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The Greening of Engineers: A Cross-Cultural Experience

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ABSTRACT: *Experience with a group of mechanical engineering seniors at the University of Colorado led to an informal experiment with engineering students in India. An attempt was made to qualitatively gauge the students' ability to appreciate a worldview different from the standard engineering worldview—that of a mechanical universe. Qualitative differences between organic and mechanical systems were used as a point of discussion. Both groups were found to exhibit distinct thought and behavior patterns which provide important clues for sensitizing engineers to environmental issues in future educational initiatives. Cross-cultural and global dimensions of these initiatives are discussed.*

I. INTRODUCTION

One of the wonders of human communication is the ability to capture in a word, so to speak, the consciousness of an age. The term "green" is one of these magical words. One can think of few symbols in literature, or even in folklore, that have had as much impact on the imagination and consciousness of entire societies around the world in recent times as this simple word. The word itself represents a rather wide and loosely defined spectrum of thought, attitudes, philosophy and practice, centered around the common theme of concern for and protection of the environment.

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As might be expected, this spectrum represents different shades of "green". At the one end are the "deep ecologists" with a worldview that would be considered radical by many people—both in its analysis of environmental problems and the proposed solutions. This group calls for a fundamental reorientation of values, goals, priorities and life style to make human society blend in with Earth's ecology. At the other end of the green spectrum are the growing numbers of people all over the world whose concern for the state of the environment has caused them to call technology into account—but only in this particular area. This shade of green consciousness and opinion would have technology *manage its impact*, without necessarily modifying its overall pattern of development.

In the middle of this spectrum is a sizable body of thought associated with the mainstream environmental movement as represented by the Sierra Club, for example, which opposes the present pattern of development, calling into question the very notion of development as a good in itself. It envisions instead a stable, sustainable society supported by "technology with a human face", made up of small decentralized systems. In its theoretical forms this line of thought questions not only the philosophy but also the sensibility of modern industrial and post-industrial society, reflected in ever-increasing consumption levels and demands for higher standards of living as a means to a better life.[1, 2]

"Green Thought" as represented by mainstream environmental thinking, may thus be said to constitute a worldview which may be contrasted with the mainstream view of engineers on a variety of fundamental questions. For example the "green worldview" assumes ecology to be a basic theoretical and empirical discipline rather than an offshoot of other fundamental branches of science. The engineering worldview, on the other hand, either implicitly or explicitly uses physics and chemistry as the basic theoretical and practical framework for problem solving. The two contrasting frameworks—organic and mechanistic—often lead to fundamentally different perceptions, analyses and solutions of environmental problems at the interface of engineering and the environment.

The interface between green philosophy and classical engineering theory and practice is only just beginning to form, largely in response to the pressure on industry to conform to environmental laws and standards. As such, the considerations have been more or less piecemeal and in no way amount to a revision of fundamental assumptions as called for by a green critique of western science and technology.

There is another basic difficulty. Characteristically, the philosophical assumptions of engineering are *implicit* in its theory and practice and can only be intuitively deduced. They are not necessarily synonymous with the implicit assumptions of science, on which a considerable body of analytical and philosophical literature exists.[3] With the development of quantum mechanics, science, or at least physics, has become much less rigid in its descriptions of things. Notions of causality, locality, etc. have become increasingly difficult to pin down. However these theoretical problems and their philosophical implications have remained purely academic matters. The gulf between the physical and the life sciences has tended to become wider rather than narrower, except for certain esoteric interface areas. This gulf is dramatized in the encounter between engineering and green philosophy, as a result of the domination of engineering by the ethos of classical physics.

As reported in this paper, I did not attempt to systematically gauge or quantify the reactions of students to the green viewpoint. Rather, I simply made it a point to allow the students to express themselves on a variety of social and philosophical issues related to the impact of technology. The green point of view was presented as a basis for discussion. As it turned out, teaching experiences with two very different groups of students yielded a harvest of valuable data, so it is not entirely inappropriate to label them experiments in retrospect.

The first group was a class of mechanical engineering seniors at the University of Colorado at Denver. The second consisted of final year mechanical engineering students at Kumaraguru College of Technology, a small private engineering college located at Coimbatore in South India. In the latter case I was guided not only by my earlier experience with the Colorado students, but also by recent developments in India and the world in the area of environmental protection. These results are therefore more specific and topical.

