



# Educating Engineers for Sustainable Development

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**Abstract:** In the last three decades, the environmental movement toward sustainability in industrialized countries has motivated researchers and industry coalitions to seek ways to minimize the negative environmental impacts of the built environment and find ways to build green. Developing countries on the other hand have concentrated their efforts in building the much needed infrastructure for improving the living conditions of their people and have not given sustainability the attention it deserves. Education and training are essential components in the dynamics of environmental protection, especially in engineering. In the higher education, a university culture should be created with a core philosophy of environmental stewardship, sustainable development, and critical examination of all activities in light of their environmental impacts. This requires an environmentally knowledgeable faculty, a research program that develops clean, resource efficient technologies with low environmental impacts, and a university with a small ecological footprint. Educating a new generation of scientists, engineers, and technologist with highly developed knowledge of the environment and natural systems and their contributions to human well-being is an essential element of environmental sustainability. This paper reviews the fundamental concepts of sustainability that should be integrated with the engineering education in Iran. Several strategies used in industrialized countries to integrate principles of sustainable development in engineering education are discussed to provide an overview that can be used for successful revision of the engineering education in Iran.

**Keywords:** Engineering Education, Sustainable Development, Developing Countries,

## 1. Introduction

In the last two centuries and in parallel to industrial revolution, engineers made significant contributions to well being of society elevating the standards of living and adding to the comforts of life through

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introducing new technologies. Engineers contributed to the progress made in material science, power generation, machine tools, transport, and communication, but they didn't pay attention to the negative side of scientific advancements such as contamination of water, degradation of soil and emissions in the air, the three elements of our living environment. And those are only the visible ones; there are also other invisible problems such as climate change, and ever-increasing number of diseases. The main environmental issues of the present age are safe drinking water, wastewater processing, solid and hazardous waste disposal, outdoor and indoor air pollution, ecological risk management, and pollution prevention through better, safer products or improved process design [1]. Engineers as innovators and problem solvers need to make an effort to providing more environmental friendly infrastructure in the built environment for the well being of society and they need to gain the required knowledge through engineering education for sustainable environment.

## **2. Definition of Sustainability**

Nowadays, environmental issues affect almost all commercial and industrial sectors, and are a central concern for the public, governments, and even international relations [2]. In recent decades, the enhanced public awareness of environmental degradation has prompted the shift of focus in the built environment from passive waste clean-up and pollution control to proactive pollution prevention and ecological sustainability [3].

The concept of sustainability or sustainable development is pertaining to all aspects of life in the world and is generally expressed as using resources in a way to meet the needs of present population without compromising the rights of future generations to meet their own needs [4] using methods, systems and materials that won't deplete resources or harm natural cycles [5]. It means progress in human well-being that can be extended or prolonged over many generations rather than just a few years [6]. Sustainability integrates natural systems with human patterns and celebrates continuity, uniqueness and placemaking [7].



In order to ensure sustainability and ecosystem well being, attention must shift to acquiring more output from less resource, with less waste, and less damage to the environment [9]. The main objective is to attain sustainable ecosystems that integrate human society with its natural environment for the benefit of both [10].

### **3. Sustainability in Developing Countries vs. Industrialized Countries**

Currently, at the global level, evaluations of the measures of environmental sustainable development that are applied in a country or company are being used to evaluate the stage of its development. A country may be considered to be developed when it has appropriate environmental protection policies and programs in place. Lack of such protection measures within developing countries may lead to a negative political reputation. Failure of some companies within developing countries to meet adequate environmental performance standards compared with companies in developed nations may lead to the pretext for excluding such companies from the global market arena [11].

The industrialized countries, with only 16% of the world's population, consume 75% of the total global energy and natural resources. Uncontrolled pattern of production and consumption in these countries is one of the main reasons for environmental problems at the global level. On the other hand, poverty and unfair income distribution in the developing countries has a severe impact on their environment and causes extensive destruction of their natural resources [12].

Moreover, the quality of human life is different in developing countries in comparison to industrialized nations. Expectations of people in developing countries are lower; therefore more people meet their essential needs with fewer resources. As a result, their local environmental objectives are different from developed countries. However they are expected to join the movement toward global sustainability to



protect the environment and prevent climate change catastrophe. These differences should be considered in establishing educational needs in developing countries.

#### **4. Sustainable Development in Iran**

Iran is facing serious problems of pollution and devastation of its environment. In recent years, Iran has followed the same approach as that of other developing countries; i.e. it has placed economic development above environmental considerations. In this way, growth of industries, roads, towns, vehicles, etc., has and will continue to result in irrevocable consequences for the country. Some regions such as large cities or forests are being devastated by environmental pollution that is already nearly irreversible in some locations [13]. During the past 30 years, the area of the forests decreased from 18 million to 5 million hectares. The number of floods has increased 9 times and the severity of disasters has increased 20 times in the former forest areas. More than 40,000 tons of urban refuse are produced in the country daily and are buried without proper management. This is leading to more soil and groundwater pollution [14].

