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Transdisciplinarity - A New Vision in Forming Specialists in the Field of Environmental Engineering - Case Study

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Abstract. The complexity of industrial activities, the requests regarding the integrated pollution prevention and control, the development of the eco-design, the growth of the environmental performance and of the energetic efficiency, all of these need specialists trained in Universities, in the field of environmental engineering. The field of study of Environmental Engineering is considered both multidisciplinary and interdisciplinary. In the paper it is shown the necessity of a new approach of this field through transdisciplinarity. The case study refers to the relation between transdisciplinarity and the systems of renewable energy.

Introduction

The concept of transdisciplinarity developed starting with the 1970's and has been interpreted in various ways. The common feature has been the fact that multidisciplinarity and interdisciplinarity do not sufficiently answer the reality that surrounds us [1]. In order to understand the surrounding reality, a unity of knowledge is necessary [2]. A good example is represented by the degradation of the environment, which has become a major problem of mankind and which can be approached through transdisciplinarity [3].

The field of study of Environmental Engineering is well represented through bachelor study programs applied on sectors of activity (power systems, agriculture, food industry, biotechnical systems and constructions) or bachelor programs with a general character (Engineering and Environmental Protection in Industry**),** meant to ensure a greater mobility on the labor market of the graduates. The curriculum is structured on the principles of multidisciplinarity (in the first two years) and interdisciplinarity (in the last two years of study)[1].

In tables 1 and 2 are presented examples of interdisciplinarity. A first example is represented by the subject of 'Environmental pollutants' from the last year of study of the bachelor program Engineering and Environmental Protection in Industry.

Table 1. Interdisciplinarity in the study of the pollutant factors of the environment

Chemistry	Environmental pollutants
Physics	
Numerical Methods	
Radiation sources and protection techniques	
Ecology	
Environmental monitoring and diagnosis	
Waste management	

The principle of interdisciplinarity is also applied in the case of the 'Environmental audit' discipline, as it is shown in table 2.

Table 2. Environmental audit as an interdisciplinary field

Environmental Management Systems	Environmental audit
Quality management	
Economy and environmental accounting	
Waste management	
Environmental pollutants	

A different approach is necessary in the case of the master programs. University of Craiova organizes such a program within the Department of Engineering and Management of Technological Systems, Drobeta Turnu-Severin: Environmental Management and Sustainable Energy. This approach is within the general tendency of universities to reform engineering education (the structure of the curriculum, abilities gained, educational approaches etc.) [4].

Transdisciplinarity in Environmental Engineering

The goal of industry is the production of goods that satisfy the qualitative and quantitative requests imposed by a specific market. The anthropogenic impact of the production and of the products through the degradation of the environment has led to the appearance and the development of environmental engineering.

In the current phase, when the major producers from industry, agriculture or constructions must follow the requests of the Directive 2008/1/EC of the European Parliament and of the Council concerning integrated pollution prevention and control, Environmental engineering represents a complex field, taking part in the application of the general principles governing the basic obligations of the operator[5]. These refer to: all the appropriate preventive measures are taken against pollution, in particular through application of the best available techniques; no significant pollution is caused; the waste hierarchy; energy is used efficiently; the necessary measures are taken to prevent accidents and limit their consequences; the necessary measures are taken upon definitive cessation of activities to avoid any pollution risk; return sites to their original state when the activity is over. The systems of environmental management or those the quality, environmental and occupational health and safety integrated management systems involve environmental engineering in the continuous growth of environmental performance.

The solutions of these problems are based upon transdisciplinarity and are results of the research in directions such as: preventing climatic changes, sustainable development, clean production, environmental risk or hazard study. The research must be performed by mixed teams, the presence of specialists in the domain of environmental engineering being absolutely necessary.

In the environmental science there are numerous examples of transdisciplinary approaches: strategic planning, life cycle assessments, ecodesign of products, integrated monitoring of environmental factors, applications of the general theory of ecosystems, formation in the spirit of eco-efficiency, management of the protected areas, waste management. The European Union is very active in what regards environmental legislation. The participation in collectives that issue European directives requires the approach of preparing future specialists in the light of transdisciplinarity.

In specialty literature it is shown that transdisciplinarity is based upon scientific integration, international integration and sector integration [5,6]. Thus, academic concepts, the fields of study of social, humanistic and engineering sciences must be combined and applied both worldwide and at a local level, under circumstances of multiculturalism. This way, a balance between science and society will be kept.

Forming MA Students for Working in Research Teams

One of the objectives of the Environmental Management and Sustainable Energy (EMSE) master program is to form specialists which can be integrated in research collectives, proving that the prejudice of the young graduate lacking experience is false. In order for this to happen, the education plan must be built on the principle of transdisciplinarity.

In accordance with the structure of the programs of a number of prestigious European and Romanian universities, the last semester of studies id dedicated to research. This is the time period when the bases of work in transdisciplinary teams can be put. The curriculum is structured so that it ensures the insertion of the graduates in the labor market by means of its harmonization with national and foreign programs. The bases of transdisciplinary collaboration can be put through syllabuses.