II. THE U.S. EXPERIENCE

Several years ago, while teaching a course on energy conservation at the University of Colorado at Denver, I had the opportunity to conduct an informal experiment. This has been reported in an earlier paper[4] and is summarized here. The course was intended to be a regular technical course and a standard textbook on the subject was used as the main text. However, the class frequently included seminar-type discussions addressing a wide range of questions. For example, energy was discussed in different ways, paying attention to where it comes from and what happens in the course of its use by society. This perspective linked energy inextricably with human society and the physical and biological environment. Various questions were raised and it soon became clear that the traditional lines separating technical questions from social, philosophical, cultural and environmental questions are artificial and arbitrary.

Coincidentally, the same semester I also taught a short course on the topic of energy for a rather diverse group of non-science majors, comprising business, accounting, liberal arts and psychology majors. As there was little formal content of the course, a considerable amount of time was spent in discussion and watching videotapes, one of which was by Amory Lovins on “Soft Energy Paths”. Lovins is a technologist who advocates a comprehensive redesign of technology to make it environmentally-friendly, or “soft”. This tape was generally well-received by the group. They found Lovins’ arguments persuasive and thought-provoking. Interestingly, the same tape shown to the engineering group elicited guarded, generally negative responses. Several students thought Lovins was biased and “anti-technology”. When I asked why Lovins ought to be considered anti-technology, one student answered, “Because he is anti-nuclear.”

One group discussion in the engineering class brought up a philosophical issue. I mentioned that one of the criticisms of science by writers whose books have become important in the wake of the environmental movement concerned science's implicit worldview and assumptions about the nature of reality.[5] For example, according to these writers, Western science seems to entertain the axiomatic belief that eventually everything can be reduced to physics and chemistry, now or in the future. This assumption implies that the universe, and everything in it, is a machine which functions according to prescribed laws and that these laws could in principle be completely determined by applying the methods of science—sometime in the indefinite future. I asked the students whether they subscribed to this belief and whether they thought its implications had any practical significance—for example, in what engineers do. Many students considered this fundamental belief "justified", "self-evident", "obviously true". One student claimed, "It's not an assumption. It's a fact!" Some students had no opinion. No one considered this article of faith to have any practical significance.

At the time I taught these two courses, I was not particularly well-educated on green philosophy or the totality of the green point of view, including its emphasis on the significance and relevance of the science of ecology for engineering. In spite of this, I was struck by the observation that engineering curricula, or at least the typical mechanical engineering curriculum, paid virtually no attention to environmental science. At most, a book on energy conversion, thermal power plants, or automobile engineering, might have a chapter or two on pollution control. No attempt was made to see the world, even the organic world, as an organism rather than as a machine—delicately poised, fragile and vulnerable to irreversible stress and death.

In recent years the impact of green thought on engineering education in the U.S has become much more noticeable.[6] This is partly due to new job and market trends favoring environmentally-friendly technologies. It is quite possible that engineering students in the U.S now are not only much better environmentally educated than their counterparts in the mid-1980s, but are also more keenly disposed towards environmental protection. In spite of this, I doubt that this externally driven change is deep enough to cause a fundamental change in worldview (see Section IV).

III. STUDENTS IN INDIA

Recently, while teaching a course entitled "Energy Resources and Utilization" for mechanical engineering seniors at Kumaraguru College of Technology, a small private engineering college in South India, I once again had the opportunity to interact with engineering students on a variety of technical, social, cultural and philosophical issues centered around the problem of energy.

Like the energy conversion course at the University of Colorado, this course was almost completely technical in content. In India, the exact content, or syllabus, of each course is decided by a university committee, rather than by the teacher. For this course, the syllabus and the textbook prescribed by the university emphasized standard topics, such as thermal and hydroelectric power plants and nuclear power. One chapter in the text was devoted to renewable energy sources. There was an introductory chapter which presented a broad overview of the energy situation in the world and in India. Even though the textbook had a chapter on pollution, this was not a part of the course syllabus prescribed by Bharatiar University, to which the college is affiliated.

This was a much larger group (40 students) compared to the U.S. group (not quite 20) and it was a required course rather than an elective. Other than that, the technical level and technical backgrounds of the two groups of engineering students were comparable. Cultural backgrounds and certain other contexts discussed below were of course very different.

In the first session, as a starting point for an opinion discussion, I asked the class if they had heard the term “sustainable development” and whether they had any thoughts about what it implied, especially in the context of energy technology and energy planning. Of the 30 or so present, a small number said they had come across this term in their readings or in educational television programs. Only one or two students were able to adequately explain what the term meant and comment on its significance for engineering.

However, once the concept was introduced and explained, most students quickly picked up on it. They were able to appreciate that, unlike in the past when important social and cultural choices had been made unconsciously by human societies, either on the basis of unconscious value systems or due to various historical factors, the world is now faced with the need to make explicit choices, and the process of making these choices must be collective, intelligent and responsible.

