

Educating engineers

An ecological viewpoint

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This article argues that engineering education is on the wrong track and should be changed. Because it is rooted in the tradition of humanism and "the conquest of nature" it is having disastrous results in the world around us. Its aim of technical competence is not enough. The cure, says Dr Hartley, is for engineering education to use systems analysis — a method it already possesses — to examine critically the humanist assumptions that have dominated engineering so far.

The development of modern technology has been a great adventure that many people have justly regarded as the conquest of nature. Until recently, most engineers have prided themselves on making this conquest possible. Many, perhaps most, still do. What other attitude is possible for them? Can engineering be anything else but the conquest of nature?

Perhaps it is obvious from my tone that I find the conquest of nature questionable at best. Yet I must immediately make clear that I am not speaking from across a supposed gap between the so-called "two cultures"; I am not opposed to engineers or engineering, nor am I ignorant about them.

If I were a humanist, my problem would be immensely complicated and probably hopeless. Fortunately, I am not a humanist. I am a cultural ecologist with a literary background. Therefore, I can set to one side the "two cultures" approach, which completely blocks any resolution of the question. I can point out with no discomfort that the past attitude of engineers bears a close affinity, not to the vocabulary or preoccupations of those who consider themselves humanists, but to the dominant conception in our society about the supreme importance of strictly human interests in the general scheme of life. Humanism, if not the cause is certainly the essence of that ignorantly anthropocentric outlook.

The pressure of history allows us no choice but to use the term "humanism" for that ever increasing tendency to consider human life apart from all else — a tendency which inevitably becomes indistinguishable from the assumption that life has no value apart from human purpose. This humanist view displays and indeed constitutes humanism's inherently non-ecological character.

"Progress" promises a general amelioration of human life, making possible for everyone good education, cultivated sensibility, and not only the provision of bodily

necessities but the addition of every material comfort. The education, insofar as it has been attainable, has of course been a humanist education singing the praises of human achievement through the power of human intellect, and defining the world as something for that intellect to exercise itself upon. Even material comfort itself is subsumed under the purposes which humanism in its more self-conscious moods likes to dwell upon; I have heard people maintain that material progress is necessary to provide us with energy slaves so that we can all be free to spend more time exercising our more purely human (i.e. mental) faculties.

Humanism is the dominant ideology of modern times, comprehending both capitalism and socialism, and being not merely an ideology but the practical commitment of every society that is modern or trying to become so. Its main practical effect is to increase without limit the per capita amounts of resource use, pollution, and environmental destruction. Its rationale is basically its commitment to human self-importance — a generalized egoism that encourages socially and environmentally corrosive egoism in every human individual.² In practice, this means that engineering has indeed been at the service of an outlook that at its foundation is humanistic. Modern engineering, in fact, has had no other purpose.³

The world as a manipulable object

Engineers follow notions of improvement set forth originally by poets and philosophers dreaming a world of perfect felicity for man. In its engineering manifestation, then, humanism contrives to manipulate the environment in ways that its philosophical and literary manifestations deem beneficial — to make improvements that accord with human purposes. In those terms we can even regard modern science as a creation of humanism. Operationally, modern science has been humanism's technique for defining the world as a manipulable object and for discovering the basis for effective procedures of manipulation. Engineers have simply applied those procedures in carrying out projects determined by humanistic notions of improvement.

The question of professional responsibility

This article is a shortened version of one that originally appeared in the December 1980 issue of *The Ecologist* and is reprinted by kind permission of the editor of that journal.

bility boils down to whether we can define full professional adequacy in engineering merely as technical competence to carry out such projects. This amounts to asking whether we should try to establish a radical separation between engineering and humanism to replace the fantasy separation that our cultural self-delusion has maintained. I started out by asking whether we had to identify engineering with the conquest of nature. In fact, *humanism* is the conquest of nature. This is humanism's fundamental arrogance and irresponsibility. Engineers like to think of themselves as being committed to responsibility. Can engineering turn away from the conquest of nature? Can engineering behave with full responsibility? Can there be a non-humanist engineering?

