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AUTHOR	de Korte, Aart
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ABSTRACT

Perspectives on the need for retailoring science education so that college graduates will be better prepared to make decisions about scientific, technological priorities and personal career options are presented in this paper. The values and problems associated with an interdisciplinary approach to science education are discussed and a new interdepartmental course entitled Science in a Cultural Context (SCC) is highlighted. Components of SCC include: (1) historical and modern views of scientific theory; (2) examples of theory formation from biology, chemistry, and physics; (3) science, technology, and society; and (4) the consequences of the nuclear arms race. A sampling of comparable courses from selected colleges are also identified. The benefits of a science and culture oriented program are outlined for non-science as well as science majors. (ML)

SCIENCE EDUCATION IN OUR TIME:

THE NEED FOR AN INTERDISCIPLINARY APPROACH

Aart de Korte

Fairleigh Dickinson University

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FAIRLEIGH DICKINSON UNIVERSITY

Educators must be concerned with more than the transmittal of the technical, factual content of their disciplines, certainly on the undergraduate level. Higher education should be more than the training of future professionals to perform the tasks that call for high levels of proficiency and commitment. True, without experts complex societies cannot function in a competitive world. However, complex societies also present their members with a staggering array of choices that call for more than narrow professional proficiency. Society expects judicious decisions from the highly educated, who are also likely to hold leadership positions. We, therefore, as educators have the added responsibility of broadening the scope of knowledge, and we hope the minds, of our students. We share the faith--I believe I speak for the majority--that a liberal education, consisting of a general, intensive sampling of relevant subject matter, can best achieve our goal. One important, continual activity in higher education is the tailoring of the sample or relevant subject matter to fit the forever changing demand for good judgement.

For the last fifty years or so with the possible exception of the 1960s, when core curricula were abolished in many colleges, this liberal education sample has included a course in pure science. The reasons for this inclusion of a general science requirement were the recognition of the success of scientific methodology in its attempt to understand nature, and the trend to apply this methodology in other fields, such as the social sciences and economics. Also, learning to speak the language of scientists appeared desirable not only from an academic but also from a managerial point of view. As the number of scientists employed by industry and government grew, managers had to know something about the ways science works and scientists think to be able to communicate. It is the present, overwhelming industrial and governmental involvements with science, with the concomitant emphasis on practical problem solving and technology rather than on science's traditional building of theory-model constructs, that call for a change in science education, be it for majors or non-science majors.

The involvement of governments with science in industry and academe has since the end of the Second World War led to the promulgation of official science policies that assign priorities to research projects. Through agencies created under the aegis of a science policy, such as the National Science Foundation in the U.S., research funds are dispersed.[1] In effect, these agencies are enforcers of science policy. In this manner governments have become increasingly capable of exploiting the efforts of scientists and technologists (engineers, etc.) for projects they perceive of as beneficial to the state. These projects are mainly defense projects, including nuclear arms, carried out in national laboratories, frequently affiliated with universities, industry, and academe. (70% of the 1985 federal Research and Development budget is allocated to defense projects.) As a consequence, researchers in pure science are often obliged to ride the coattails of military and industrial lobbyists to obtain funds for their work. As the distinction between pure and applied science becomes inevitably blurred, pure science finds itself squeezed into an unpopular corner. Senators bemoan and ridicule the expenditure of federal funds on what they call wasteful, scatterbrain research projects in pure science. Science is exposed to attack from the government for failing to achieve commitments as some projects necessarily fail; and to attack from radical, non-establishment groups that see science as the main culprit in a military economic power build-up with accompanying neglect of real societal needs.[2] Because of its involvement with the affairs of government and industry, science can no longer be considered neutral. Some say that it has become mainly an industrialized, politicized enterprise.[3] The pure scientist as objective value-free observer and interpreter of nature may already be an extinct species.

It is my intention in this paper to propose a way of retailoring science education so that college graduates will have options available in assessing the current situation of science. Also, they may find themselves better prepared to make decisions about scientific, technological priorities; and about what is even more important--their own careers.