I asked the class to write an essay in four parts. In part one they were to describe what sort of world they would like their children and grandchildren to live in. In the second part they were to say specifically what sort of material things they would like their children to possess or be able to possess. In the third part I asked them to discuss how they thought the world described in part one could be brought about. And in the fourth section of the essay they were asked to review what they had written in the second part in the context of the first and third sections.

Most of the students seemed to enjoy this deliberate exercise in imagination. Everyone wished for a world at peace. Most, but not all, specifically mentioned a world free of pollution. Many (70 to 80%) described in different ways a world in which the marvels of science and technology would make it possible to conquer disease, eliminate hunger and close the gap between rich and poor nations—an essentially utopian world, globally integrated by computers and communication networks.

For the second part of their essay, with the exception of one, everyone wanted their children to have such things as a car, TV, telephone, refrigerator, etc. (Such things are presently available to only a relatively small fraction of the urban population in India). Many said they wanted their children to be educated abroad and be free to travel anywhere in the world.

How could the world described in the first part be brought about? A number of students said that things should be left in the hands of the scientists and engineers—that all the major problems could be solved if the politicians would get out of the way.

A few said specifically that most of the problems were due to corruption in government, mismanagement and misuse of resources.

My intention in posing the question for the fourth part of the essay was to make them reflect on whether the standard of living they wanted for their children was in any way incompatible with their overall vision of the world; or more specifically, whether this standard of living could be "sustained" in the world on a large scale. None of the students in the class seemed to catch on to the underlying point. No one noticed any apparent contradiction. It was difficult to tell whether they wanted this high standard of living for the whole world and considered this a practical possibility or if it was to be vouchsafed only to their own children.

I followed up these early sessions by two seminar-type sessions towards the end of the course, after most of the individual pieces of the energy puzzle had been separately considered from a technical angle. Following the line prescribed in the course syllabus, we had studied in considerable technical detail all the major energy sources presently on the scene, including renewable energy sources as well as those like nuclear fusion, considered "potential".

As mentioned earlier, neither the course text nor the course syllabus, had much to say about the environmental questions in the context of energy resources utilization. For example, in a 50–page chapter on nuclear energy approximately one page was devoted to nuclear waste disposal.

In the final group discussions, we returned to the theme of sustainable development. I asked the students to review their "wish worlds" in the light of this concept. Could such a world be sustained by the environment? Clearly, to answer this question we need to know a great deal about the environment: What are the things that make it up? How does the environment sustain itself? How does it sustain us? How are we related to this intricate system? What might happen if ecological balance and cycles are disturbed? etc.

I expressed the view that our role as engineers obliges us to wear two hats. The one hat we wear as participants in a free society—as consumers and workers who expect and demand our rights and want the best for ourselves and our families. The other hat we wear as engineers, whose intellectual resources oblige us to critically evaluate our own demands and expectations. As engineers trained in systems analysis, we cannot ignore the overall context of our work: our living planet is a delicately balanced system, to which the activities of human beings are a source of potentially serious disturbance. Our work therefore carries a special responsibility. I told the class that this was my view, that they were free to form their own, that I would like them to give the matter some thought.

The final discussion centered on the relationship between engineering and the environment. We considered a number of questions in a rather personal context. Does it matter how an engineer feels about the environment? About nature? Are these feelings likely to affect the style and content of his or her work? How serious are the world's environmental problems? How can they be solved? What should be India's policy towards the environment ? Towards development?

The discussion was productive, although only half of the thirty or so students present participated. There was a general feeling that environmental problems can be solved by enacting and enforcing suitable laws. But that these laws must be "reasonable" and must not compromise development. Engineers can help by creating environmentally friendly technologies. Sufficient lead time must be allowed to convert to clean fuels and new technologies.

The idea of carefully planned, environmentally dictated sustainable development did not find favor with the class. Practically everyone who spoke wanted to see India develop to a high technological level as quickly as possible. A few students said that care must be exercised in planning development to ensure that the environment is not "unduly" damaged.

A small number of students spoke strongly for the protection of the global environment, expressing concern about possible cataclysmic changes from ozone depletion and the green-house effect. First world countries were blamed for these problems.

A few students had strong feelings about materially over-developed countries using huge amounts of the world's resources. It was also felt that these nations are impeding the development of other countries.

I asked the class to consider whether they would be personally willing to pay a higher price for a substantially cleaner fuel and, if so, how much. The respective counts in a group of 34 were:

0%	increase in price	0
Up to 10%		18
10% to 25%		10
25% to 50%		4
More than 50%		2

As a final exercise, the students were asked to read the following statements and indicate to what extent each statement mirrored their thinking.

