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ABSTRACT

This conference was designed to provide information on the development and implementation of seven undergraduate science courses primarily for non-science majors at Lehigh University, to examine what ought to be the objectives of courses such as these in the liberal arts curriculum, and to describe parallel efforts with similar educational objectives at other institutions. The Lehigh courses, which are taught on a continuing basis by senior science and engineering faculty, include: (1) chemistry for the consumer (chemistry); (2) regulation of public safety (metallurgy and materials engineering); (3) the factory of the future (industrial engineering); (4) tall buildings and urban design (civil engineering); (5) computer modeling of our world (chemical engineering); (6) mineral deposits, economics, and world politics (geology); and (7) a course designed to serve as an introduction to engineering as a problem-solving discipline linked to applications of scientific research and to economic, political, and social interests in those applications. An opportunity was also provided during the conference to assess the state of a science and technology literacy movement that has been steadily growing in power and influence since the late 1970's and to examine issues related to the development and teaching of science and technology literacy courses. (JN)

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Science, Technology and the Liberal Arts:

Report on a National Conference Held at Lehigh University

April 1-3, 1984

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In the Spring of 1984 Lehigh University was the site of a national conference entitled "Science, Technology and the Liberal Arts". The immediate occasion for holding this conference was a commitment by Lehigh to the National Science Foundation that Lehigh would disseminate the results of a NSF-funded curriculum development project initiated four years earlier through the now defunct NSF directorate for Comprehensive Assistance to Undergraduate Science Education (CAUSE). Lehigh chose to use the occasion to offer the attendees an overview of parallel efforts at other institutions working towards the same goals as those of Lehigh's project, namely, bringing science, mathematics and technology "literacy" into the liberal arts curriculum.

The Lehigh conference, then, was much more than a display of what Lehigh had done. It was an opportunity to assess the state of a science and technology literacy movement that has been steadily growing in power and influence since the late 1970s. At the moment, the key "players" in this movement are the National Science Foundation, the Congress of the United States, a growing number of state departments of education, the Sloan Foundation together with the corps of colleges and universities it is actively supporting in this area, and various national educational associations. Moving to play a more active role are the Association of American Colleges (representing some 700 liberal arts colleges), the Association for the Advancement of Science and, somewhat tentatively thus far, a number of corporate foundations.

The movement is being kept active, in part at least, by the prospect of hundreds of millions of federal dollars likely to be targeted for improving the level of competence of the American people in mathematics and science, primarily, and in technology secondarily. The activity reflects as well authentic concern over the adequacy of education at all levels in areas that are preconditions of excellence in science and engineering, insofar as these are conceived to be preconditions of national prosperity in the decades ahead. Such concern has been voiced in highly publicized reports of the National Research Council, the National Commission on Excellence in Education, the Carnegie Institute for Higher Education, the National Science Foundation, and the Sloan Foundation.[1] Earlier than these reports was the activity of a group of engineering educators organized into the Council for the Understanding of Technology in Human Affairs (CUTHA). Founded in 1979, CUTHA sponsored conferences at MIT (1980), Chatham College (1981), and the University of Maryland (1982), at each of which science, humanities and engineering faculty tried to articulate what it was about technology that liberal arts students ought to know, and how to teach it to them.

In retrospect, then, one can see a steady and rapid development during the past five years centered on calls for significant modifications to existing elementary, high school and college curricula on behalf of increasing competency levels in those quantitative and reasoning skills relevant to a wider public involvement with scientific research, applied science and engineering. The motives underlying these calls are diverse. Some reflect the same sort of anxieties that pervaded the calls for educational reform following the launch of Sputnik in 1957, now with our ally Japan joining the Soviet Union as an additional threat to our national well-being. Some motives reflect concerns about the ability of the American populace, in the absence of a deeper understanding of science and technology, to deal with the increasingly important roles in our society of science- and technology-related policy-making decisions. And some, doubtless, reflect, from a more purely academic perspective, concern about the adequacy of an educational system that does not equip its students with cognitive tools fundamental to an active involvement with powerful social and economic forces shaping their physical, social and political lives.