Some general problems of science concern: 1) the misunderstanding by society, the public-at-large (referred to in this paper as "we"), the scientist and the non-scientist, of what science is and the confusion of science with technology; 2) confusion on the part of scientists and humanists alike about the place of science in the societal and intellectual frameworks (As a result of this confusion the question whether scientists and technologists have any more responsibility than other citizens and their leaders for the uses and effects of technology remains unanswered); 3) the modern interpretation and reevaluation of science as a cognitive enterprise by philosophers and historians of science, and the lack of awareness and concern on part of scientists of the conclusions that are current about the methodology and cognition of science; 4) the involvement of science with (nuclear) weapons research and development. Insofar as these problems stem from lack of communication, their resolutions fall in the area of education. There exists a paradox, however. Traditionally, education in scientific fields is the bailiwick of scientists, who for the greater part are strongly committed to status quo concepts of themselves as scientists and of science. Consequently, the way out of a dilemma presents itself as a dilemma: the re-education of educators who are very likely to be recalcitrant to the idea. The question arises how and to what extent interdisciplinary science education, towards which steps have been taken recently in some colleges and universities, can yield solutions to the stated problems and dilemmas. A good part, at least initially, of these interdisciplinary efforts will be the search for and definition of areas of convergence and overlap of the sciences, the social sciences, and the humanities. Thus, a description in more detail of the problems and their implications might be a useful preliminary to finding answers; and it might actually suggest answers.

We, the general public, confuse science with technology. According to Kuhn[4] part of our difficulty in seeing the profound differences between science and technology must relate to the fact that progress--as opposed to the more static appearance of non-technological and humanistic endeavor--is an obvious attribute of both areas. Massive expenditures on science are justifiable only by imagining that scientists are magicians who must supply us with a never ending stream of miracles and gadgets. As Nagel states:

> Moreover this emphasis (on technological wizardry) tends to portray science as a miscellany of surprising wonders and gadgets and to create an image of the scientist as a miracle worker with a nostrum for every physical and psychic ill, whose opinion, like those of scucessful businessmen and military leaders, are to be taken as authoritative even on matters about which they have demonstrable incompetence.[5]

The essence of science is seen by many of us as the technology that engulfs us. We are fascinated by such technological feats as the Apollo manned moon-landing, which, incidentally has been decried by many scientists as an unnecessary extravaganza and as a circus act without truly scientific significance. Unmanned moonprobes and spectroscopic analyses of the moon's radiation yield the same information at much less expense. We look towards the science technology contingent for a cure for cancer, computer wonders--mostly in the form of "games"-- and a longer life span; and generally we are not disappointed. So, frequently scientists bask in our admiration. However, disaffection lurks not far around the corner as technology has a frightening tendency like magic and voodoo to misfire.

We look toward science and technology for the machinery of war, euphemistically termed "defense"; and in our commitment to a forever expanding economy, based on industrial processes that devour energy in spite of dwindling conventional sources, we force the production of nuclear power. The deals we make are Faustian. The horror of a nuclear holocaust appears imminent, and the perils of nuclear energy production are real. Without dwelling further on the hazards of modern "technocracy," which have been convincingly described and documented by Lewis Mumford[6] and others, it is evident that we tend to turn against the scientific-technological community for the failures of technology. We do not seem to realize that scientists and technologists are "we" and have as great a stake in the safety and sanity of our society as we all do. In having wrought the predicaments of our technological and military establishment all our hands are bloodied through the interconnected maze of all our economic and political activities. Holton speaks in terms of a rescue operation about the present day technology crisis. Typical of the circularity of the crisis, the rescue operation will have to be an operation bootstraps. He says:

> At the very least technology is clearly in need of rescue from its chief exploiters--primarily large scale industry with a vision of its social purpose far too narrow to match its enormous power, and the military with its seemingly uncontrollable appetite and its success in avoiding democratic accountability---This book (Mumford, 1970) and its success are exhibits of the failure of educational institutions in the period of rapid increase of scientific knowledge.[7]

The implication of this statement is that education can do better and that there is hope in contrast to Mumford's pessimistic view of the problems of our technocracy as being symptomatic of the bankruptcy of the entire system--education, scientific and humanistic, included. Mumford suggests that we abandon ship. That is to say, only by recognizing that all our institutions are corrupt, by abandoning them, and by returning to a simpler life style is there any hope that man will not perish by his own sword--nuclear annihilation--in the near future. As I share Holton's optimism in spite of serious misgivings, I believe that we should attempt a solution through the "system."

