

Challenges before Engineering Education – Role of Humanities and Social Sciences

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ABSTRACT

The recent global changes and lack of sustainable development have thrown open many challenges as well as opportunities. The material and economic development processes of last two centuries have increased social inequalities among nations and communities and led to unsustainable activities that are associated environment damages, global warming, climate changes and threats to security on food, health, shelter, water, air and society. These challenges demand a change in the way we think and act. The issues like renewable energy sources, conservation of resources (including water, adoption of technologies which are clean and have lower carbon foot-prints) are coming to the forefront. So are the issues of social behaviour and value system. The current way of evaluating success based on economic parameters and balance sheets needs to be changed to capture parameters like social inequalities, changing value system, increased corporate social responsibilities, lower green house gas emissions and improved ecological impacts. The teaching process has to stress on the changing scenario and to meet the challenges of quality of living, social justice, equality, sustainability, in addition to techno economic feasibility. Agriculture, Agro forestry, energy, food, communications and industry sectors need changes in the way things are being currently practiced. The needs include greater stakeholders' participation, responsive industry, private-public partnership and voluntary disclosure. The new generations of students need inputs on sustainable operations, resource conservation, renewable energy resources, clean technologies, new value system, climate changes, as well as environment protection and carbon foot-print and societal issues. Education looks at the new concepts of environmental, societal sustainable feasibility to ensure a sustainable development and improved standard of living. Meanwhile, the

approach to investment decision making on developmental issues has to change. This includes Humanities and Social Sciences (HSS) teaching in engineering education

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which needs a fresh look to provide holistic inputs. Thus, HSS has to play a key role in engineering education quite differently from the way it is being managed today.

Keywords: Engineering education, environment, sustainability, competitiveness, social inequity, humanities and social sciences

CHALLENGES OF DEVELOPMENT AND SUSTAINABILITY

The globe has seen unparalleled material development with severe stress on our interdependent economic, social and environmental systems. With global population likely to touch eight billions by 2025, with associated excessive consumption and poverty, a state of environment more fragile and degraded, we are in a state of severe crisis. The alarming trends include:

- 2 billion hectares of soil (with 15% of the earth's land) is degraded as a result of human activities.
- Half the world's resources are severely depleted/polluted.
- 1130 mammals (24%) and 1183 (12% of bird species) are regarded as threatened.
- Ozone layer depletion is high and ozone hole is greater than 28 million sq km.
- CO₂ concentration stands at 25%, which is higher than 150 years ago.
- Every year, over 11 million children die of preventable causes.

In addition, the global meltdown has given a wake-up call to the world's economy to review its developmental activities. The economic growth and sustainable development do not seem to move hand in hand. In addition, over 50% of the global population is plagued by poverty, hunger and disease. Around 10% of the world's richest own 65% of world's household wealth. The widening inequalities serve as a source of wide spread discontentment and social alienation. Social unrest and terrorism today threaten every corner of the earth with a large number of people living on the edge of despair and insecurity (UNDP, 2010).

The decades of developmental process has paid scant respect to replenishing the rich natural resources leading to losses of biodiversity and natural resource regeneration capability. The world is living beyond its means. Global warming and climate change are impending catastrophes. The future has been severely compromised. The present economic models of competitiveness based on rewarding on financial returns, expanding consumer franchise, enhancing shareholder value and using profit and loss as means of measuring success, have failed to capture the social inequalities and ecological destruction. Clearly, the current economic model of development is not sustainable. The future has been compromised. There is a need to look at new methods to ensure our common future faces the challenges of over consumption of earth's resource and stop the grinding poverty. The requirement is a developmental process that meets

the demands of the present without compromising on the needs of the future. Over consumption of resources, social value system and ecological balance have to be addressed (Marquita, 2004; Rao, 2011; Azapagic *et al.*, 2004).

