and eleven universities to conduct seminars and workshops, and for the development of curriculum materials. The Foundation believed that the success of the New Liberal Arts Program would ultimately depend upon the availability of written materials to serve as curriculum materials for new courses.

Grants were given to faculty at Princeton, Stony Brook, and other schools, to prepare monographs from their courses. These monographs were intended to present a few case studies or to make a presentation of specific technological concepts of themes. Other faculty members who had developed successful new liberal arts courses began to prepare textbooks. Eventually, the Foundation worked with MIT Press and the McGraw Hill Publishing Company to publish a series of books on the New Liberal Arts. A review of textbooks published under the NLA Program can be found in the annotated bibliography section of this report.

A listing of monographs published under NLA support follows. Those with greatest applicability in technological literacy programs are reviewed. NLA monographs are available from the Research Foundation of the State University of New York, Stony Brook, NY 11794. Also following is a listing of extended syllabi available through the NLA program.

NLA MONOGRAPHS

1. Alfonso M. Albano, William Case and Newton H. Copp. Forces and Forms in Large Structures. Bryn Mawr College, Grinnell College and the Claremont Colleges respectively, 1990. 122 pages.

    This monograph introduces the basic techniques used by structural engineers in the analysis and design of bridges. Part One presents the design concepts such as stress, strain, bending moment, and shear force in experimental form. Application of these concepts in the design of the

Eiffel Tower and the George Washington Bridge are discussed. Included are a number of exercises for the students to solve in order to understand the design of Salginatobel Bridge. Part Two is a structural study of the Felsenau and Ganter Bridges. In addition to analysis of forces it gives historical dimensions in the design of concrete bridges. Part Three discusses the need for freeways and introduces the basic principles of design such as various loading conditions, bending moments at various sections, and prestressing.

All sections of the monograph are presented with diagrams and photographs of the various structures discussed. It is a very useful volume for the introduction of the basic principles of design and the challenges faced by engineers in the design of bridges.

2. David E. Henderson. Air Pollution and Risk Analysis. Trinity College, 1990. 103 pages.

3. David P. Billington and Alfonso M. Albano. Episodes in American Invention: The Steamboat and the Telegraph. Princeton University and Bryn Mawr College, 1990. 81 pages.

Presents the technical and scientific view of the steamboat and the telegraph in the early years, and the major roles they played in transforming the nation into a technological society. The first part focuses on the historical developments of the steamboat, from the 1780s to the 1820s, as an engineering object. Some basic ideas about reciprocating engines, horsepower, boiler explosions, and motion of the ships through the water are also presented. The second part of the monograph presents the development of the telegraph. A major portion is devoted to topics like Volta' batteries, Ohm's law, Oersted's experiments, and Henry's works on electromagnets and telegraphs. It also evaluates the social impact of this invention.

4. John G. Truxal. FeedBack Automation. SUNY at Stony Brook, 1989. 84 pages.

This monograph introduces the concept of feedback and its applications in automation. It describes how engineers use feedback to force the system to behave in the desired way. Some of the examples used to illustrate feedback include the control of tunnel traffic and the economic system. Another section presents historical perspectives on the development of feedback. Also included is the application of feedback in cases like the cardiac pacemaker and in supermarket automation. A number of problems from all walks of life is also included in the monograph as part of student exercises.

5. John G. Truxal. Probability Examples. SUNY at Stony Brook, 1989. 87 pages.

6. Jonathan Hallstrom and George B. Todd. Hypercoustics: An Introduction to Sound and its Digital Representations. Colby College and Middlebury College, 1990. (Only in diskette form (2 diskettes).

7. Joseph D. Bronzino and Ralph A. Rorelli. Knowledge Based Expert Systems. Trinity College, 1989. 122 pages.

This module presents the basic concepts underlying the field of artificial intelligence, and highlights the techniques employed in the development of knowledge-based expert systems. It provides a brief history of AI evolution and discusses the three major branches within it. A major portion of the monograph deals with organization of expert systems, their impact in commercial, scientific, medical, and industrial domains, knowledge representation approaches, and the knowledge engineering process. Finally, it addresses the advantages and disadvantages in the use of expert systems.