The most immediate difficulty in the project to conquer nature is its effect on *human nature* — its deleterious effect on society, and the concomitant diminution of human personality which results from the loss of sustaining interpersonal fabric. Humanistic egoism makes people unable to know society as anything but an aggregate of separate egos, or the earth as anything but an aggregate of mere non-human bits and pieces. But notwithstanding the vaunted importance of those isolated egos, they become objects of manipulation just as surely as the bits and pieces of estranged nature do — and by means of the same process. The industrial system is impossible unless most people in the industrial machine obey orders like robots. In *The Abolition of Man*, C. S. Lewis says: "Man's power over Nature turns out to be a power exerted by some men over other men with Nature as its instrument."⁴ That, and not the environmental problem as usually conceived, is the most immediate professional dilemma of the engineer.

The exaggeration of separate human importance has created a general social estrangement such that the individual can have no real significance. There are no longer any transcendent interpersonal bonds that can confer fully differentiated individual significance.⁵ Engineering has contributed to this situation not only because it has created the technological basis for industrial production as such, but also because industrial technology has been the means whereby the isolation of individuals in socially irrelevant modules has become possible. Survival — even comfort — has become possible without reference to others.

People's material needs are provided for not through binding human contact, but through mere distribution of standardized goods and services, which can be routed in any combination and at any speed to any number of individual customers whose

main relationship then is to the general productive mechanism rather than to other people as such. The mechanism requires that human behaviour must be compatible with the requirements of mass production; insofar as possible, individuals must be replaceable and interchangeable parts. Their relationship with each other becomes as exterior and standardised as their relationship to the mass system. Differentiated, unique personalities become as impossible as the differentiated social networks that once sustained them.

Quite simply, the energy that once flowed through those networks no longer does; energy now flows in wires and pipes. The effort to satisfy basic material needs that once gave urgency in social relationships and filled them with sustaining material content no longer exists. It has been engineered out of existence in an attempt to fulfil the humanist fantasy of liberation from mundane concerns deemed unworthy of the human intellect, or to realise the fantasy of pastoral felicity and effortless accommodation.

Engineering must be a social science

The point is that engineers do not merely design hardware; they design the material framework of society, and thus they design social relations as well. Its effect on social ecology is the greatest ecological impact of engineering. If engineers are to be fully professional, they must take full professional responsibility for their actions. Engineering must recognise and address its social science dimension; the engineer must be a social scientist as well as a designer of equipment and material processes.

The alternative view, still probably typical of most engineers, is that an engineer should merely *react* to situations or requirements that he must accept as given; he should not presume to make judgments except in terms of his technical expertise, which should be as narrowly specialized as possible so that he can be maximally expert at what he does. Social responsibility tends to be regarded in terms of adherence to government regulations. In practice, an engineer who is educated to react will tend to criticize those regulations only on the basis of whether they make his job more difficult. He will feel little professional obligation to evaluate and criticize policy on broader grounds, and certainly he will not feel obligated to take a public stand as a professional on questions of resource use and general ecological impact (including social impact) that go beyond the purview of the regulations.

To be sure, technical competence is a *sine qua non* of adequacy in any profession. But if technical competence is all we mean when we say an engineer is professional, then we cannot regard engineering as a profession on the same footing as other learned professions, which are ultimately

based on standards of ethics and responsibility that go far beyond merely technical criteria. We are left with a conception of the engineer as no more than a high-grade technician, a functionary not fully professional — that is with no responsibility for his actions beyond their technical adequacy. A glorified mechanic. But someone who is professional in the fullest sense is responsible for taking into account the *ultimate* meaning of his professional actions, and is expected to have the background for doing so. We must assume that a real professional is the ultimate authority for all his own professional acts — then he can't pass the buck, can't define himself as someone who merely reacts to given situations.

In the past we have taken the unwarranted liberty of making radical changes in an environmental system that we did not understand; yet we have long known that random changes in any orderly system are likely to do harm. We are not dealing in vague sentiment here — from a strictly engineering point of view, it should appear most reasonable to hold suspect any proposed radical departure from conditions which prevailed at the time when the human species developed its present phylogenetic constitution.

Such practical questions of systemic integrity can show us how to establish a real separation between engineering and humanism. Unlike humanism, engineering can assimilate ecological thinking. To the extent that it does, we will have the non-humanist, responsible engineering we so badly need. At present, many engineers advocate a "broader" curriculum for engineering students. Naively, they suppose this would require a better grounding in the humanist tradition, which panders to their desire for cultural approval. Those of us in engineering education who have been immunized against the self-adulating rhetoric of humanism must disabuse our engineering colleagues before they overload the curriculum with humanist propaganda. Grounding in traditional humanism will merely deceive the students into feeling well-educated, while making them better able to rationalise their acts and fend off real systemic analysis.