NEW PARADIGMS OF COMPETITIVENESS

The new paradigms of competitiveness should reverse the unsustainable trends of development, revive growth, meet the essential needs and aspirations of the people, conserve and enhance resource base and reorient technologies to manage risks. Sustainable development includes sustainable agriculture, agro forestry, industry practices to provide security in food, energy, health and overall well-being of society. This calls for low carbon business environment, green business, green

livelihoods, greater equity and sustainable practices. There is a need to improve energy efficiency, reduce specific consumptions and green house gas generation and improve eco-efficiency. Sustainable technologies will be dependent on information and communication technologies, biotechnology, nanotechnology, renewable energy technology, based on close cycle operations with life cycle analysis, safety and security. Adoption of clean technologies, changes in value system, increase of product service life, increased use of renewable resources, reduction in specific consumptions and reduced generation of wastes will be the needs of the day. The ecological footprints of today’s developmental process will impact the future generations and hence need to be greatly reduced and monitored (Soares, 1999; McKinney *et al.*, 2007; Manahan, 2007).

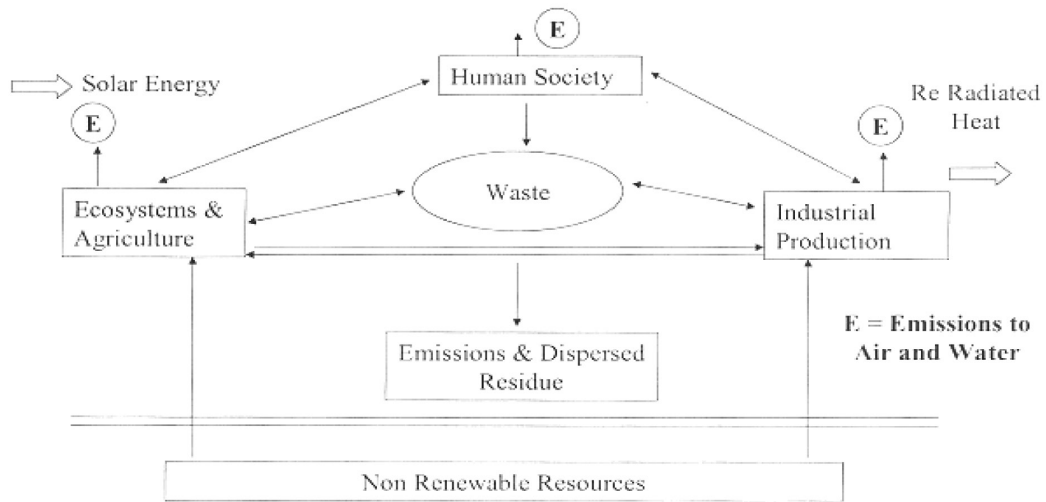


Fig. 1: Resource Flows in Human Economy

NEW MODEL OF TEACHING PROFESSIONAL ENGINEERS

The practice of sustainable development needs to be embodied in the approach of engineers and scientists to the problem solving. The practice of open decision processes need to be encouraged with professional engineers working as “Honest Brokers”. The new paradigm of teaching should encompass the constraints on natural resources, techno-economic capabilities and societal needs in the sustainable world. The answer would be the holistic approach to teaching. New pathways need to be explored with active learning via problem based learning process. The professionals will be required to take new responsibilities to use the talent to modify nature in which sustainability is not neglected. The capacity of modifications can be thought of as a series of resources flow, energy flow and waste flow, as shown below:

The teaching and learning processes have to take into consideration the four basic questions:

1. What are the skills and attitudes required of the new model expert? The ability to capture sustainable decision making skills to transform him from technology advocate to the role of an “Honest Broker” of technical information.
2. What are the implications of the new model of expertise for the accustomed structures and cultures in science and engineering? Sustainability calls for an exploration of the new models of professionalism and a capacity to work with different concepts of rationality.
3. While active learning is necessary for teaching and learning, a new model of expertise is required. The connection between practice and the attributes needed has to be developed.
4. How can fore-sighting and back-casting assist in shaping our new approach? Case studies can demonstrate the significant opportunities available and synergies possible in complex problems.