1. Excerpt from a speech by Chief Seattle, a North American tribal chief, delivered in 1854.

   "The white man must treat the beasts of this land as his brothers. I am a savage and I do not understand any other way. I have seen a thousand rotting buffaloes on the prairie, left by the white man who shot them from a passing train. I am a savage and I do not understand how the smoking iron horse can be more important than the buffalo that we kill only to stay alive.

   "What is man without beast? If all the beasts were gone, man would die from a great loneliness of spirit. For, whatever happens to the beasts, soon happens to man. All things are connected."

Mirrors my thinking : Totally	-	3%
Substantially	-	12%
Moderately	-	24%
Slightly	-	45%
Not at all	-	6%
No response	-	9%

2. Excerpts from the Sierra Club Environmental Health Source Book:[8]

"If we fail to change both our own private habits and public policy, there will be poverty, human suffering, tremendous squandering of natural resources, and broad environmental destruction such as has never previously been experienced by the human race. The kind of inappropriate behavior that has led up to this point cannot last for more than 2 to 3 decades without radically changing the basic nature of the living earth".

Mirrors my thinking: Totally	-	3%
Substantially	-	3%
Moderately	-	24%
Slightly	-	51%
Not at all	-	12%
No response	-	6%

3. Statement by an Indian government official concerning criticism that a hydroelectrical mega project would cause massive destruction of forests and displacement of tribal populations: "Such (environmental) problems are inevitable. We will try to minimize them but we can't let them stop us. We have to get electricity to tens of thousands of villages. How can we do that without big (hydroelectric) projects?"

Mirrors my thinking: Totally	-	42%
Substantially	-	40%
Moderately	-	9%
Slightly	-	6%
Not at all	-	0
No response	-	3%

The course ended at this point. I did not use a written questionnaire to receive feedback on the course. Verbal comments and reactions were invited.

A number of students referred to the creative fantasy exercise, calling it a "lot of fun". Many said they felt very much involved in the exercises, something they missed in standard course material. Appreciation was expressed for my efforts to relate the course material to general social questions and for developing "perspective" on the environment. Some students remarked that this was the first time in their educational experience that someone had tried to put things together to form a big picture. One student called the exercises a "thrilling experience".

Four students came to see me after the course and expressed the desire to do their final year project on an environment related topic. However, subsequent interaction with the rest of the group did not produce any evidence that the students' general worldview had been noticeably influenced. My conclusion was that without regular reinforcement of ecological ideas and awareness throughout the four year program it is unlikely that isolated educational initiatives would have much chance of success.

IV. DISCUSSION

The analysis, discussion and conclusion in this section are inspired by, but are not restricted to, the two teaching experiences described. From repeated encounters with engineering students in India and the United States, microcosmically reflected in these experiments, certain patterns have emerged which I have tried to interpret and categorize.

Like students in general, engineering students are susceptible to a great deal of naiveté in their worldview. This naiveté can be costly, since most engineering work has a direct impact on the natural environment and other dimensions of human life. If students are not sufficiently sensitized, educated and trained to understand, appreciate and respect the delicate web of relationships in nature, the result is likely to be what we have been witnessing—witting or unwitting infliction of harm to the environment, followed by piecemeal efforts to repair the damage.

It seems to me that engineering education, based as it is on physics, rather than the life sciences, has set itself up for endorsing and perpetuating the above approach. By studying simple, non-living things, or by making engineering theory artificially simple through assumptions and abstractions, undergraduate engineering theory creates the impression in students that the world is made up of separate objects which can be manipulated at will. The feeling implicitly and unconsciously extends to include the organic world.

The engineering method is based on a process of selective attention. What does not fit into the prevailing theoretical framework—a framework derived from physics, is either ignored or discarded. Complexity, interconnectedness, the facts of ecology in general, do not fit into this framework. "Results" are achieved by selectively valuing certain effects above other effects. The process is self–reinforcing because it automatically discards what does not fit.

By the time engineering students reach their third or fourth year of college, this kind of "technothink" has become an unconscious mindset. I have noticed it time and again in class discussions on ecology—a failure to appreciate the complexity and fragility of organic systems. This is also apparent in the two teaching experiences reported above. Technothink presumes that things can be fixed and even though the students may know that a dead tree is a dead tree, they find it difficult to understand that the living environment as a whole can be killed.

The conceptual framework of technothink devalues the living dimension of the environment. The environment is perceived as a source which can be freely drawn upon, or as a sink into which things can be dumped with immunity; burying radioactive waste underground in steel tanks or dumping the tanks into the sea renders the problem solved—now and forever, even in a projected scenario in which nuclear fission is seen as a primary energy source. That the chapter on nuclear power in the Indian energy text had only one page on nuclear waste disposal is an example of such tunnel vision.