The adequate scholar method is case study. This way, case studies on life cycle assessments for different products require studying the steps: procurement of materials, manufacturing, distribution, use, disposal, and recycling. Each step can be structured in technical, technological and economical aspects, GHG emissions, hazardous substances (RoSH), legal requirements etc. The study can take place together with the students from Logistics Management Systems master program, which is within the same department.

Case study on eco-efficiency of products and services is based upon the relation between the quality of life and environmental impact. From the consumer’s perspective, the quality of life must never stop growing, being transposed in comfort and convenience, safety and reliability, design and innovativeness. From the point of view of the reduction of the environmental impact, the efficient use of resources (Sustainable industrial production discipline), the mitigation of climate change, the waste hierarchy (Environmental protection and sustainable development discipline), ecodesign etc. are important.

Case Study: Transdisciplinarity in the Study of Renewable Energy Systems

Renewable energy is a relatively new field. Romania has an important energetic potential from renewable sources: solar, aeolian, water, biomass and geothermal energy [7]. The energetic strategy of Europe foresees that in 2020, 20% of the production of energy be assured from renewable sources.

The case study refers to the possibility of applying the principle of transdisciplinarity in structuring the curriculum and the syllabuses, in order to form future researchers in the field of sustainable energy by using renewable energy (table 3).

Table 3. Curriculum of EMSE master program

Curriculum	Semester
Environmental protection and sustainable development	1
Sustainable industrial production	1
Integrated pollution prevention and control	2
Life Cycle Assessments. Ecodesign	2
Quality and environmental management	1
Management of energy resources	2
The audit and certification of management systems	1
Computerized measuring systems	2
Research	1, 2

Table 3 (Continued)	
Curriculum	Semester
Renewable energy sources and technologies	3
Biomass and biofuels	3
Environmental Project Management	3
Materials for renewable energy systems	3
Dissertation research	3, 4

In the context of sustainable development, the exhaustive study of renewable energy systems is of transdisciplinary type and can be part of the science-technology-society and economy relation [2]. In figure 1 is presented this relation from the point of view of curriculum. The topics of the syllabuses are the following:

1. Science. Research in the field of renewable energy systems have been financed by governments and by the economic and politic unions which have understood how valuable the alternative sources of energy are for the future evolution of humanity. The evolution of production technologies of renewable energies has not been possible without the evolution of the materials of which the basic functional components are mad, but the research regarding new resources of energetic raw materials.

Renewable energy systems comprise advanced materials that make the conversion of the above-mentioned sources in electric or thermal energy:

- advanced materials for photovoltaic cells (semi-conductors of types GaAs, Cd-Te, or $CuInSe_2$, semi-conductor polymers, solar cell based on nanostructure sensitized with porous nano-crystalline TiO_2 dye and dyes based on ruthenium complex, complex dyes of zinc coupled with fullerenes),
- advanced materials for aeolian energy (composite materials based on glass fibers, carbon fibers, Kevlar fibers, permanent magnets based on neodym).

At the same time, the research regarding the improvement of the types of energetic plants has intensified. This is a new field for agriculture [8]. The development of these crops, with high density, created by species with high production yield, had led to the appearance of risks connected to land-use change. Limiting the extension of surfaces for energetic crops is the object of laws regarding forest management, cropland management, grazing land management and revegetation, at the same time with research on terrestrial sequestration of carbon dioxide potential from anthropogenic sources.

Hydrogen is considered to be the fuel of the future because it is an energy carrier that can be used in internal combustion engines or fuel cells. The researcher understands the importance of a shift to a hydrogen economy. Hydrogen storage and transport are issues of intense research.

Projects to locate energetic fields (solar and aeolian) must be scientifically substantiated in order for the investment to have maximum efficiency. At the same time, legally speaking, when implementing such projects, environmental evaluations to highlight main effects or risks on the environment are mandatory.

2. Technology. Advanced materials have led to an increase in the conversion yield, through the technology of producing photovoltaic gadgets based on thin layers, DSSC technology, solutions to improve the performances of photovoltaic cells: photovoltaic cells with surfaces with losses through minimum reflexes, capturing the light energy in a domain with large wavelengths with photovoltaic cells in tandem.

When producing energetic equipment, ecodesign and life-cycle assessment (LCA) with an accent on waste collecting and recycling must be taken into consideration.