I will now turn my attention to scientists as members of our society. Library shelves of books have been written about the social roles of scientists. An anthology, entitled <u>Science Technology and Society: A Cross-Disciplinary Perspective</u>, edited by Spiegel-Rosing and de Solla Price,[8] which appeared in 1977, is an excellent representative. Recently, a reviewer of the book, an interdisciplinarian physicist-political scientist, stated that "it is a mark of our time that scientists want to know how they fit in the social matrix." He further observes:

.... the interaction between science and society is actually much better understood by social scientists than one might think.... Philosophers, historians and psychologists of science know a great deal about the personal creative process. Sociologists of science have gained impressive insights into the social structure of scientific communities. Economists comprehend well the distinctions between science and industrial technology. And political scientists are very knowledgeable about the coupling of scientific expertise and political process.[9]

He goes on to say that any scientist who owns a copy of the CRC Handbook (a compilation of physical, chemical and mathematical data) should buy a copy of the anthology. I agree. However, my personal experience and observations by several students of the science scene do not support the reviewer's optimism about the scientist's concern for his social role. To quote Holton:

....the vast majority of working scientists in fact are quite happy to leave discussion of societal concern to the small minority of concerned scientists (Holton estimates that it is now and will never be more than one percent)...Indeed the psychodynamic vectors that propel a scientist into the bright world of solvable problems often turn out to have, on examination, components originating in the flight from the dark world of anguished compromises and makeshift improvisations that commonly characterize the human situation.[10]

It is unlikely that a scientist's education, especially on the graduate level, includes a study of the discourse, the methodology, and the cultural and social significance of science. But even if it did, there will be a resistance among most scientists--established and potential--to actual involvement in these matters since they tend to see any deviation from the acquisition of the enormous amounts of knowledge that make up their sciences or any interference with their research and publishing activities as dangerous luxuries. Ironically, one might expect this resistance to be the strongest in the most excellent and, of course, also the most competitive academic environments with well established philosophy and history of science faculties.

The existing educational process perpetuates the phenomenon of the scientist who can live comfortably with the dichotomy between what goes on in his laboratory and what happens as a result, direct or indirect, in the outside world. For the educational process, to paraphrase Holton,[11] biases the selection, training and socialization of its future scientists against the entry into the field of science of people who can feel social indignation. In connection with the psychological make-up of scientists McClelland states: "Scientists avoid and are disturbed by complex human emotions, perhaps particularly interpersonal aggression."[12] The traditional education of scientists is much like a professional school education with a strictly defined curriculum and course objectives with little or no room for variation or imagination. The attainment of excellence in this narrowly defined area spells success; adventuresomeness might be a distinct obstacle. Also traditionally, it seems, the tacit assumption is that a scientist's personal life, his feelings, his temperament even, are better kept totally separated from his scientific activities in the name of total objectivity. The more he leaves his emotion out of the laboratory the sooner he will get his Ph.D. Admittedly, this description is somewhat extreme, since the personalities of graduate students in science run the gamut. Yet there is a heavy concentration of people who seem to consider the laboratory or study as shelter from the vicissitudes of the outside world. To them social indignation, justified aggression, and "causes" are anathema.