In the course of the five year development of this movement, the meaning of "literacy" in the terms "science literacy" and "technology literacy" has barely been specified. Nor has there emerged a precise specification of how this literacy is to be fitted into the liberal arts curriculum, or the high school curriculum, apart from global proposals for improving the teaching of science and mathematics and imposing more stringent course and competency requirements at all levels. Finally, there has been little sign that activists on behalf of science and technology literacy appreciate the distinctive character of course work in the humanities _vis-à-vis_ course work in science, mathematics and engineering. Where the latter are offered to self-motivated students who have to master course materials because they will be integrated sequentially into increasingly sophisticated technical problem-solvi ills they need to acquire, humanities courses have a mo use and "horizontal" character, and are keyed to acquiring . ative, rather than technical problem-solving, skills. Insoı s humanities students are required to take science and mathema ics courses, they generally lack interest and motivation, perhaps because they know that these materials will not be integrated nto their subsequent learning experiences or professional activities. Ignoring these distinctions virtually guarantees that new science and technology literacy courses will not readily be assimilated into liberal arts curricula, even if the new courses are imposed as requirements. For all of the sound and fury being expended, one would hope to achieve more than has been accomplished to date in those institutions that already require liberal arts students to take some number of existing, or specially designed general education, courses in physical science and/or mathematics.

Considerations such as these formed the backdrop for Lehigh's "Science, Technology and the Liberal Arts" conference, and informed Lehigh's own project in this area, "Elements of Technology in a Liberal Education". This project required the development of seven new undergraduate courses, to be taught by senior science and engineering faculty on a continuing basis and to be aimed primarily at students not majoring in science or engineering. Six of these courses were to be funded out of the NSF/CAUSE grant. The seventh was a "gateway" course that would serve as an introduction to engineering as a problem-solving discipline linked, on the one hand, to applications of scientific research and, on the other, to more parochial economic, political and social interests in those applications.

The courses chosen to be developed under the NSF/CAUSE grant were: Chemistry for the Consumer (Ned Heindel, Chemistry Department); The Regulation of Public Safety (Alan Pense, Department of Metallurgy and Materials Engineering); The Factory of the Future (Mikell Groover, Industrial Engineering); Tall Buildings and Urban Design (Lynn Beedle, Civil Engineering); Computer Modelling of Our World (William Schiesser, Chemical Engineering); Mineral Deposits, Economics and World Politics (Charles Sclar, Geology).

Each of the seven Lehigh courses was described at some length both in plenary and parallel workshop sessions at the conference. Participants were "walked through" the course development process, the internal and external evaluations to which each course and the project as a whole were submitted, the positive and negative experiences of the instructor and students, and the current syllabi. (Each course was taught twice before completing its development phase.) The workshop sessions were interactive discussions of the course objectives: format, texts and alternatives were described and argued in active exchanges. Here, as throughout the conference, the overriding objective was to provide participants with concrete and candid information that would be of direct relevance to their own curriculum planning efforts.

The non-Lehigh contributions to the conference, all plenary session presentations, were on: outstanding existing science/technology literacy courses, at Yale (Robert Wheeler and William Ralph Bennett), Columbia (Herbert Goldstein), and Brown (Don Avery); comprehensive science, mathematics and technology literacy programs underway, at Syracuse (Gershon Vincow) and Polytechnic Institute of New York (Donald Hockney); and the status of Sloan Foundation-funded projects, reported on by Leon Trilling of MIT, director of the regional resource center set up by Sloan to assist the New England and Middle Atlantic states institutions to which it had awarded curriculum development grants.

Over all this activity, and the 93 participants from 60 institutions who attended, hovered the "hidden agenda" of those who had steered Lehigh's "Elements of Technology in a Liberal Education" project: determining what ought to be the objectives of courses such as these in a liberal arts curriculum. We were committed from the beginning to the view that these needed to flow from the broader educational objectives of a liberal arts college rather than from the narrower instructional objectives of curricula for students majoring in mathematics, (physical) science and engineering. Unfortunately, it is all too often the case that current science and mathematics requirements for humanities and social science students impose on them courses of this instructional kind, and this is universally acknowledged to have failed to achieve literacy in these subject areas, whatever "literacy" means.