To develop an adequate philosophy, engineering does not have to borrow from humanism. The principles of good systems design should provide an adequate basis, as long as engineering develops a broader perspective regarding the systems it deals with. Engineers must begin to apply good engineering analysis to issues that in the past they have pretended to ignore. Engineers have produced many unanticipated and undesirable effects not because they have failed to be humanists but because they have failed to be thoroughgoing as engineers. Adequate grounding in systems science will make obvious the fact that even a concern for medical effects as such is not good enough for good engineering; the social organization which brought about those effects is also part of the problem. This is why I emphasise the *social* aspects of the considerations to which engineering must pay attention.

In the long run, there is little point in

merely designing ways to mitigate the bad effects of productive operations when such effects are the inevitable result of the principles constituting the organizations involved — principles that engineers have fostered without understanding the implications of what they were doing.

The activities of giant corporations dominate our lives, and as long as we accept the principles on which they operate, we shall be helpless before them. Engineers are the ones who have done most to help the development of industrial giantism, with its attendant transformations of community life, family life, and behavioural values generally, not to mention its virtual destruction of competitive free enterprise. Ironically enough, most engineers tend to view themselves as social conservatives. Yet their activities have made and continue to make inevitable the most radical kind of social change, all because they refused to examine the implications of what they were doing.

Even if engineers as a group would prefer to avoid the responsibility of full professionalism, society cannot allow them such a luxury any longer. What engineers do is too important; the effects of their activities are too profound. The advice of a physician affects one life at a time; the advice of an engineer may determine whether hundreds of people develop cancer ten or twenty years later. We can no longer afford the kind of ignorant specialization that hampered understanding in the past. We must insist on the most rigorous, fully developed, and comprehensive kind of professional standards in engineering, and we must give engineers an education that makes them capable of living up to standards of that kind.

Fundamental changes to curriculum needed

This involves some fundamental rethinking about the very nature of an engineering curriculum. The education I mean must be integral with technical instruction; it cannot be a mere addition to the technical curriculum. Courses aimed at giving "breadth" tend to be superficial, and to be regarded as extraneous by the students. If we cannot make the change an integral part of engineering instruction, we shall continue to graduate engineers who have only the technical skill to perform as narrowly based, irresponsible functionaries having no conception of the larger and more important effects of their activities.

Systems analysis is a basis of ecological study, which the ecologist tries to make as rigorous, as exact, as quantitative as it can be. Energetics is an essential topic for systems analysis in ecology, and along with the study of material and information flow it should be a basic topic for an approach to non-humanist engineering. Properly understood, this approach provides a tool for social analysis organized in a way clearly relevant to the technical considerations of engineering, couched in a language easily assimilable to the language that engineers

already know. An engineer should know how to think about social organization as a control system. All engineering is essentially systems engineering of one kind or another; our aim must be to give every engineer a more generalised understanding of systems thinking and an ability to apply that thinking to a wider range of systems, making it possible for each engineer to relate his speciality to its broader systems context in a professionally meaningful way.

Present engineering education is in effect a method for training people to ignore insofar as possible everything that does not bear directly on the immediate technical problem. The main result of this is a tendency to suboptimize partial systems models in terms of very unrealistically defined criteria of "demand" and "need." These simplistic criteria enable planning to go forward without any analysis of systemic context and systemic alternatives. To proceed in such wilful ignorance is unprofessional.

Professional view is process-oriented

The systemic view, which we could also call the operational or realistic view, would enable the engineer to take a much more solid pride in his work. We could even call this view the *conservative* view, for a conservative in the best sense is someone who is process-oriented — that is, "concerned for the on-going inter-relationships and effects of elements within the system on each other." It is also the only conceivable professional view. At present, a technically competent engineer is in the position of designing good components for use in a badly designed overall system — a system that we could rapidly re-design for better energy efficiency, without any essentially new technology, and without radical social change.