One might object to the singling out of the scientists from the rest of the scholarly community for such psychological and sociological scrutiny as the above. The metaphor "ivory tower" aptly describes the isolation of much of the academic world, scientific and humanistic alike, from the everyday world of hard knocks. "In their ideal form a life devoted to science and a life devoted to the humanities exhibit a common temper of mind," Nagel remarks.[13] Certainly, as all academics know, humanities faculties are no less victimized by the publish or perish dictate than scientific ones, and the two disciplines demand equally single-minded devotion. However, scientists are much more frequently than humanists involved in far reaching decision making by industry and government, when they serve as consultants in scientific and technical matters. The narrowness of their education, their avoidance of conflict in their personal and societal involvements, and their shunning of "causes" leave the majority of scientists unworldly. Their advisees see them as such and do not entrust them with decision making responsibility (There are notable exceptions such as the members of the Union of Concerned Scientists. As these persons tend to be left-of-center, government and industry might tend to avoid their counsel.) This circumstance places the community of science in a position of great power without granting it at the same time any true responsibility. It is Ravetz's[14] argument that what he sees as an alienation of scientists from society is connected with the absence of opportunities to be directly responsible for important decisions (the doctor-patient relationship type of responsibility). This contradiction, resulting from the "ill-defined social structure of science" or the refusal of scientists to get truly involved and grab responsibility so to speak, is seen by Ravetz as potentially crippling to both scientific endeavor and society.

The most peculiar aspect of science is the gap between how scientists see themselves and their activities and how they and their work are perceived by the modern, post-Vienna School, philosophers of science. Although the latter have a very important and intellectually interesting message, scientists, for the greater part, turn a deaf ear and display what can only be called a distinctly anti-intellectual attitude in this regard. The philosophers' message even holds promise of liberation from unwarranted intellectual confinement. Oddly, most scientists thus far appear to want to stick to their mistaken ideas of inflexible empiricism and rational theory development. Though this primarily academic problem is, if at all, less threatening to society than the problem of scientific accountability discussed previously, it is marked by the same circularity and contradictions.

The naive, inductivist and falsificationist account of rational scientific development is still very much the doctrine of science today, and it is still proclaimed, with some minor modifications, in the introductory chapters of many textbooks of physics and chemistry. Based on evidence culled by historians and philosophers of science from historical accounts of science and case studies of present day scientific discovery and theorizing, quite a different picture has emerged. Scientists do not proceed according to sets of rational or logical rules; progress is not a systematic stepping from one theory by elimination and expansion, using those rules, to the next, better and simpler, more explanatory theory. Instead, as Kuhn states:

> Scientific progress is not different from progress in other fields (a rather irrational, groping process), but the absence at most times of competing schools that question each other's aims and standards makes the progress of a normal-scientific community far easier to see (than in the humanities, for instance).. Once a common paradigm is accepted the scientific community can concentrate exclusively on the subtlest and most esoteric of the phenomena that concern it, and progress is rapid.[15]

Kuhn discerns in scientific progress a problem solving activity that starts with a "pre-paradigmatic" stage characterized by non-systematized, rather haphazard, data gathering. (Much of molecular biology exhibits this stage at the present time.) Hypotheses and conjectures will abound during this stage, but not until such time that these become sufficiently convincing either because they are stated by many investigators or by an authority figure is the paradigmatic stage reached. The paradigmatic stage is characterized by commonly accepted theories and laws such as the laws of Newtonian mechanics, the theories of Copernican astronomy, the postulates of quantum mechanics, the laws and formalism of thermodynamics and statistical mechanics. Now a period of "normal" science, a period of paradigm testing, starts. Anomalies will be found that contradict the theories and laws of a paradigm, and when these anomalies become important enough in quantity and quality a "crisis" is reached followed by a "scientific revolution," during which the old paradigm may be abandoned.