Iran is heavily reliant on energy-intensive industries for domestic economic production and export. It also has a high dependence on oil products to meet primary energy needs and for its petrochemical and metal industries [15]. Energy consumption per capita in Iran has increased 5 times in 35 years and gasoline consumption is increasing at an annual rate of 8-10%. If this trend continues in the next two decades, Iran's oil consumption will be more than its current production [14]. Currently Iran possesses proven reserves of approximately 133 billion barrels of oil and 24 thousand billion cubic meters of natural gas. These constitute 11.6% and 15.6% of the world's proven oil and gas reserves respectively. Iran has the second richest oil and gas reserves in the world [15]. Due to abundance of oil and gas products, renewable energy in Iran has been neglected for a long time. By 2003 there was slight improvement in the share of renewable energies in total primary energy supply. The share of hydropower increased to 1.8%, with the



share of wood and traditional biomass increasing to 0.18% and modern renewable to 0.004%. Renewable energy comprised 2% of total primary supply of energy [15].

With respect to Environmental Sustainability, Iran is one of the highest carbon emission-intensive countries in the world. Total CO<sub>2</sub> emissions in 1990 were 201.8 MMT, which has increased rapidly at an average annual rate of 5.7% to 372 MMT by 2003. Per capita carbon emission in 1990 was 1010 Kg, 10.6% less than the global average of 1130 Kg. This figure increased to 1514.5 Kg by 2003, 4.5 times higher than the global objective of 339 Kg/capita of carbon emissions [16].

According to First Millennium Development Goals Report of Iran, the main challenges facing the country in ensuring environmental sustainability by 2015 are the following [16]:

- I) Establishing a comprehensive environmental information system for continuous monitoring of environmental degradation,
- II) Confronting pollutant industries,
- III) Addressing environmental considerations in macro-economic policies,
- IV) Internalizing environmental concerns in the development planning model,
- V) Seeking technical advice on biodiversity protection and
- VI) Setting energy consumption standards.

## **5. Sustainability in Higher Education**

It should be emphasized that education and training are essential components in the dynamics of environmental protection, especially in engineering [10]. The United Nations has declared a Decade of Education for Sustainable Development to run from 2005-2014. The goal is to fully integrate sustainable development into education and learning of all segments of the society.



Universities play a leading role in developing a multidisciplinary and ethically oriented form of education designed to devise solutions for the problems linked to sustainable development [17]. Central to all of these developments is the core concept recently restated by University of Florida's President J. B. Machen: "I graduate 15,000 students a year. If I could turn out half of them with a sensitivity to sustainability and turn them loose on the world, that's a hell of a contribution" [18]. UF President describes sustainability as "It's a way of saying that we should protect the environment and conserve our natural resources for our children, and for their children. Sustainability also means creating a more equitable society" [19]. UF President together with presidents of more than 500 American universities and colleges has signed the American College and University Presidents Climate Commitment. University presidents committed to be deeply concerned about the unprecedented scale and speed of global warming and its potential for large-scale, adverse health, social, economic and ecological effects [20].

The Declaration of Barcelona that was created out of the 2004 Engineering Education in Sustainable Development Conference in Barcelona, Spain declares that: "Today's engineers must be able to:

- understand how their work interacts with society and the environment, locally and globally, in order to identify potential challenges, risks and impacts.
- work in multidisciplinary teams in order to adapt current technology to the demands imposed by sustainable lifestyles, resource efficiency, pollution prevention and waste management.
- apply an holistic and systemic approach to solving problems and the ability to move beyond the tradition of breaking reality down into disconnected parts.
- listen closely to the demands of citizens and other stakeholders and let them have a say in the development of new technologies and infrastructures" [30].

## 6. Sustainability in Iranian Engineering Education System

Engineers are in a unique position to take steps to protect the environment from damage and to correct existing problems. Educating a new generation of engineers who recognize the importance of sustainability and are able and willing to cooperate with people from a variety of other disciplines is a major challenge for engineering educators around the world. In the higher education, a university culture should be created with a core philosophy of environmental stewardship, sustainable development, and critical examination of all activities in light of their environmental impacts. This requires an environmentally knowledgeable faculty and staff, a research program that develops clean, resource efficient technologies with low environmental impacts, and a university with a small ecological footprint. Educating a new generation of scientists, engineers, and technologists with highly developed knowledge of the environment and natural systems and their contributions to human well-being is an essential element of environmental sustainability. Fig. 1 shows the path to sustainable development through greening engineering education and Fig. 2 shows the characteristics of traditional and sustainable engineers.