8. Kirk Jeffrey. Pacing the Heart. Carleton College, 1991. 116 pages.

9. Marian Visich, Jr. Bar Codes and Their Applications. SUNY at Stony Brook, 1990. 56 pages.

This monograph presents the development of the six most popular bar code symbologies. In particular, it deals with bar code symbols, their applications, and working principle of optical scanners. Brief descriptions of Wand Scanners, Fixed Beam Scanners, and Moving Beam Scanners are also included. The six bar codes covered in this module are Universal Product Code, European Article Numbering, Interleaved Two of Five Code, Three of Nine Code, Codabar and the United States Postal Service Code.

10. Morton Tavel. Information Theory. Vassar College, 1989. 54 pages.

11. Newton Copp. Vaccines: An Introduction to Risk. Claremont Colleges, 1989. 78 pages.

12. Newton H. Copp and Andrew W. Zanella. The Electrification of Los Angeles: Engineering, Science, and History. The Claremont Colleges, 1990. 84 pages.

This is a case study of technologies introduced in Los Angeles between the 1880s and the middle of the twentieth century to provide electricity for the growing population of that city. Specific fossil fuel-powered plants and hydropower plants are selected and studied for their historical and technical significance.

This monograph introduces selected scientific principles associated with major technological advances in electric power production. In particular, it deals with different forms of energy, concepts of power and efficiency, laws of motion, laws of thermodynamics, and a general description of steam engines, generators, and turbines. A discussion about the search for alternative energy sources presents the key issues such as recent advances in science and engineering, the abundance and limitations of energy sources, and our value system. An interesting feature of the monograph is a list of visual materials available to support the lectures.

13. Vincent H. Smith. The Economics of Technology. Montana State University, 1990. 125 pages.

14. Victor A. Stanionis and Hugh Berberich. Computer Music: Science and Technology of a New Art. Iona College, 1989. 114 pages.

15. Warren Rosenberg. End Stage Renal Disease. Iona College, 1990. 84 pages.

EXTENDED SYLLABI

Arthur Steinberg and Christopher Craig. "Technologies and Cultures: Technologies in Historical Perspective." Massachusetts Institute of Technology.

David H. Roberts. "Introductory Astronomy." Brandeis University.

Donna Jo Napoli. "Phonetics and Phonology." Swarthmore College.

Edward W. Sloan. "The Shock of the Machine: Technology and Western Culture in the Industrial Age." Trinity College.

Harriet Pollatsek and Robert Schwartz. "Case Studies in Quantitative Reasoning: An Interdisciplinary Course." Mount Holyoke College.

Haim H. Bau. "Introduction to Technological Concepts Through Kitchen Experiments." University of Pennsylvania.

Jack S. Goldstein. "Technology and the Management of Public Risk." Brandeis University.

John Tomsich. "Technology in America, 1820 to the Present: Its Developments, Social Shape and its Effects." Reed College.

John P. Brockway. "Bioengineering and Health Technology: An Interdisciplinary Approach to Five Machines of Medicine. Davidson College.

Lyle H. Ungar. "Expert Systems: Applications of Artificial Intelligence." University of Pennsylvania.

Lawrence J. Kaplan. "Chemistry and Crime: From Sherlock Holmes to Modern Forensic Science." Williams College.

Michael S. Mahoney. "Technologies and Their Societies: Historical Perspectives." Princeton University.

Solomon R. Pollack. "World of Bioengineering: A Top Down View of Engineering for Freshmen." University of Pennsylvania.

Victor A. Stanionis. "Commercial Systems: An Interdisciplinary Approacn to Teaching Science and Technology to Business Students. Iona College.

*For more NLA course syllabi, please refer to the list of the NLA course syllabi published by Stony Brook Center.

TECHNOLOGICAL LITERACY PROGRAMS, ISSUES AND PROSPECTS

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ANNOTATED BIBLIOGRAPHY OF SELECTED BOOKS

The following is an annotated bibliography of selected books published recently and useful as ready references to the technological literacy field. The list includes all the books so far published jointly by the MIT Press and McGraw-Hill under the Sloan Foundation's New Liberal Arts Program. Several of the books were written as part of the Science, Technology and Society (STS) movement and hence, approach their subject matter from a broad interdisciplinary perspective. Richard P. Brennan's book is particularly useful in providing a solid background in basic principles of science and technology.

Brennan, Richard P. Levitating Trains and Kamikaze Genes. New York: John Wiley & Sons, 1990. 262 pages.

Intended to provide technical knowledge, this book gives a solid background on basic technological concepts and systems. It sets out to define what technical literacy is and explains basic concepts in space exploration, biotechnology, computer science, energy technology, and super conductivity. It also explores innovations and concerns in medical, environmental, transportation, and defense technologies. One interesting feature of this volume is the wide range of issues covered, some of which are hard to find in the current technological literacy literature. This is very useful as a textbook for the understanding of basic principles of science and technology.