Other philosophers of science (Bohm, for instance) have argued that the testing of paradigms is not by far as rational a process as would seem from this description since the theories of a paradigm are themselves a determining factor in the selection of the anomalies or tests for them. Scientists find themselves at one point in a closed circle of activity, from which there is no escape other than through the abandonment of a paradigm for no apparently rational reason. Hence comes the concept that paradigms simply die (become unfashionable). Bohm introduces the notion of an unanalyzable complex of informal and formal language, in which the scientist speaks about the world. The informal language is the one scientists use to start talking, in ordinary language, about the theories of a paradigm (Bohm does not use this term) and the formal language is the one they finally usually wind up in, the language of mathematical formalism that is so typical of many mature scientific theories. A time will arrive in the development of a science when it becomes necessary to start speaking about the world in an entirely new informal language, for example as in the case of contradictory notions of "reality" in quantum mechanics and the theory of relativity that Bohm discusses. When old languages, informal and formal as they form an unanalyzable whole, are replaced there is no rational connection between them and the new language. A decision is simply made by the scientific community that incompatibilities and inconsistencies of old theories cannot be patched up by adding to the content of those theories. (I see the new language of Bohm roughly as the same thing as a new paradigm in Kuhn's construct.) Progress is seen by Kuhn as the transition from paradigm to paradigm; but he detects no approach to an ultimate truth or reality. Neither is there any accumulation of knowledge about the world as one view simply replaces another. As scientists enter the area of a new paradigm, they commence to talk about the world in terms of a new "reality" without reducing in any way the number of problems to be solved. Each new paradigm leads to a whole new area of problems. It should be added that not all observers of scientific procedure agree with Kuhn's concept of scientific progress. For instance, Laudan[16] presents evidence that there is not as sharp a distinction between "normal" science (the paradigm testing stage) and "revolutionary" science (the paradigm toppling stage) as Kuhn maintains. Rather, in a field of science several paradigms are usually operating at the same time while, as the testing is going on, some of them are gradually gaining favor over others. Laudan sees science as always "revolutionary." Thus he questions Kuhn's concept of "mature" science marked by paradigm monopoly and testing. Laudan also allows for paradigm abandonment to be a regressive step. He merely sees a change in the methodological and structural features as a science grows older and no necessary progress through "revolution."

These views of scientific progress differ distinctly from that of the naive inductivists according to which: 1)theories are abandoned as soon as even one contradiction is found, 2) experiments are designed in the framework of a theory, but independent of it; and they truly test the validity of a theory, 3) the progress in science is a rational and logical movement towards a state of knowing the ultimate truth about nature, its essential reality as supposedly a Creator knows it.

Since there is such a marked difference in ideology between its practitioners and theoreticians (i.e. those who theorize about science), the field of science is distinctly out of touch with a mainstream in intellectual thought. It does not speak well for our educational institutions that they harbor and seemingly are unable to deal with such a flagrant intellectual schism. It is up to educators in the sciences,philosophy as well as the humanities to insure that what amounts to a dishonesty in intellectual life, the withholding of information--admittedly it is in the library, but the dishonesty consists of not mentioning it in the classroom--is removed and that students, whether they are future scientists or not, become aware of the modern concepts of the cognitive nature of science. It is my belief that at least some of the present stagnation in theorizing about the world is due to entrenched dogma and a refusal to consider or follow the directions shown by philosophers. When science stagnates, the cost can be very high in actual dollars and cents as may well be the case in particle physics where the maintenance of a paradigm demands astronomical expense for the construction of more and more powerful atom smashers.

Would Kuhn agree with the statement that all of science is a paradigm and that it--science -- just like the paradigms in individual scientific areas eventually may well be in the throes of a crisis? It is unlikely that scientists with their vested interests are willing or capable to admit such a crisis. Yet a resulting revolution would be the only way the whole of science could progress towards new paradigms, which eventually could lead to unified theories of physics, chemistry and biology--to a theory of life itself. Once we are indeed approaching the grand "scientific revolution" the philosophers of science may be seen as the midwives in the birth of the new paradigm for all of science.

Feyerabend, though frequently iconoclastic, cogently urges what appears to be at least semi-revolutionary change in Against Method. He says: "Science is (should be) essentially an anarchistic enterprise; theoretical anarchism is more humanitarian and more likely to encourage progress than its law-and-order alternatives."[17] He calls for an "anything goes" attitude in theorizing and claims that a pluralism of theories and metaphysical views is not only essential for progressive scientific methodology but an indispensable part of a "humanitarian" outlook.

I suggest that scientists might find out that taking time to learn the nature of their methods and to become aware of the cognitive aspect of their work, to learn to see it as a way to lend reality to the world around them, will have important payoffs. They will be able to assess the present state of theoretical accomplishment in a new, possibly progress directing light; they will be able to add an interesting dimension to their work and find added rationale for it; and they will be able to reestablish contact with the other intellectual disciplines, to bring their science back into the mainstream of all humanistic endeavor, where, like all attempts to see the world in a variety of ways, it properly belongs.