The conference's keynote address was thus deliberately chosen to highlight our concern about the terms under which new efforts were to be made to incorporate current conceptions of literacy in science, mathematics and technology into the arts curriculum, as well as to articulate what those conceptions were. The address was delivered by Dr. James M. Banner, Jr., historian, founder of the American Association for the Advancement of the Humanities, and Scholar in Residence at the Association of American Colleges in Washington, D. C. Dr. Banner noted the need for students to learn to "...understand science and technology as we have long sought to have them understand the other subjects of the course of study: to understand life." At the same time he noted this was only "one dimension of the problem" and that "the entire undergraduate curriculum is in need of overhaul." The challenge is "how to keep knowledge of science and technology from becoming just another specialty of an over-specialized faculty, manifested in just another set of electives in a curriculum overflowing with electives. The issue instead is how to have knowledge of science and technology permeate the curriculum throughout." He called for an understanding of both the nature of reasoning and the principal methods used in each of the major fields of science, engineering and mathematics and of how "each is a product of the social and symbolic configuration of culture." These studies in turn must be connected and fully integrated into, not just grafted onto, the undergraduate liberal arts curriculum.

By pre-arrangement, Lehigh's President, Dr. Peter Likins, responded to Banner's remarks. Dr. Likins emphasized his concern that educated people in the modern world understand the various modes of human thought, and, in particular, that they understand "how scientists and engineers think" rather than what they think. He noted important differences between humanists and engineers in terms of their approaches to problem solving. While "it is a characteristic of the educated humanist that he tends to define problems that he cannot solve, it is a characteristic of the educated technologist that he tends to focus his intellectual energy on defining problems that he can solve". Likins expressed his disappointment in the educational establishment's failure adequately to point out this difference, a difference whose explication could well constitute the theme of this conference.

Banner's and Likins' comments set the tone for much of the discussion during the next two days and were particularly relevant to the presentations on the seven Lehigh courses.

Chemistry for the Consumer examines a small number of socially significant chemical applications such as the use of food additives, the licensing and manufacture of drugs, the manufacture of plastics and paints, and the chemistry of future energy sources. The issues in which these applications are caught up are used as means for exciting student interest in chemical concepts. For example, detergents offer an ideal vehicle for teaching the relationship between chemical structure, bonding type, and chemical properties. In this way chemistry and its laws are related to important societal problems and values, "painlessly" instructing the student in both.

The Factory of the Future was designed as a vehicle for discussing the principles and technologies of current and projected automated factory production, computer-run assembly lines, computer aided design, industrial robots, programmable machine tools, et cetera, in the context of the social and economic changes that such production engenders.

The Regulation of Public Safety is intended to make the student aware of the decision-structure of government regulation of the products of modern technology. It traces the growth of regulation on behalf of public safety in boiler and pressure vessel manufacture, bridge construction, and nuclear power plant construction. The approach to the course is sufficiently quantitative that students can calculate margins of safety and determine the engineering choices to be made in appropriately simple cases. Such calculations supplement the conceptual parts of the course and are designed to show the extent to which quantitative solutions to complex problems can and cannot be used as a substitute for (ultimately subjective) value judgements.

Computer Modeling of Our World has as its principal objectives an introduction to: 1) the formulation of mathematical models for complex socio-economic-technological (SET) systems; 2) the details of programming SET models in a standard computer language; and 3) the execution of the model programs to gain insight into the behavior of the SET systems. An emphasis on both quantitative modeling and underlying qualitative judgements is facilitated by concentrating on problem areas which are currently of major interest and will probably remain important throughout the working careers of these students: energy, air and water pollution, population, atmospheric carbon dioxide and natural resource depletion.

The objective of <u>Urban Design and the Skyscraper</u> is to present the parameters that affect the decision making, the planning, the design, the construction, and the operation of tall buildings, considered as systems that bring together many disciplines within and outside of engineering. The course presents the primary professional tools available to, and commonly used by, the various engineering specialities involved in tall building design within the total urban context. Topical material includes: building systems, (structural, mechanical architectural), the tall-building design team, the design of structural members, and taking into account potential hazards, natural and man-made.

<u>Mineral Deposits, Industrial Development and World Affairs</u> treats the occurrence, distribution, and economic development of industrially important mineral deposits with a view to allowing the students to assess the interaction of social and political realities with technological constraints in decision making for raw material development. After setting a foundation for the students on how global tectonic dynamics and the detailed geological history of a region govern the processes by which elements are concentrated to produce potentially valuable mineral deposits, the economic, political, and technological basis for the development of mineral deposits is explored. Such strategic commodities as tin, niobium, and germanium are singled out for detailed analysis of their occurrence, technologies available for their recovery, and the history of their commercial supply. The course is thus a blend of the principles of physical geology,

geo-chemistry, economic geology, mineral beneficiation, extractive metallurgy and economics, the whole heavily seasoned with the interaction of modern technological developments and world politics.