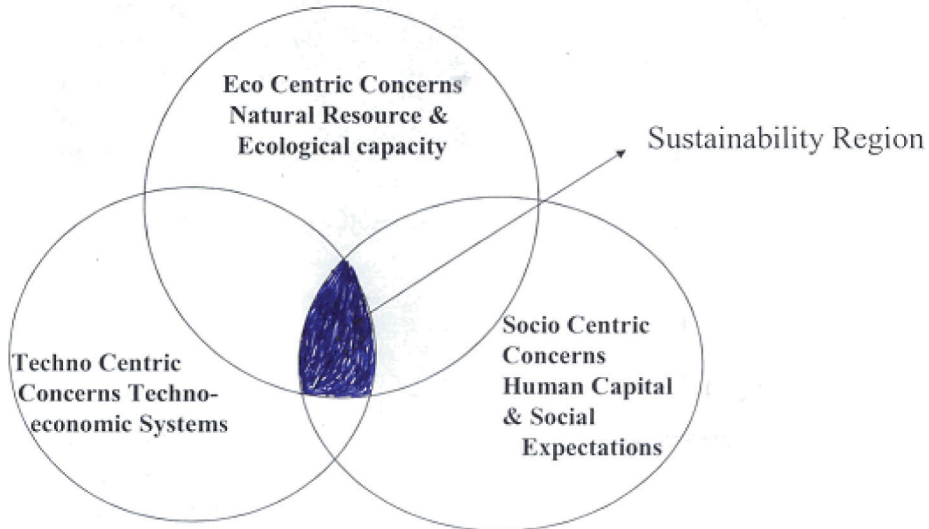
Human society requires various inputs for its needs, be it food, shelter, health, comfort or well being. These needs are met by using various natural resources including solar energy both renewable and non-renewable. The resources are transformed into useful value-added products. Such transformation process is done through agriculture and ecosystem or through industrial processes produces wastes, emissions, residues or re-radiated energy impacting the environment. The general material flows, including wastes and emissions, are parts of the economy (Fig.1). The new model expert is required to learn to live within constraints and this is the new responsibility to be acquired. The need is to look at how to reduce wastes and how to use wastes by studying a complete supply chain within the economic system through lifecycle analysis. The process intensities in using materials and energy need to be captured by benchmarking ecological footprints and looking at reduction in specific resource consumption.

Consequences of the environmental damages are global warming and climate change, which have become mother of all challenges. The aim is to look at options where we control Green House gas emissions and use this as a new parameter of competitiveness.

The business in general takes decisions for investment based on technical feasibility and likely economic gains. This is the Techno-Economic approach. These decisions when implemented will lead to consumption of natural resources, generation of wastes and emissions, destruction of ecological balance. These are the “Eco (Ecological) concerns.” The consequences will impact the society at large and influence human resource and their expectations.

These are “Socio Centric” concerns. We get the sustainability region, the region of overlap of these concerns, as shown in Fig.2. These three form the core of dimensions of sustainability. The shaded portion in Fig.2, i.e. “Sustainability Region,” will satisfy these three concerns. Hence, we need to identify this region in our decision making process.

The creative business of future will talk of societal and techno-economic parameters with sustainability and climate change as other factors (see Fig.2). The new dimension will include carbon footprints, water footprints, recycling practices and system closure, energy efficiency and renewable energy use.



One needs to move away from the current techno/techno-economic centrality in decision making to sustainable decision making which includes techno-economic, eco-centric and socio-centric concerns (Soares, 1999; Funtowics & Ravetz, 1993; Ravetz, 1996; Singh, 2005).

Fig.2: The 3 – Dimensions of Sustainability

The three dimensions of sustainability will then include techno-centric approach [with human expertise and ingenuity], eco-centric approach [with the ability of the planet to sustain] and socio-centric approach [human expectations and aspirations] for satisfying lifestyles and quality of life for everyone. The sustainability region would then be one which encompasses techno-economic, ecological and social expectations.

MEANS TO END HIERARCHY – NEW EDUCATIONAL APPROACH

The means to end hierarchy is a transformation process in three steps. Science and technology transform natural capital into built human capital [intermediate means]. Meanwhile, the society's political economy transforms these intermediate means into intermediate ends of human and social capitals through philosophy and ethics. These intermediate means need to be transformed to our ultimate goal of "well being".

Scientists and engineers transform natural capital into built capital and human capital. The new education will help the engineers to look at transforming built up capital into human capital and human capital into well-being. This is the challenge. The current decision making based on cost-benefit analysis looks at the sole criteria of long- and short-term economic gains and shareholder value. In regard to the latter, some environmental parameters are being included in this analysis for decision making. The decision making objectives

based on a single matrix of economic developments is not adequate. Moreover, the impacts of social, environmental and sustainable parameters is rarely accounted for. The single matrix conceals information and leads to suboptimal decision making particularly in complex systems. In strategic decision making, accounting uncertainties as a basis is necessary. We need to define the objectives and the criteria as a part of decision making process. This is the new role of a professional engineer. Setting environmental standards, use of land and other natural resources, management of facilities and wastes, and accounting for social needs are the areas of training for tomorrow's engineer needs.