Ecology is a natural science. It cannot accommodate pragmatic human considerations, conventions and arbitrary geographical demarcations. Taken in its natural context, its implications are radical. This comes across rather clearly when we look at the social and political questions related to energy development, as it did in the discussions with the two groups of students described above. Globally, there is growing awareness of the essential unity of the earth's environment. Yet the affairs of the world continue to be governed by the self-interest of nations, societies and economic organizations. They also continue to be shaped by human predilection for extravagant consumption, whenever and wherever such resources are available. The "wish worlds" of the Indian students, reported in Section III, exemplify this.

The number of schools in the U.S. offering environmental engineering programs seems to be slowly, but steadily, increasing. Some initiatives also seem to be underway to integrate engineering with environmental science and ethics.[6,7] Quite often, trends originating in the developed countries tend to spread to the rest of the world. For example, a good percentage of textbooks used in engineering schools in India are by American and British authors. If a new emphasis and direction develops in textbooks in the U.S. and U.K., it will doubtlessly have an impact on engineering students in many parts of the world.

However, if they are to do justice to the needs of the environment, this new generation of texts will have to do more than teach engineers to design environmentally friendly technology. The entire framework of "technothink"—its implicit assumptions, inherent values and traditional methodology, must be reconsidered.

Engineering students must be helped to understand that the work that engineers do involves dealing with organic systems. These systems are fragile: we do not understand them well and, even if we did, that would not make them any less fragile. One cannot approach the organic environment on the basis of technothink. The relationship must, first and foremost, be one of feeling—a sensitivity that is reflected in the passages of the Chief Seattle speech.[8]

There is no reason why ecology may not be treated as a fundamental science on a par with physics and chemistry. It might well be an essential part of engineering curriculum at all levels. But the study of ecology does not guarantee sensitivity to the environment. For that we need a sweeping cultural change—a change in our entire perception of and relationship to nature. It must be seen and experienced as alive, an integrated and delicate whole.

In order for engineering to help create a society at peace with the environment, it will have to do more than produce environmentally benign technology. It will have to transform itself. There is too much at stake.

V. SUMMARY AND RECOMMENDATIONS

The two teaching experiences provided valuable insights into reactions of engineering students to “green philosophy”. Their reactions indicate a clash of paradigms: “technothink” vs. “green thought”. Technothink implicitly assumes that things can be understood by analyzing them and, if something goes wrong, can be fixed.

This is the implicit mindset of many engineering students and may reflect premature specialization in engineering before a student appreciates that his or her primary role is as a citizen of the planet.[9] “Green philosophy” on the other hand demands humility, respect and sensitivity towards the natural world. This paper has argued for a serious and critical reappraisal of “technothink” assumptions and beliefs with respect to the natural environment and a corresponding revision of the standard engineering curriculum to include the study and understanding of living systems.

In this context I make the following recommendations.

1. A one or two semester course on “ecological relationships and living systems” should be *required* at the sophomore level in the engineering curriculum.
2. A new style of teaching and engineering textbook writing should be adopted to emphasize the notion that all living things are connected and cannot be separated.
3. Multimedia and global networking technology should be used to enable engineering students to view energy, materials and environment-related issues from a global perspective.
4. There should be a serious debate and discussion among engineers on the validity of “technothink”.
5. Engineering curriculum and teaching methods in countries like India should be changed to make engineering students environmentally literate.

REFERENCES:

1. Illich, I. (1977) *Toward a History of Needs*, Pantheon Books, New York.
2. Roszak, T., Ed . (1972) *Sources*, Harper & Row, New York.
3. Maslow, A.(1966) *The Psychology of Science*, Harper & Row , New York.
4. Ansari, A. (1984) Energy: Raising the Consciousness of Engineering Students, Engineering Education, *Journal of American Society for Engineering Education* (Nov.1984): 111-115.
5. Roszak, T. (1972) *Where the Wasteland Ends*, Doubleday, New York.
6. Meade, J. (1992) No Course Is an Island, *PRISM*, magazine published by American Society for Engineering Education (Dec. 1992): 20-23.
7. Catalona, G.D. (1993) Developing an Environmentally Friendly Engineering Ethic: A Course For Undergraduate Engineering Students, *Journal of Engineering Education* **82**/1: 27-33.
8. Samuels, M. and Zina, H. (1983) *Well Body , Well Earth: The Sierra Club Environmental Sourcebook* , Sierra Club Books, San Francisco.
9. Capra, F. (1997) *The Web of Life*, HarperCollins, London.