Each of these courses motivates learning technical scientific, mathematical and engineering materials by disclosing their embeddedness in pressing contemporary issues. The technical material is taught: it is not skirted or just talked <u>about</u>. Rather, care is taken to show the students how the decision-making, from which the impact of science and technology on society directly flows, is pervaded by knowledge-bases in science and engineering, knowledge-bases which in turn incorporate mathematics in characteristic ways. Without any understanding of relevant subsets of those knowledge-bases, there is no way that informed decisions can be made at the level of anticipated social impact, whether the particular case involves the installation of a municipal natural gas storage tank, the release for marketing of a new drug, offering tax incentives for manufacturing-plant modernization, building a high-rise office/apartment tower, imposing restrictions on the burning of fossil fuels in the American midwest, or subsidizing the currently uneconomic development of a domestic extraction industry for a strategically important metal now being imported from a politically unstable neutral, or even friendly, nation.

All of these courses were developed under the auspices of Lehigh's Science, Technology and Society Program whose director, Steven Goldman, was Principal Investigator of the NSF grant and co-director of the project, along with Alan Pense and Stephen Cutcliffe, Project Administrator. The continued offering of these courses, however, will be the responsibility of the College of Engineering and Physical Science in conjunction with the STS Program.

The gateway course, "Introduction to Technology", was developed in coordination with the six NSF/CAUSE-funded courses and focuses on the distinctiveness of engineering as a problem-solving discipline. While the syllabus pivots about a model of engineering which clearly identifies engineering as an element in a wider system of action in which economic and political motives play formidable roles, a special effort is made to distinguish engineering and physical science. In practice, of course, the two overlap extensively, but in principle they are distinct, and this distinction is central to an appreciation of the social ties of engineering. Initially it was conceived that this course would not be open to engineering majors. As it developed, however, the syllabus increasingly centered on a model of engineering that was the basis for exploring the non-technical factors that shape the practice of engineering in the "real world". Engineering students discovered that the course provided a treatment of engineering that was of direct personal interest and available nowhere else in their curricula. It seems likely, therefore, that for the future the course will be open to all students, regardless of major.

Recognizing that the Lehigh model was neither unique nor privileged, the conference program aimed at presenting a range of parallel efforts with similar educational objectives at other institutions.

Robert Wheeler, Chairman of the Yale Physics Department, described a course on applied science/technology for liberal arts students that has been highly successful over its eight year lifetime. Under a single rubric, students can take one, two or three consecutive discrete mini-courses of one credit each. Each mini-course is on a different self-contained topic, taught by a faculty member expert in that area. Each mini-course consists of eight lectures and an examination, along with demonstrations, homework and/or projects. In any given term six mini-courses are offered, and a student can take all six, for six credits, or take more than three and opt for his/her three best grades. Recent topics include: laser technology, nuclear science and technology, fluid mechanics in nature and technology, biotechnology, architectural acoustics, and aerodynamics of aircraft.

Wheeler's own mini-course, "Microelectronics - The Chip", is built around answers to a set of key questions: what is it; what does it do; how is it organized; how is it made; why is it small; what is expected in the future? The sequence of lectures by means of which these questions are answered is the following: clocks and calculators; binary arithmetic; electricity; atoms; silicon; the p-n junction; semi-conductor devices; the planar manufacturing process; limits in nature and in society. Wheeler uses slides, demonstrations, scholarly and popular reprint material and involves the students by referring to topical news items and focussing on the people behind the technology.

The mini-course program satisfies Yale's distribution requirement for liberal arts students of two courses (6 credits) in science and mathematics. Enrollment is stable at approximately 180 students per semester, and the flexibility of the mini-course format is doubtless partially responsible for this continuing popularity. Faculty can respond relatively easily to student requests for new topics and staffing is far simpler than for a traditional three credit course. Yale has certainly succeeded in introducing the often neglected technology component into the arts curriculum.