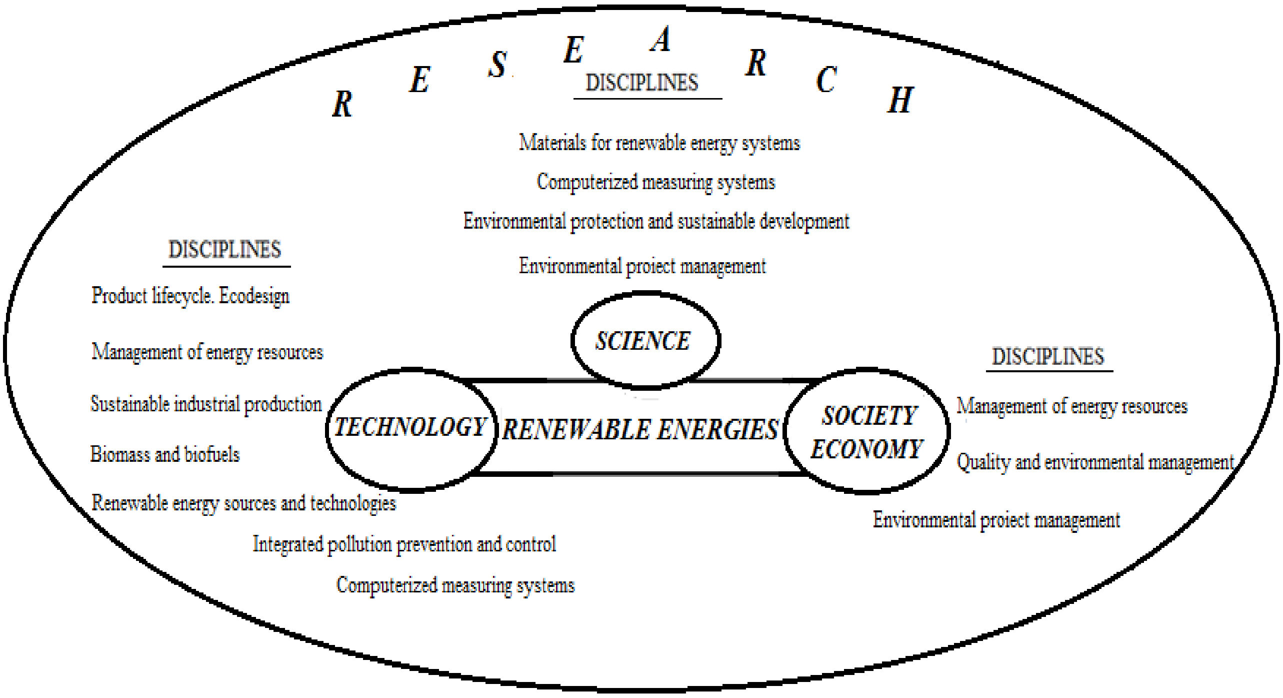

Fig. 1. Transdisciplinarity in renewable energy systems

3. Economy. The importance to protect the environment has led to the appearance of a new economic field named Environmental Economy. It completes research through three scientific clusters: Economic Modeling, Economic Valuation and Economic Instruments. Environmental performance is analyzed applying as economic principles: the polluter pays, economic models and methods (cost-benefit analysis) and economic instruments (payments for ecosystem services) [9].

One objective of the economic politics is represented by decoupling economic growth from environmental degradation by reversing the ratio between the consumption of resources and the creation of added value, on the one hand and the proximity to the average indices of performance of the EU regarding sustainability of the consume and the production (Management of energy resources discipline) [10]. Renewable energy systems are connected to the national energy network, being jointly consumed with classic sources of energy. At the same time they participate to the accomplishment of the regional energy market (in South-Eastern Europe) and of the European exclusive market. Renewable energies continues to attract investment in Romania, benefiting through the 'Green Certificate' by means of supporting and advertising for the production of electric energy from renewable sources of energy.

4. Society. The policies of sustainable development are essential in the usage of renewable energies. The benefits for the communities can be: supplying isolated places with energy, thus bringing civility to them, workplaces with high qualification, local taxes, eco-efficient development of the communities-green neighborhoods.

In Romania there have been initiated national politics to sustain programs such as 'Green house', 'Program regarding the reduction of greenhouse gases emissions in transportation, by promoting infrastructure for vehicles of road transport that does not energetically pollute: stations of recharging for electric vehicles and electric hybrid plug-in', 'Eco-civic. Program regarding the education and the awareness of the public regarding the environmental protection'. Implementation of the policies and the legislation in the field of renewable energies is realized through local stakeholders: Agency for Environmental Protection or municipality through a program of local energetic efficiency.

Conclusions

Transdisciplinarity is the base of the success of research activities. Master programs, as a resource for research, must be structured so that they educate students in the spirit of transdisciplinarity. Restructuring complies with the request of the European Union to improve the education quality, strengthen the research performance and promote innovation and knowledge transfer. The principle of transdisciplinarity is transposed through curriculum, especially the syllabuses.

Studying renewable energy sources in the context of sustainable development is a necessity. Environmental Management and Sustainable Energy is a master program whose aim is to implement the principle of transdisciplinarity in its own curriculum. The approach can be part of the science-technology-society and economy relation.

Using renewable energies is conditioned by the regional potential. The main components of the renewable energy systems are made of advanced materials. Using these systems is limited by price and maintenance expenses. This is why it is necessary to develop policies and projects in order to facilitate the access of the population to these forms of energy.

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