Bronzino, Joseph D., et.al. Medical Technology and Society: An Interdisciplinary Perspective. Cambridge: MIT Press, 1990. 571 pages.*

This book explains the technological base of some of the most important innovations in medical technology and discusses the economic and ethical issues associated with their development and use.

It is divided into three parts. The first part deals with major technological, economic, and ethical issues associated with the changes that have taken place in the American health care system since the turn of the century. In particular, it deals with topics like how changing economic conditions, and federal and state programs affect development and adoption of new medical technologies. It also discusses cost-benefit analysis, assessment techniques for social costs, and analysis of the types of moral arguments that surround debates concerning the use of new medical technologies. The second part of the book examines the specific areas of medical technology such as cardiovascular technology, critical care technologies, computers in health care systems, and fundamental principles of several medical imaging modalities. The last part of the book focuses on contemporary ethical and social concerns raised by the highly technological character of modern health care.

Haskins, Loren and Kirk Jeffrey. <u>Understanding Quantitative History</u>. Cambridge: MIT Press, 1990. 366 pages.*

This book is mainly intended for historians and apprentice historians who have little background in mathematics, and for undergraduates who are taking history courses, whether they are history majors or not. It presents the various terms and symbols used by quantitative historians and teaches one how to analyze statistical charts and tables. In particular, it deals with statistical techniques like sampling, regression, and tests for statistical significance. Several practical examples are used to demonstrate the applications of quantitative techniques. This book is particularly useful for students interested in statistical applications in history.

Mark, Robert. <u>Light, Wind, and Structure: The Technology of Historic Architecture</u>. Cambridge: MIT Press, 1990. 209 pages.*

This book covers the technological underpinnings of development of new large-scale building types during the three historic eras: ancient Rome; the period of structural experimentation in High Gothic architecture; and the era of the great Renaissance domes. All of these periods had lasting impacts on architectural planning. It reinterprets technological precedents that are often misunderstood in contemporary architecture. It also presents some of the basic concepts of structural engineering such as tension, compression, stress and strain, conditions of support and shear failure etc. This text is aimed at the general reader as well as students of architecture and architectural history.

McGinn, Robert E. <u>Science, Technology and Society</u>. Englewood Cliffs, New Jersey: Prentice Hall, 1991. 302 pages.

This is an introductory study of science and technology in society with particular attention to the contemporary era in the West. Part One develops foundation materials useful for analyzing science and technology in society. It introduces science and technology as a field and discusses the general nature of science and technology in society. Part Two presents the influence of scientific and technological innovation on modern society. In particular, it deals with changes in individuals, institutions, and social groups, values and world views, and the international order. Part Three is an interesting discussion on how modern society has influenced scientific and technological developments. Issues of particular interests discussed include central agents of societal influence, types of influences, and the impacts of societal agents on modern science and technology.

Truxal, John G. The Age of Electronic Messages. Cambridge: MIT Press, 1990. 487 pages.*

Presents the ideas which underlie the technology of communication. It shows what scientific principles drive modern communications systems, what their potential danger are, and how they impact our lives. In particular, it provides accounts of the origin and utility of bar codes like those used in supermarkets and the postal system. It also describes the way electronic signals are formed and used in such systems as radio, television, navigation, and medical imaging. Not only is this a useful text for its mathematical and physical explanations, but also valuable for presenting the fundamentals and sociology of communications technology.

Volti, Rudi. Society and Technological Change. New York: St. Martin's Press, 1988. 279 pages.

Intended to be for use in courses about technology and society, this book presents perspectives, theories, and facts that will help the reader understand the consequences of technological change, as well as the forces that produced it.

It is divided into six parts based on specific dimensions of technology. Part One introduces the nature of technology, its settings and its limitations. Part Two describes the process of technological change. Specific issues discussed include invention and diffusion as social processes. Part Three presents the role of technology in the transformation of the work place. Parts Four and Five deal with communication and military technologies. They describe the basic techniques involved, and trace the economic, social, political, and religious consequences of these technologies. Some of the specific technologies discussed include printing, radio, and television. Part Six explores the interrelationship between technology and organizations, and the governmental control of technology. This book is practical in approach while discussing general processes. It is very useful as a general introductory textbook for technological literacy courses.