William Ralph Bennett, also at Yale, offered a description of his course "The Computer as a Research Tool" which consistently attracts large numbers of humanities students. This course, interestingly, was instigated by Bob Wheeler and resulted in a book by Bennett, Science and Engineering Problem-Solving With the Computer,[2] that is now the text for the course. In spite of its rather forbidding title, the book is an outstanding vehicle for motivating learning to use the computer for the sake of its usefulness to set up and solve problems that could not practically be treated otherwise except by specialists. For his presentation, Bennett took one chapter of his book, the one dealing with language, and in a talk that was as humorous as it was informative, showed how important characteristics of linguistic structure and literary style could be disclosed and explored using simple programs well within the capabilities even of entry-level programming, simultaneously drawing the student in a natural and self-motivating way into an appreciation of the relevance of statistical distributions to natural phenomena. [Those interested who do not have ready access to Professor

Bennett's book can get a feeling for his presentation from the Computer Recreations column in the November 1983 issue of *Scientific American* magazine.] This course comes closer than Wheeler's to matching the pedagogical strategy of the Lehigh courses in embedding the motivation to learn technical material in apparently non-technical issues of general interest.

This same strategy, though with a narrower reference, is at work in Donald Avery's "Yacht Design" course at Brown University. The first part of the course is an intensive introduction to the dynamics of fluid flow in the two media in which sailboats operate. The second part is a design project that each student must successfully complete in order to receive credit for the course. The project requirements are that the student lay down a full set of criteria for a functional boat, including detailed specifications down to performance, materials and cost. The boat must then be "built" and dynamically "tested" either in fact (rarely, but often enough to have spawned a couple of commercial operations after graduation),* on paper or through a computer model incorporating the fluid dynamics component of the course. This course, too, is a continuing success, regularly attracting some 40 students each time offered.

Herbert Goldstein of Columbia University described a new team-taught course with which he has been involved from its beginning three years ago. This course, "The Scientific Experience", is designed to teach students something of the way scientists reason about the problems they address. Goldstein teaches the course together with a mathematician and a biologist.

The mathematics portion of the course is taught first, effectively as a set of skills to be used in the rest of the course although a special effort is made to "unpack" the mathematical formalism and explain the relationships behind the notation. The biology and physics components draw upon original documents and "real" problems of historical and contemporary significance, interweaving the logic of scientific problem-solving with biography, history and philosophy of science.

Moving away from course presentations, Leon Trilling offered an overview of the Sloan Foundation's New Liberal Arts initiative. Trilling described recent activities coordinated by MIT for Sloan in its capacity as technical resource institution for regional liberal arts colleges that have received first-round Sloan curriculum development grants, or anticipate subsequent participation. These activities include faculty development leaves and training, conferences, workshops and a "Movable Seminar" that rotates among the participating institutions. Full-scale course development at most of these colleges has only just begun, so it was not possible to describe projects in detail or to anticipate with any confidence their future success. As anyone familiar with the developmental history of STS programs would expect, these projects are very institution-specific and much energy needs to be channeled into articulating the relevant, and generally unarticulated, features of the home institution before lessons can be learned from the experiences of other institutions. To aid in this process, MIT will host several "New Liberal Arts" faculty in a sabbatical arrangement during the academic year 1984/85 and will offer specialized summer workshops for faculty this summer. In addition, MIT is in the process of developing an integrated freshman year at MIT to serve as a "living laboratory" for New Liberal Arts strategies and for the development of curricular materials.

Ideally mathematics, science, technology/engineering and STS-type courses should flow naturally from one into another, building on previously acquired skills, so that a student can enter more deeply into the material of each successive course area. For example, a mathematics course should not only satisfy mathematics skills requirements, it should also describe the relationships being "modelled" quantitatively in such a way as to provide a foundation for the scientific and technical material that will be encountered in subsequent science and technology engineering courses. Similarly, the science and engineering courses, if they utilize appropriate materials, will facilitate entering into a more sophisticated analysis in STS courses of science- and technology-related social issues than is currently the case. Two programs, one at Syracuse University and the other at Polytechnic Institute of New York, attempt to do just this, and presentations on both were made at the conference.

Dr. Gershon Vincow, Dean of Syracuse University's College of Arts and Science, summarized their integrated four-course cluster option in science, technology and STS. As Arts and Science students at Syracuse must complete a four-course cluster in the sciences, this allowed the relatively easy design of a comprehensive, integrated series involving three main features:

1) introduction to scientific literacy - a two-semester

introductory course in biology, chemistry, geology, or physics involving a laboratory.