Decision making in the face of uncertainties, missing information, requires new skills. The need is to involve divergent stakeholders to decide on the criteria for decision making. In complex systems, the outcome of decisions with regard to sustainability is unpredictable and stakes are high. The methodology for managing complex system decision making, involving uncertainty and plural values, is known as "Post Normal Science".

When the stakes of the uncertainties are high, special skills on judgment are needed with a willingness to involve stakeholders. That is the role of an honest broker. Transit from one right solution to a range of technical solutions, with multiple stakeholders, is what one calls as consultative decision making for optimal solutions. The consultative decision making includes, among multiple stakeholders, informing,

bargaining, deliberations, participation, compromises and consensus. Ecological demands may be integrated with social contract and business orientation. A bond between society and profession becomes the core code of ethics. The teaching process should lay stress on evolutionary participation process with clients and stakeholders (Ravetz, 1996; Miller, 2004; Chokar *et al.*, 2008).

IMPLICATIONS ON TEACHING

Science and engineering are essentially objective in nature. The need is to bring subjectivity to capture social and environmental contexts. An honest broker has to be taught to see design as an evolutionary participatory process. One has to move away from one simple problem – one simple solution to complex uncertain problems with more than one right answer by capturing the diverse nature of subjective and objective parameters. This leads to a search for optimal solutions.

The four principles of learning and how to learn are as follows:

- i. Help learners to understand why the consideration of sustainability is in their interest. This is the motivational aspect.
- ii. Use appropriate pedagogies for active engagement with issues.
- iii. Help learners gain plural perspectives in understanding the transformation of “natural capital” to “well-being”.
- iv. Encourage learners to continue thinking about such issues beyond their formal education, namely, the concepts of

ecological, socio-political, techno-economic constraints.

Active learning - active teaching processes should be built on rapidly changing expectations of professional competence. Dynamic interactions will lead to developing the art of enquiry. Problem based learning is an approach to active learning. There is a need to utilize the extended peer review community for active learning and also identify stakeholders, define the problem and develop objectives and criteria for solutions, identify potential solutions, analyze the solutions to reach at optimal solutions. The learners should be able to identify and embed lessons learned, experiences gained, and gaps to be bridged. These are the steps in Post Normal Science.

The new inputs in teaching of engineering should lay stress on:

- techno, social and sustainability parameters.
- significance, impacts and evolution techniques.
- holistic approach to activities (Rao, 2010a, 2010b; Kulkarni, 2011; Hu & Wang, 2011; Indo-US Summit on Higher Education, 2010; Kumar, 2011; Chopra, 2010; Biswas *et al.*, 2010).

CHANGES IN COMPETITIVENESS EVALUATION

The current business decision making process, based on techno economic evaluation, should give way to a complex evaluation process, which includes performance/productivity indices, social

responsibility indices, sustainability based indices, beside techno-economic indices. While current teaching talks of techno-economic indices for decision makers, the other three need to be dealt with in a manner befitting this specialization in which the student trains himself. The parameters mentioned above should be included in the teaching-learning process. The various factors in these three parameters are briefly listed below:

- Performance productivity based indices –
 - specific consumption norms
 - operation efficiency parameters
 - waste generation quantity and quality
 - value addition/ turnover per unit GFA [gross fixed assets]
 - manpower productivity
 - capacity utilization and
 - manpower used
- Sustainability parameters –
 - Ecological footprints for carbon, raw materials, water
 - Material used efficiency parameters
 - Material conservation initiatives
 - Energy quantity from renewable resources including waste energy recovery
 - Water from rainwater harvesting and degree of closure
 - Quantity of waste generated and percentage waste recycled/reused
 - Supply chain management

- Environmental pollution - quantity and quality, disposal including toxic and hazardous wastes
- Handling of toxic, inflammable, hazardous materials
- Disaster management practices
- LCA data and Green practices data
- Societal parameters –
 - Corporate social responsibilities [CSR]
 - Corporate responsibilities for environment protection [CREP]
 - Transparent environmental and social reporting
 - Stakeholder involvement in decision making
 - % gross earnings spent on CSR/SHE (Safety, Health and Environment)/ Greening/Resource conservation/ Education/Social infrastructure
 - Initiatives to reduce the social and economic inequities
 - Initiative to bring security in food, water, energy, health and well-being to the society around (Rao, 2010a, 2010b; Kulkarni, 2011; Hu & Wang, 2011; Indo-US Summit on Higher Education, 2010; Kumar, 2011; Chopra, 2010; Biswas *et al.*, 2010).