From the foregoing admixture of observations, speculations, and tentative analyses the rather obvious conclusion emerges that the education of scientists is lacking in the broad area of the humanities. This educational lacuna leads to misunderstanding of the nature of science and its methodology on the part of scientists. There is a resultant confusion between the expectations scientists have set for themselves and their work, and what the rest of the intellectual world and society expects from them. Such a situation is, of course, a sufficient spur for educators to act and to set things straight with more and better education. Already there are signs of remedial activity. Of course, it is not clear or, perhaps, important whether the professional consciousness of the educational world has been shaken by the discovery of an educational "crisis" or by the arguments of writers like Mumford about the larger world crisis. It is my hope that teachers will reveal to their audiences the motives for their attempts to reunite the sciences with the humanistic endeavors and that priority will go to the larger world crisis

Many non-science majors fulfilling the traditional core curriculum laboratory science requirement are poorly motivated and prepared. The need to replace an inevitable chore--the lab course--with a meaningful experience is apparent.

Science majors are usually determined in their career choices and able to handle science courses because of early interest and special aptitude. However, they often suffer from culturally induced resistance to study in areas other than the sciences and mathematics, and perhaps, some practical courses like technical English and economics. To the extent that they remain ignorant of 1) the nature of science as an intellectual pursuit and 2) the consequences of science's close association with technology, especially war technology, they remain dangerously uneducated as scientists.

A letter appearing in the official membership publication of the American Chemical Society, a professional scientist proclaims: "Surely no cognitive person can fail to grasp the difference between 'science' and 'humanities'--one field is not created by man. True science is not a creation of man, nor in my opinion, of any manlike being."[15] Though there were several correcting responses to this letter, I believe that its content and variations on it are fairly typical and symptomatic of educational failure.

The upshot of the existence of official science policies, of governments with self-serving interests in science and technology, and a world heavily committed to war technology, is that not many scientists and technologists can avoid their influences even in academe. A dilemma that may face a science graduate is the difficulty of finding non-academic employment or research funds that are not connected with weapons development. Or it may be the psychological and moral dilemma of direct or indirect participation in the building of a nuclear arsenal that may have brought mankind to the brink of self-extinction.[19] On a less emotionally charged level this arsenal is considered (by a former science advisor to the British government) so immense and destructive that it has lost all its practicality. This advisor writes in a recent book:

> In the nuclear world of today, military chiefs, who by convention are a country's official advisers on national security, as a rule merely serve as the channel through which the men in the laboratory transmit their views. For it is the man in the laboratory, not the soldier or sailor or airman, who at the start proposes that for this or that reason it would be useful to improve an old or devise a new nuclear warhead . . . . It is he, the technician, not the commander in the field, who starts the process of formulating so-called military need . . . The men in the nuclear weapons laboratories of both sides (East and West) have succeeded in creating a world with an irrational foundation, on which a new set of political realities has in turn to be built. They have become the alchemists of our times, working in secret ways that cannot be divulged, casting spells which embrace us all.[20]

Science and technology are intimately intertwined with the destiny of mankind because of the menace from a sophisticated war technology and, sometimes, from ill-conceived industrial technologies. Feyerabend asserts that the people no longer trust science the way they used to because of the use of science and technology by government and business, "in which humanistic considerations are at a minimum."[21] The loss of the public trust is very serious business for an academic discipline. Many scientists are horrified by what amounts to the violation by the war machine of the code that science must be for the good of man. They seek the opportunity to do something to free science, a subject they chose and love because of its "freedom," from the shackles of abuse and misguided application. They may find this opportunity in bridging between the academic disciplines, which can result in the understanding, perhaps the disentanglement, of the complex network of fears, blind patriotism, opportunism, miscalculation, ideology and economic pressures that poisons man's reason and propels the juggernaut of war technology. It is tempting to be pessimistic and say that academics in their efforts to resolve a global predicament are grasping for straws. Yet for academics not to exploit the present joining of hands--I hope, forces--and not to do as much as they can to change the course of our destruction bent world would be not only foolhardy but irresponsible.