2) introduction to technological literacy - a one-semester course involving lectures on concepts of engineering with an accompanying microcomputer-based laboratory component plus specific applications of technology and applied science drawn from the field of science taken by the student.

3) a course focused on understanding the impact of science and technology on society. In this course each class breaks up into small discussion sections on particular socio-technical problems relevant to the particular field of science on which they have chosen to focus.

The third course in the sequence, the introduction to technological literacy is the most unique and deserves some special mention. The first part of the course, entitled The Engineering Approach, contains three major components as outlined below and a series of micro computer-based laboratory games that illustrate the basic engineering themes. In the latter part of the course, as noted above, students break out into individual sections to look at technical applications related to the particular scientific area on which they are focusing.

COURSE CONTENT

1. Description of Selected Major Engineering Developments

   A. Computers and Communications.
   B. Structures and Dynamic Machinery.
   C. Energy Conversion.
   D. New Materials - Electronic, Structural and Chemical
   E. Instrumentation and Measurement.

2. Principles of Engineering Design.

A. Systems Modeling.
B. Optimization, Trade-Offs and Decision Making.
C. Feedback and Stability.
D. Energy and Signal Conversion.
E. Instrumentation and Measurement in the Design Process.
F. Design Decisions and Materials Availability.

3. Issues of Problem Definition and Complexity.

A. Quantifiable and Nonquantifiable Parameters.
B. Designing Against Large Numbers of Interacting Variables and Conflicting Constraints.
C. Examples from Mass Transportation, Nuclear Energy, Health Service Industries, and Resource Allocation.
D. The Element of Cost.

The teaching mode includes lectures and a laboratory with assignments on computer simulated designs and decision assessments.

According to Dean Vincow, "students typically register for a cluster ....based on a satisfying experience in the first year science course. We attempt to integrate the subject matter, primarily through the science field --its basic principles, then its technological applications, and finally socio-technical problems arising from these applications." He went on to stress the importance of remembering that these students are humanities and social science undergraduates, not science or mathematics majors, and that "it is essential that we design lively courses to capture [their] imagination and interest, since they do not have the prior mindset to be intrinsically interested in science and technology."

At Polytechnic Institute of New York, a slightly different approach is being taken. Although primarily a technically-oriented institution, Polytechnic does have a number of liberal arts majors. These students are required to take a core curriculum based, as Humanities and Social Science Division Chairman, Don Hockney put it, "on the idea that a well-educated liberal arts undergraduate should be exposed to the man-made, in both its technological and traditional forms." The core consists of forty-eight credit hours and is required of all humanities, journalism, and social science majors. The core amounts to almost half of the 126 total hours required for graduation. The Freshman core consists of a year-long sequence, "The World of Mathematics and Computers" (8 credits), a three credit course "Technology and Society in Historical Perspective" and a physical science course with laboratory, "The Physical World" (4 credits). The Sophomore core continues with two more science-based courses, "The Biological World" and "The Behavorial World", each with a laboratory and carrying 4 credits apiece. During the second semester of the Sophomore year, the student also takes "Ethics and Technology" (3 credits), which is designed to examine some of "the basic ethical theories of human action and how these relate to technological making and using." The Junior year core continues with a series of four specific, STS-type courses, each of which is designed to explore in some depth a particular facet of the general relationship between science, technology and society. The courses include: "Materials and Social Issues," "Machines: Extensions of Man," "Information, Communication, and Society," and "Energy Technology and Social Issues" (3 credits each). Finally, in the Senior year the student is asked to draw all this material together and to demonstrate a connected and comprehensive understanding of it. The first semester includes a course, appropriately entitled ""The Making of Connections" (3 credits), which is intended to draw out the basic issues and general relationships introduced by the previous courses --topics such as the relationship between machines and human nature, between freedom and the individual in a technological society, and between probable futures and alternative social policies in light of rapid scientific and technological change. In addition, the student is required to do an individualized, year-long senior seminar/thesis project culminating in an extensive paper (7 credits).