THE ROLES OF HUMANITIES AND SOCIAL SCIENCES (HSS) IN HOLISTIC DEVELOPMENT OF ENGINEERS

The new engineering professional as an “Honest Broker” has to follow open decision

making process, along with the other stake holders. The role demands knowledge on transforming ‘Natural Capital’ to ‘Human Capital’ through the interface with professionals from diverse HSS-domains like economics and commerce, psychology and sociology, law and culture, philosophy and ethics. There is a need to sustaining innovations by institutionalizing the same in teaching and learning processes. Open-ended projects and problem-based learning provide the avenues for the institutionalisation of innovation. In fast changing global scene, the concern for ethics and values has grown. The ethical issues in academic, scientific, research and professional fields have to be included in education. Another major issue that needs attention from HSS angle is to bring parameters on society, security, sustainability and transparency into professional education. Similarly, the areas pertaining to investment decision making have to shift from ‘Economic Decision Making Criteria’ to more wider concepts of ‘Multi-Stakeholder Participation Criteria’. This would mean the inclusion of Techno-Centric, Eco-Centric and Socio-Centric parameters in decision making. The concepts of ‘Corporate Social Responsibility’ and its obligations should become integral to HSS teaching and learning processes.

A holistic development of professional engineers should include ‘Green Accounting’ ‘Social Connect’ and ‘Inclusive growth’. There is a need to develop professionals as ‘Citizen Engineers’ and HSS has a definite role to play in this regard.

So far, HSS inputs in engineering curricula have been mostly through the ‘Compulsory or Core Subject Mode’. Their teaching methods, effectiveness and acceptance by engineering students have left much to be desired. The situation can become interesting with the adoption of student centric ‘Flexible Credit System’ in engineering education. Flexible credit system will have lean core subjects and compulsory HSS courses will be very few (about half the present subjects). Thus, many subjects will get into the ‘Elective’ list and each course has to fight for a place in the students’ choice of elective courses. While a student chooses an elective of his choice, he has to be helped to include HSS getting a ‘Minor’ specialization status. This will help him in becoming a ‘Honest Broker’.

Otherwise, relatively less popular subjects may even get marginalized. This is a major challenge to many subject areas including some of HSS. The real challenge is to formulate a wide range of HSS electives to motivate an engineering student to pick up HSS Elective subjects and get a minor specialization. This will go a long way in enabling ‘Holistic Development of Engineering professionals’ (Biswas *et al.*, 2010; Rao, 2010b; Pitorda, 2009).

CONCLUSION

The new concept of teaching will include – concepts of societal needs and sustainability, stakeholder’s participation, responsible and responsive industry, public private partnerships in developmental process,

transparent and trustworthy operations based on value system and resource conservation with sustainability as core drivers. The new education process needs to change the present methodologies so as to meet the needs of the future. This will enable creation of a manpower that is capable of seeding new ideas, germinating new thought processes, creating new innovations to ensure sustainable development. Hence, the author suggests the matrix below to show how investment decision making can move from Techno-Economic parameters (Profit) to the Principles of 3- S, P, E, R, M (SPERM), which will lead to multi-stakeholder multicriteria decision-making.

SPERM

Society	Security	Sustainability
Production	Profit	Productivity
Energy	Environment	Efficiency
Resource	Recovery	Recycle
Materials	Money	Manpower

HSS has stakes in all the 3-S (Society, Security and Sustainability), and 2-M (Money and Manpower). This will be the essence of sustainable development, in which all care and share one Earth. The need will be to have green, clean and close cycle operations so that a healthy adequate contended lifestyle for all is possible as areas needing careful attention. The human resource of tomorrow should be dynamic, forward looking, competent, innovative and ahead of its time. That is the challenge which engineering education has to address.

HSS can provide a strong means of creating ‘Citizen-engineers’ of tomorrow who act as “Honest Brokers” in discharging of their duties.

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