Fortunately, a solid, scholarly basis for this aspect of interdisciplinary studies already exists in the Study of Science, Technology and Society, which predates the present interdisciplinary convergence by a good many years and forms an impressive body of knowledge, with many clear conclusions. As Spiegel-Rosing states in Science, Technology and Society: A Cross-Disciplinary Perspective: "SSTS is born of war."[22] She also detects that socialist countries--presumably the Soviet Union--are concerned with SSTS as one would expect since, after all, the entire human community finds itself victimized by runaway war technologies.

The new interdisciplinary (interdepartmental) approach to required science education that I propose replaces at least one semester of the traditional laboratory science course with one that I call "Science in a Cultural Context" (SCC from now on). The content of the course is the several issues that I have examined in this paper. It is my contention that present day laboratory courses for non-science majors rarely mean much to them since they are training courses, even on the elementary level. Ideally, the SCC course should be followed by one semester or more of a laboratory science course with subject content, but still taught with as much emphasis on the cultural context as possible. It is quite likely that students will have the desire to learn more about the sciences they have read about in the SCC course so that they now have the proper motivation for the "content" course. For the potential science major a sensible major choice will probably be easier after having taken a course about science than, in the traditional way, by plunging right into a major field on the basis of hearsay and suspected liking. As many students come to college these days with rather severe deficiencies in one or more areas required for the "hard" sciences, the postponement by one semester or year of their "content" courses has the advantage of permitting them to make up for deficiencies.

Let me emphasize that the SCC course is meant to be required for all students in the undergraduate curriculum, and that it fulfills one half of the general science requirement. If a science major does not wish to postpone his major work in science, it could be commenced concurrently with SCC in the freshman year. The course is by its very nature interdisciplinary (interdepartmental) and will probably be taught by faculty from the sciences, history, philosophy, sociology, and, perhaps, psychology and political science. Possible components of SCC are:

I. Views of scientific theory, historical and modern. The ways in which theory is derived from (created on the basis of) observation are examined. The so-called scientific method is further explored together with the feasibility of verification and falsification of a theory through independent, unbiased experimentation. The rationality of inductive and deductive reasoning is scrutinized. Abundant material for this section of the course is available in the books by Kuhn, Holton and Nagel (notes 4,5,7). Nagel is a proponent of the rational, positivistic view of the process of theory formation. An effort should be made to present a balanced treatment where conflicting notions are current. This component of SCC will probably be taught by faculty from the sciences and philosophy.

II. Specific examples of theory formation from biology, chemistry, and physics. Dalton's Atomic Theory is a good example of a straightforward connection between observed fact and theoretical interpretation. Its coexistence together with modern atomic theory illustrates the persistence of a theory in spite of falsification as well as the common complementarity of theories. Further examples of the impossibility of verification and the partial success of falsification of theories can be discussed. Some salient, particularly interesting events from the history of science can be used to enliven this section of the course. Some anecdotal material would not be out of place. Faculty from the sciences and the history of science will teach this section.

III. Science policy, the politics and economics of scientific and technological research. The sociology and psychology of science and scientists. This section deals with material known as SSTS, the Study of Science, Technology and Society. The anthology by Spiegel-Rosing and Price (note 8) is a thorough, comprehensive source of information for this section of SCC. The dilemmas that face scientists as researchers and teachers in an ideologically and politically charged environment should be highlighted. Faculty will probably come from sociology, psychology and, perhaps, political science.

IV. The nuclear arms race; its consequences for the scientific community in terms of funding and ethical-moral compromise. Nuclear war and its prevention will be a very important feature in this section. The question of whether science has become a big business enterprise might be considered, and the consequent need for "science ethics" (as it has become part of business administration programs) should be discussed. Faculty from the sciences philosophy, history and political science will probably wish to teach this section.