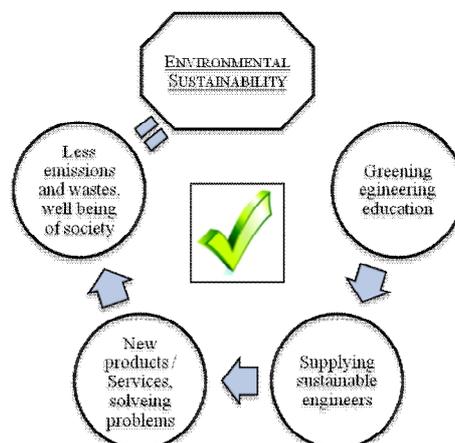


Fig. 1: Environmental sustainability through greening the engineering education

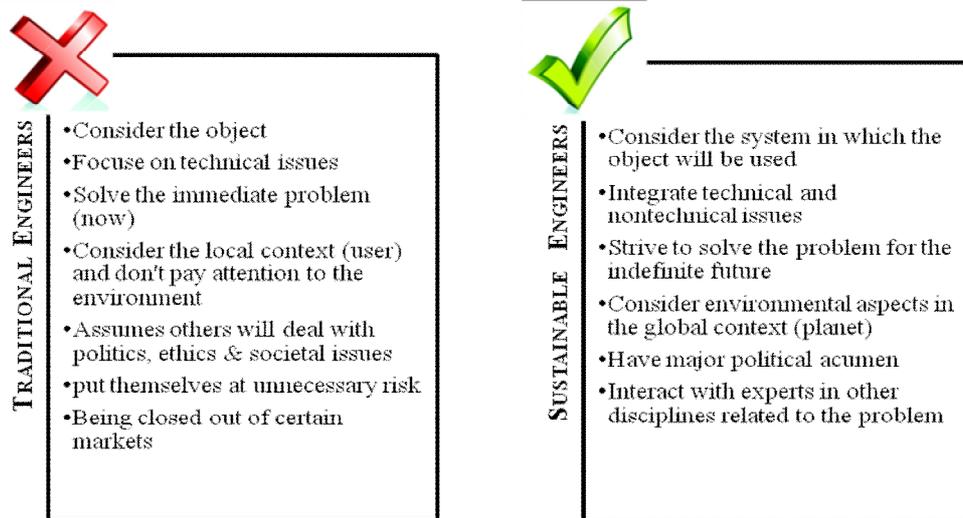


Fig. 2: Traditional engineers vs. sustainable engineers

Every engineering student should be provided with at least a minimum understanding of environmental issues. The education system should provide students with a basic understanding of some of the environmental issues currently attracting public concern and to provide also the required scientific background. The education system has to make engineering students aware of the social, economic, political, and environmental effects of their chosen field and the technologies that they will develop. There is a recent trend to integrate sustainability into engineering curriculum of different disciplines such as mining engineering [21], design [22], ecological engineering [23], environmental engineering [24] [25] [26], and civil engineering [9].

Environmental engineering programs at graduate level have established in Iran since 1990. At the present time, there are ten universities in Iran that present environmental engineering program at the graduate



level [2]. Amirkabir University of Technology (AUT), as one of the main leading Iranian technical universities has adopted a strategy to be the “pioneer of sustainable development” in Iran for the next decade [27]. The three main strategies that AUT is pursuing to achieve its sustainable development goals in engineering education are [27]:

1. The establishment of an environmental engineering curriculum at the graduate level;
2. The addition of new sustainability-oriented courses to the undergraduate and graduate curricula of all engineering fields;
3. The establishment of an “Environmental Research Institute”

These strategies can be modified and applied to the other engineering disciplines and engineering education system of Iranian universities. The curriculum requirements and regulations of engineering education system in Iran is defined and updated by the Iran's Ministry of Science, Research and Technology. In addition to expanding the above three strategies to other engineering disciplines, there are several other approaches that can be adopted in the Iranian system of higher education to educate engineering students for sustainable development.

1. *Revising engineering curriculum:* To foster sustainable development, engineering education should be re-examined and its curriculum should be revised. In addition to mathematical and technological subjects, the engineering curriculum should include implementation of sustainable development in the design and construction of the built environment. This could be accomplished by introducing environmental science into the conventional engineering curriculum and expanding the basis for engineering education by introducing relevant subjects from other disciplines such as the social sciences, environmental architecture, economics, law, and environmental politics can help.