The total package of fourteen courses thus introduces the student in a natural way first to mathematics, then to the basic sciences --natural, biological, and human-- and technology, and finally to their social context. In the end, it asks the student to display both a comprehensive general STS understanding and a more detailed specific understanding of a particular issue as reflected in the senior thesis project. It is precisely this kind of integrated understanding of science and technology that we would argue is called for in an undergraduate liberal arts education and precisely that which can, at most, reasonably be expected of students who do not have the inclination to become scientific or technically-oriented professionals. Furthermore, we would argue that this kind of understanding would be equally valuable for this latter group of students as well.

The limitations of an already full program prevented the inclusion of presentations on all of the valuable science and technology literacy courses presently being offered. Many of these have been described at previous conferences, including one on the Fundamentals of Engineering in a Liberal Education hosted by Lehigh in 1981, and those sponsored by CUTHA at MIT in 1980, Chatham College in 1981, and the University of Maryland in 1982. Several efforts are worthy of special note, however. The Department of Technology and Society at SUNY-Stony Brook offers a series of courses designed especially for non-engineering students and including: "People, Technology and Society," "Patterns of Problem Solving" and "The Societal Impact of Computers." Other, more general, STS courses are also offered. Another program of interest is the Values, Technology and Society Program at Stanford University, in which all students are required to take at least one course related to technology. Civil Engineering Professor David Billington of Princeton University offers a particularly intriguing course, "Structures and the Urban Environment." It is designed to relate an understanding of the scientific and technical rationale behind the structural form of large-scale public works to their societal context, aesthetic image, and the symbolic meaning of these structures. Billington's knowledge of engineering, both historic and contemporary, combined with his perceptive aesthetic insight makes this one of the most instructive of such courses.

Ultimately the key to the success of all these courses and programs lies in their recognition of the necessity of integrating science and technology with their societal context.[3] The starting point which informs all the Lehigh courses and, we suspect, most of the other courses presented at the conference as well, is a conceptualization of technology as a social process, a conceptualization that distinguishes the artifacts and processes that embody the work of the engineer within the broader complex of social processes that shape and define that work by providing engineers with their problems and at the same time by setting many of the parameters within which the engineer must solve those problems.[4]

Given this starting point, it is not enough merely to teach liberal arts students the same mathematics, the same science, or the same engineering materials that are taught to majors in those fields. Watered down or gussied up, these materials will fail to make an impression if the teaching of them does not recognize and make explicit the complex social process in which the science, the engineering, and the mathematics are woven into a whole cloth. It is precisely this image that CUTHA's publication, The Weaver, tries to convey through its title.

We need to have a holistic understanding of what we mean by the "literacy" we are trying to achieve. The mathematics, the science and the technology, yes even the computer, should be seen as elements within a wider intellectual and social framework. Educational institutions considering new courses in this area need to articulate the objectives of those courses and, in the case of existing distribution requirement courses, will likely have to reconceive their goals. Mathematics, computer, science, and technology literacy courses should be designed to meet the educational needs of liberal arts students, and not consist of introductory instructional materials suitable for majors in those fields to build upon.

Taking educational goals as the objective would suggest that students should become familiar with scientific and technological reasoning, with major current concepts and methodologies, and with design and modeling strategies in the discipline[s] they are studying. Such understanding will not make a scientific or technical expert out of any liberal arts student, although it may make him/her more aware of the complex social, economic and political milieu which perforce surrounds all scientific and technological decision-making. The educational significance of this kind of "literacy" is nonetheless vital, serving as it does to illuminate fundamental dimensions of our humanity. These dimensions are no less expressive of what it means to be human than are literature, philosophy, art, religion, or history. To be ignorant of mathematics, science, or engineering is to be ignorant of some of Mankind's greatest achievements as well as some of Mankind's greatest failures. That this is true of the other humanities as well, suggests that the importance of mathematical, scientific, or technical literacy should be on a par with literacy in art, music, poetry, literature, history, *et cetera*, neither higher, nor lower.

While much of this has been recognized for some time, we have not always sought for our liberal arts students what we should have in the way of science and mathematics education, letting instead a minimal number of introductory courses designed for majors fulfill an arbitrary and numerically defined requirement. Beyond this, few if any schools, until recently, have required their liberal arts students to learn about engineering.