A wealth of source material is available from major universities that offer courses in the areas envisioned for SCC. For instance, Columbia University in New York lists a Colloquium in Science (Science 1001-1002) that may be used there by non-science majors to fulfill the general science requirement. The course at Columbia deals with: "The features which characterize scientific models--the use of quantitative thinking, inference, rational construction, and predictive capability . . . . The course examines how scientific theories are invented and how they came to be accepted, verified (an impossible goal according to modern notions of theory building) and in some cases rejected . . ." Columbia as so many other colleges and universities at present also offers a course on the nuclear arms race. Contemporary

Civilization C 3003 aims to understand "the nature of nuclear weapons, the dynamics of the arms competition, and strategies for preventing nuclear war, drawing on insights from physics, biology, seismology, political science, psychology, and other fields."[23] New York University lists a course entitled History of Science and Medicine that examines "science and public policy, sources of financial support, relations between scientist and non-scientist in American History." (History V 57.0619). The departments of physics and psychology jointly offer a course Nuclear War and its Prevention, V 50.0402.[24] A number of colleges nationwide received grants from the Alfred P. Sloan Foundation for the development of a New Liberal Arts (NLA) program to introduce computer literacy, quantitative skills, and technological literacy in the college curriculum. As a result many courses relevant to the proposed SCC course were developed. A sampling follows.[25]

Bucknell	Introduction to the History of Science and Technology
Grinnell College	Advanced Special Topics: Nuclear Weapons and Arms Control
Lafayette College	Senior Colloquium: Nuclear Arms Race
Mount Holyoke	A Case Study in Science, Technology and Society: Nuclear Weapons
Union College	A Study of Issues and Choices ("explores the technology of nuclear weapons...") Nuclear Weapons and Arms Control
Trinity College	Understanding Technology
Vassar	Dilemmas of Technological Society. Technology and Global Issues.
Williams College	Philosophy and Technology (deals with ethical issues as well as the modern theory of theory and scientific method)
	Nuclear War: History, Ethics and the Environment
	Science, Technology and Human Values

I see four immediate major benefits in general of this new approach to science education through a SCC required course:
1) Science majors will not commence their studies with outdated, empiricist and logical positivistic notions about science and a false concept of scientific method. Having shared a scientific-humanistic educational experience with students from all disciplin

and having acquired the modern viewpoint of the philosophy of science, they will be encouraged to see their work in a more humanistic way.
2) Non-science majors will not find themselves in "hard" science courses, which they resist and often find meaningless.
3) Many potentially good science students, especially those with a humanistic inclination, are put off by the prevalence in science departments of an atmosphere of a special mission toward Truth, a special and difficult "rationality" and a special seriousness. Rightly, they sense a hoax and they shy away. Thus the selection of science students is biased against the type of students that should enter the sciences if they are to become more humanistic. I believe that the humanistically inclined and scientifically curious student will be attracted to the sciences again after he has heard the arguments for its being properly one of the humanities, since it is, like literature and the arts, a way of lending reality to the natural world and seeing it in forever changing ways. This result by itself is a most important benefit and could be strong justification for the proposed SCC course in the college curriculum.
4) Analysis, in a scholarly, non-ideological, unemotional atmosphere, of the complex entanglement of science and technology with the machinery of war. Universities and colleges must no longer shy away from inclusion in the core curriculum of the most important issue of our time--the nuclear arms race.Because of the essential roles of science and technology in nuclear weapons design and development, discussion of the predicaments and consequences of the arms race, including airing its moral implications, belong in SCC. A specific benefit of confronting all students with these realities is that no future worker, scientist or non-scientist, unexpectedly finds himself/herself ethically, even economically, compromised in a war technology related job. Generally--more importantly, I feel--an examination of the issues may drive home the absurdity of nuclear arms proliferation and open ways to prevent what would be the ultimate human folly--nuclear war.

At some point in this paper I proposed to find a way out of the paradox of re-educating reluctant science educators to accept, or to teach in, a "science and culture" program. In the first place, there are probably quite a few humanistically inclined science teachers that would welcome the chance to express themselves through a "science and culture" program. Secondly, enrollments in "hard" science departments are dwindling as many gifted potential scientists are turning to more humanistic endeavors such as medicine. Under the circumstances, even recalcitrant educators can be convinced that rigid traditionalism might well be turning away some of the most gifted science candidates. Of course, complete dismantlement of the paradox must await the next generation of science educators.

NOTES

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