It is necessary to define the new scope of environmental engineering to cope with environmental problems and sustainable development concerns, especially in developing countries. Several courses such as “Sustainable technologies and processes”, “Risk and sustainability analysis”, “Law issues relevant to environment”, “Sustainable Design and Engineering”, and “Management and leadership development” can be added to the curriculum of the all engineering programs as elective courses. These courses can help students gain required knowledge of resource management, waste and energy issues, risk analysis, design for environment, leadership skills, including time, people and economic management. For example mechanical engineers should focus on decreasing air pollution, risks of accidents, and fuel consumption in their design, and civil engineers have to consider the concepts of resource minimization, thermal insulation, and ease of maintenance. Importance of renewable resource management, use of recycled materials and life cycle assessment can be incorporated into the curriculum of industrial engineering.

Moreover, there are several tools available to measure sustainability, such as Life Cycle Assessment (LCA), green building rating systems, Pollution Prevention (P2), and several others. Applications and scope of each tool should be taught to the engineering students.

*2. Implementing new teaching strategies and learning techniques.* Using updated textbooks can help students become familiar with the concept of sustainability. Provide students with additional information sources beyond the course textbook and use supplemental materials such as journal articles, Internet, CD-ROMs, etc. Encourage engineering students to apply the sustainability tools to measure the effects of their design projects in the long term. Ask higher- level thinking questions and involve students in problem-solving activities. Ask students to seek solutions to real world problems to engage their curiosity and make it more interesting and exciting. The goal is to prepare students to think critically and learn how to use a variety of learning resources. Another effective technique in teaching sustainable engineering is



service-learning that combines academic learning with community service. According to Bringle and Hatcher service-learning is “an educational experience in which students participate in an organized service activity that meets identified community needs and reflect on the service activity in such a way as to gain further understanding of course content, a broader appreciation of the discipline, and an enhanced sense of civic responsibility” [29]. Term projects that aim to develop a student’s initiative and awareness of independent thought processes are very effective teaching tools. Each student is assigned an individual project and is required, under the guidance of a supervisor, to plan and carry out all the necessary research to achieve the project’s objective. Parameters should include consideration of the broad environmental impacts of the project and include the development of an environmental management program as an assessed part of the project.

3. *Establishing Inter- disciplinary and Multi- disciplinary graduate programs:* Inter-disciplinary research and teaching often precedes the creation of a new well-defined field. In multi-disciplinary research and teaching, several or many disciplines bring together several disciplinary focuses, and thus deal with more than one traditional concern.

4. *Training trainers:* Majority of academic staff are traditional and unsympathetic to even multi-disciplinary work. It is necessary to establish a program to provide education and training of academic staff to familiarize them with the core philosophy of environmental stewardship and sustainable development. The goal of such program is to encourage the academic staff to integrate sustainability within their teaching materials and provide them resources to accomplish that.

5. *Providing current textbooks:* The language of instruction in Iran’s system of higher education is Farsi and except some few graduate courses, all other courses are providing students with Farsi textbooks that are mostly translated from the books published in the United States or Europe. These translations are usually based on the old editions of the foreign textbooks that have been published in 80’s or 90’s. A



comprehensive examination is needed to identify the most current valuable textbooks abroad and translate them into Farsi.

6. *Encouraging engineering student to learn a foreign language;* Engineering students should be encouraged to learn a foreign language (preferably English) to be able to learn from advancements of leading environmental countries, using news, text books and on-line resources.

7. *Establishing Environmental Research Institutes, and Eco-Industrial Parks (EIPs):* EIPs are industrial systems of planned materials and energy exchanges that seek to minimize energy and raw materials use, minimize waste, and build sustainable economic, ecological and social relationships [28].

8. *Providing site-visits and field trips:* Engineering student should be provided the opportunity to go abroad as a group to see the advancement of world leading countries in solving environmental problems and building a sustainable built environment.

## 7. Concluding Remarks

Sustainable Development is a path to create a society in which all present and future generations are healthy, meet their basic needs, and are able to pursue meaningful work. At present, there is a large number of evidences that indicate the human action, if continued its current course, will lead to collapse of the planet. Environmental burden, ecological footprint, and wealth imbalances are a few to name. Changing this path and creating a sustainable world requires involvement of all actors of the society. Engineers are among the stakeholders in the path toward sustainable development who play a crucial role. There is a need for a new generation of engineers with a holistic understanding of the environmental, economic and social aspects of sustainability. It requires engineers who have a long-term, systematic approach to decision making and are guided by ethics and justice.



The higher education institutions in Iran have to respond to the challenges of education for sustainable development through teaching, research, and a desirable campus environment. There is a need for dedicated undergraduate courses in sustainable development that both in holistic way and through specialized courses address sustainability topics. Postgraduate programs should be developed for engineering students on specific aspects of sustainability. More importantly, a university culture should be created with a core philosophy of environmental stewardship, sustainable development, and critical examination of all activities in light of their environmental impacts. This requires an environmentally knowledgeable faculty and staff, a research program that develops clean, resource efficient technologies with low environmental impacts, and a university with a small ecological footprint.

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