Recent engineering has made everyone more and more dependent on distant sources over which they can have no direct influence. Engineering has designed a situation in which increasing control by centralized bureaucracies has become inevitable. The monstrous bureaucracy that fills conservatives with such disgust is a monument to the degree of impact engineers have had; their headlong rush to introduce technical innovation has completely revolutionised our political life, making local self-regulation and independence nearly impossible.

One of the worst problems is the general manipulation of society by the industrial-commercial bureaucracies, all pretending to offer choice while closing off options. Corporate economics really amounts to a collusion of private interests in a non-accountable private government controlling nearly every detail of our lives. The limited liability corporation defined as a juridical person is a new kind of control system, and as such it is a suitable topic for engineering analysis. From a systems point of view, the bad thing about such government is that it

is unnatural — that is, it is badly designed and has to be maintained by an excessive energy flow. It is an attempt to deny systemic reality. It is inherently irresponsible, since it is set up precisely to allow those in control to affect others without paying attention to the full responses of those whom they affect. Thus to inhibit diversity of response from within a system is automatically to increase the energy cost of maintaining the system.⁹ Any engineer should be at least minimally conversant with what systems analysis might have to say about such a problem, and should be ready to contribute to the analysis from his own point of view.

A still more profound effect of relentless technological change has been the fundamental re-design of basic personality — i.e. standard behaviour patterns — due to a complete change in the material basis for interpersonal relations and for the expectations that people have. We have engineered individual self-reliance out of existence. People who are cogs in a giant centralized corporate machine are not going to be self-reliant, though they may cling to the fantasy and soothe themselves with rhetoric. But they feel their helplessness, so they become addicts to the drug of consumerism, the endless purchase of endless trivial products. The systemic effects of technological innovation have created a population with an ever-increasing proportion of individuals who demand instant gratification, who have been programmed to "need" constant novelty. Such people represent a new kind of typical personality, incapable of restriction, incapable of permanent relationships, intolerant of life's ordinary demands. They are no longer differentiated individuals whose lives have unique value, but interchangeable components in jobs where replacements are always available, and one is as good as the next. The same inevitably becomes true of personal relationships. One worker is as good as another, one job is as good as another, one spouse is as good as another. This is freedom as designed by our present technology, the creation of engineers who just wanted to do their specialized thing, and let somebody else worry about the consequences.

In fact, we do not even need subtle analysis to prove that our system tends to maximize energy and materials consumption, nor do we need to argue about whether such a tendency is indefinitely sustainable. We need only ask how to decide on what energy and resource and organizational criteria we must use to indicate a consumption level that is sustainable, and how to apply those criteria. How should we go about designing a system that will stay at a sustainable level? This is clearly the engineering and social question for our times, and I should not have to ask it — any professionally responsible engineer should have thought of it ten years ago. Unfortunately, engineering has failed to develop real professional responsibility because, as I suggested at the outset, engineering has been dominated by humanist values, which are inherently antisystemic and, therefore, in-

herently irresponsible. The humanist dream of "progress" to which engineers have devoted themselves is a manifestation of humanism's fantasy concerning what it regards as human freedom, dignity, and power. Manipulation of the world both exhibits these things and proves that such manipulation is justified — if you are free, you have a right to act freely. There is a built-in tendency, therefore, to identify "progress" with anything that increases the amount of energy and material that people control.

When the inevitable ill results of such behaviour become too obvious to ignore, those non-engineers consciously devoted to humanism pat themselves on the back for being sensitive enough to notice the problem, while they chide engineers for creating it. The engineers then are supposed to take care of it. Non-engineering humanists are proud of themselves for having well-articulated noble sentiments, and they feel that they have fulfilled their obligation when they voice these sentiments. These non-engineers assume, however, that the solution to a problem will always allow them to retain unlimited control over energy and materials, and they humanely insist that all people should have such benefits. Thus the key to humanism — that is, to "progress" — is a belief that we can have our cake and eat it, too — that we can somehow ignore the second law of thermodynamics. That is the belief embodied in our society's basic design assumption that energy and materials use should increase every year — that we should attempt to maintain unlimited growth. The fact that engineers have accepted such a design assumption argues that engineers have been trained to be humanists first and engineers second.

Engineers by themselves cannot solve our problem, but if engineers will not take full professional responsibility for what they do, we will all continue to be helpless. Engineering education may be the key to the modern dilemma.

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