Because an understanding of engineering is central to an understanding of the broader social process interpretation of technology, this is doubly unfortunate. Engineering is different from science and an appreciation of the ways in which engineers define and solve their problems needs to be cultivated. The technology literacy courses described above attempt to do just that --to reveal how engineers must factor social, political, legal, economic, and aesthetic considerations into their definitions of what their problems are, and then into parameters of what will constitute acceptable solutions to those problems.

Assuming, then, that a case has been made for the educational validity of science and technology literacy courses, what can be said in summary about the direction which such courses ought to take? Courses designed to fulfill requirements for liberal arts students in mathematics, the sciences, computers, engineering and technology need to be designed from the outset with the understanding that the motivations and conceptual orientation of arts students will be radically different from those of majors in these fields. The courses will need to be structured around <u>educational</u> goals that draw their value from enriching the individual student's personal encounter with his/her world rather than on <u>instructional</u> goals of the sort that make obvious good sense for students planning to major in that field. Worst of all is offering to liberal arts students elementary versions of instructionally based courses, for these are neither intrinsically challenging nor at all useful to such students. A plausible approach would appear to be one that aimed at communicating an appreciation of the discipline being treated as a distinctive problem-solving discipline; presentation of current concepts and methodologies in that discipline; description and at least qualitative analysis of the discipline's current theoretical models. Mathematics courses for liberal arts students should be taught with a view to subsequent science and engineering or technology courses that they will have to take, and an effort must be made to articulate qualitatively the relationships being modelled by equations and functions.

All of this, in turn, should point toward a deeper and more comprehensive understanding by the student of the complex social context within which scientific and technological activities find their place. This can be explored more closely in STS types of courses which because of this lack of a well-developed base in mathematics, science, and engineering now seem, and often are, superficial. All this will take time, effort and money. Most of it will take special administrative support to provide the environment necessary for faculty to take really new approaches to designing the courses required. Obviously, the job will not be an easy one, but if it is worth doing at all, this, or something like it, would appear to be the only way worth doing it. Furthermore, the most likely alternative, given the vested interests emerging on behalf of doing something on behalf of science and technology literacy programming, is that a lot of time, effort and money will be spent anyway, and the outcome will be no more impressive than the lasting impact of the post-Sputnik renovations which, had they been appropriately designed for a basic understanding of science and technology as described above, would have obviated the need for promoting science and technology literacy efforts today.

Footnotes

1. National Science Foundation and Department of Education, Science and Engineering for the 1980s and Beyond (Washington, D.C.: Government Printing Office, 1980); Stephen White, The New Liberal Arts edited by James D. Koerner (New York: Alfred P. Sloan Foundation, 1981); National Research Council Commission on Human Resources Committee on the Federal Role in College Science Education of Non-Specialists, Science for Non-Specialists: The College Years (Washington, D. C.: National Academy Press, 1982); National Science Board Commission on PreCollege Education in Mathematics, Science, and Technology, Today's Problems, Tomorrow's Crises (Washington, D.C.: National Science Board, National Science Foundation, 1982); National Commission on Excellence in Education, A Nation at Risk: The Imperative for Educational Reform (Washington, D.C.: Government Printing Office, 1983); Carnegie Foundation for the Advancement of Teaching, High School: A Report on Secondary Education in America (Washington, D. C.: Government Printing Office, 1983); and National Science Board Commission on PreCollege Education in Mathematics, Science, and Technology, Educating Americans for the 21st Century (Washington, D. C.: National Science Board, National Science Foundation, 1983).

2. William Ralph Bennett, Jr. Science and Engineering Problem-Solving with the Computer (Englewood Cliffs, NJ: Prentice Hall, Inc., 1976).

3. An amplified version of the arguments that follow were originally set forth in Steven L. Goldman and Stephen H. Cutcliffe, "STS, Technology Literacy, and the Arts Curriculum,"

Bulletin of Science, Technology, and Society 2 (No. 4, 1982): 291-307.

4. The conceptualization of techndology as a social process is argued for more fully and at greater length in Steven L. Goldman, "The Techné of Philosophy and the Philosophy of Technology," in Paul Durbin, ed., Research in the Philosophy of Technology, vol. 7 (Greenwich, Conn.: JAI Press, 1984) forthcoming, and in Steven L. Goldman and Stephen H. Cutcliffe, "Responsibility and the Technological Process," Technology in Society 1 (No. 4, 1979): 275-86.