Wattengerg, Frank. Personal Mathematics and Computing: Tools for the Liberal Arts. Cambridge: MIT Press, 1990. 556 pages.*

Intended to teach students how to use mathematics to reason about a variety of real and important problems and how to use mathematics as a tool rather than as a concept to be studied in the abstract. It presents applications of personal computing in areas like politics, economics, environment, public health, and ecology.

The first part of the book contains eight programming projects whose aim is to teach, by example, True BASIC programming. Each project introduces several elements of True BASIC and several programming techniques. Together these projects provide a basic introduction to True BASIC programming and illustrate a variety of interesting applications and methods of computer-based quantitative reasoning. The second part deals with a number of applications of mathematics and computing to real problems. Student exercises are included.

Westrum, Ron. Technologies & Society: The Shaping of People and Things. Belmont: Wadsworth Publishing Company, 1991. 394 pages.

In recent times many textbooks and booklength case studies that approach technology from a historical perspective have been developed. There are a few published materials that approaches technology from the sociological perspective. This work is intended to fill that gap. Written to serve as an educational resource for undergraduate and graduate courses in "Science, Technology and Society" (STS), it covers basic concepts in the technology and society fields. Divided into five parts, contents are arranged in logical sequence to enable the reader to refer to his area of interest without the loss of continuity. Part One defines what is meant by technology, examines the interaction of technology and social systems, and presents basic definitions and issues. Part Two reviews two major schools of social theory about technology and four contemporary viewpoints. Part Three discusses the way technology is invented, designed, implemented and managed. Part Four presents the technological adaptation and the external effects of technology. Part Five addresses the ethical and value issues involved in technology and social change.

Wolfson, Richard. Nuclear Choices. A Citizen's Guide to Nuclear Technology. Cambridge: MIT Press, 1991. 467 pages.

Written to provide the background needed to make well informed choices about nuclear technology, it introduces the basics of nuclear energy and radiation, nuclear power and nuclear weapons.

The book is divided into three parts. Part One deals with the nature of the atom and its nucleus, with nuclear radiation, and with the fundamentals of nuclear energy. Part Two examines nuclear power, including our use of energy, the operation of nuclear power plants, nuclear accidents, nuclear waste, and alternatives to nuclear power. Part Three describes nuclear weapons, including their operation, their destructive efforts, delivery systems for getting them to their targets, strategies for their use or non-use, the feasibility of defense against them, and the prospects for controlling these weapons and preventing nuclear war.

*These were part of the NLA Program written materials

PROPOSALS

PROPOSAL FOR
TECHNOLOGICAL LITERACY CENTER AT ABET

- To be funded by external (non-ABET) grants and contracts

- Activities to include:

  - Information clearinghouse (database on programs, people, books, courseware, etc.)
  - Newsletter (successor to the Weaver?)
  - Ongoing efforts of NLA Center?
  - Stimulation/guidance of appropriate projects (e.g. textbook development)

- Personnel

  - Center director or co-directors (part-time)
  - Secretarial/staff support from ABET (% of time of specific individuals)
  - Advisory committee, with external chairman
  - Newsletter editor

- Budget estimate (per year): $100,000

  - Stipends for director(s), editor
  - ABET support personnel (including OH)
  - Operations (publications, mail, phone, travel, etc.)

PROPOSAL FOR
TECHNOLOGICAL LITERACY DEMONSTRATION PROJECT

- Three-year project, grant funded

- Activities to include:

    - Stimulate interest in development of technological literacy programs at colleges/universities

    - Conduct competition to select demonstration program institutions (approximately 10)

    - Obtain consultants to work with selected schools

    - Conduct workshops

        -- bidders conference
        -- selected institutions
        -- progress reports
        -- final results report to broad audience (at end of 3 years)

    - Manage the grant

        -- interface to schools
        -- interface to sponsor

- Personnel

    - Project director

    - Secretarial staff, graduate students

    - Consultants

    - Advisory committee

- Logistics

    - Grant to ABET/AAC, with funding to include support for ABET and AAC activities

    - RCJ as PI, funded part-time, with his secretary supported part-time, and graduate students

    - Seek support from NSF and private foundation(s)

- Budget estimate (3 year project) $ 1,800,000

    • Demonstration projects (10)

    • Consultants, advisory committee

    • ABET (indluding staff time, contract administration, OH)

    • AAC (staff time, OH)

    • Workshops

    • PI, Secretary, Graduate Students (including benefits)

    • Operations (phone, mail, travel, printing, supplies, etc.)