An overview of environmental engineering education in the past decade: a global perspective

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ABSTRACT: Environmental engineering education has been the focus of much attention in recent years. In the past, environmental engineering, more commonly known then as *sanitary* or *public-health engineering*, was taught as a subject within the civil engineering curriculum. As time progressed, and with it the realisation of the significance of the new field in engineering - environmental engineering - it began to evolve into a discipline with its own identity and merits. An overview of environmental engineering education in the past decade is presented in this paper to determine how the higher education institutions from both developed and developing countries have responded to global environmental challenges through their education and curricula. The authors were particularly interested in discovering the solutions or processes developed by institutions, to bring environmental engineering education to the forefront. The endeavour in this study was to report on the methods and approaches, problems and challenges that higher educational institutions face in implementing the discipline.

INTRODUCTION

Environmental engineering education exists in almost all the universities in developed countries and is still being taught and delivered as part of the civil engineering programmes at many universities. Most programmes were developed in the 1960s and, at that time, environmental engineering education primarily was focused on the issue of sanitation. However, today it has expanded to cover the air, land, water and human environment. Environmental engineering is growing and spreading rapidly across universities in developing countries [1].

This is strong evidence to suggest that the field is of great interest and importance for many educational institutions, which retain its traditional place in civil engineering. The authors' view on this is that environmental engineering would be better delivered in a more specialised programme, for example, in an undergraduate or postgraduate environmental engineering curriculum rather than as a subject within the civil engineering curriculum, to preserve the significance, relevance and identity of this unique discipline within engineering.

With environmental engineering evolving into a discipline with its own identity and merits, it can be viewed as a positive move because it creates more job opportunities for the environmental engineering profession. Data provided by the United States Department of Labour predicts a rise in future employment opportunities for environmental engineers in the US market, and it is expected that a greater number of skilled environmental professionals will be required to service this growing job market [2].

Tansel believes that more environmental engineers with interdisciplinary training and global citizenship are required to meet this expanding market [3]. Such training can only be accomplished through appropriate environmental engineering education. Further, according to Tansel, an interdisciplinary environmental education should cover a wide range of disciplines such as biology, ecology, public health, geology, and economics, and also include traditional subjects such as water, waste-water, air pollution and hazardous waste [3].

Tansel also shows that the impact on educational needs and requirements of environmental engineering education is driven by six factors:

- Technology;
- Delivery structure;
- Demographics and culture;
- Educational programmes and policies;
- Significant events with environmental impacts;
- Global interactions [3].

OVERVIEW OF ENVIRONMENTAL ENGINEERING EDUCATION IN DEVELOPING COUNTRIES

It is suggested that more emphasis should be placed on local issues pertaining to developing countries. Contentious issues include clean water supply, sanitisation, pollution control and environmental management. The assessment report released by the World Health Organisation (WHO) estimated that billions of people are still without basic sanitation and access to clean and safe drinking water [4]. This is a matter of concern, given that we are now in the 21st Century, and there are billions who do not have basic necessities.

The criteria used to measure environmental engineering education in developing countries depend very much on the various communities and regions investigated. The regions are classified into slow-industrialising, industrialised and fast-industrialising countries. The criteria used to measure how each region responds include:

- Main considerations of environmental engineering education (e.g. environmental protection, basic needs);
- Standards (e.g. local standards, international standards, accreditations);
- Environmental engineering education programmes offered (e.g. PhD, Masters, Bachelors);
- Course contents (e.g. advancement in environmental engineering, local issues, low-cost solutions);
- Teachers' qualifications (e.g. PhD or Masters level);
- Funding (e.g. student fees, government grants, sponsor agencies) [1].

In its focus on technology and research programmes, most developing countries have opted for the less expensive, cheaper technology alternatives and basic management systems [1]. This is probably due to the limited, or lack of, financial resources available.

The primary focus of environmental engineering education at universities in developing countries is on the basic infrastructure, sanitation, water supply, solid waste management, and low-cost, simple technology. The main teaching methodologies applied and proven effective include lectures, seminars, role-playing, video, Internet, study tours and field visits. There are also collaborative environmental engineering programmes established between universities from both developed and developing countries to promote the sharing of resources [1]. The authors strongly support the collaborative programmes, provided the local issues and problems are addressed appropriately in the curriculum. Such programmes may be a viable option for many universities where financial and human resources are scarce.

Ujang et al believe the way forward for environmental engineering education in developing countries is to expand the scope of environmental engineering programmes to include issues such as industrial pollution, waste minimisation, industrial ecology, cleaner production and appropriate technology. It is not enough to focus only on basic sanitation and water supply. They suggest that some of the earlier programmes on sanitation and water supply in developing countries need reviewing [1].

As outlined by Ujang and Buckley, the progress of environmental engineering education and research for developing countries is shown in Table 1 [5]. This table provides a good summary of the evolution and changes of environmental engineering education, from its inception in the early 1960s to the 1990s.

Table 1: Progress in environmental engineering education and research for developing countries [5].

Period	Themes	Objectives
1950 -1970s	Low-cost technologies Labour intensive systems Ease of maintenance and upgrading	Satisfying the requirements of donor agencies International funding purposes Basic public health infrastructures
1980s	Optimisation and upgrading of low-cost technologies Public health improvement Environmental protection	Satisfying the requirements of donor agencies International funding purposes Rapid urbanisation purposes
1990s	Cost-effective high-performance technologies Management systems for better governance Cleaner production	Academic research programmes Rapid industrialisation Rapid urbanisation Meeting international standards

These changes are not only observed within the environmental engineering education curricula but also in the physical environment right up to recent years. In the 1970s, issues such as air quality, water supply, toxic chemicals, nuclear power and energy crisis were the focus of the decade. Then, moving on to the next decade, the 1980s, it was observed that ozone depletion, global climate change, hazardous waste clean up, health-risk assessment and toxic chemicals started to be high on the agenda. In the 1990s, the environmental concern was on greenhouse gases, greater emphasis on global climate change, recycling, renewable energy, life-cycle-analysis and deforestation. In the recent decade (the 2000s), the main environmental concern is still global climate change, sustainable development, green technologies, global environmental issues, biodiversity, disaster management and reduction, urbanisation, issues of security, and so

on [3]. What can be concluded from this transition is that the emerging issues have become more complex, and have shifted from local to more global in nature.

ENVIRONMENTAL ENGINEERING EDUCATION IN DEVELOPED COUNTRIES

For the purpose of illustration of the issues, problems and challenges, universities based in three countries from the developed world were examined to determine the progress and status of environmental engineering education. In this paper, selected universities from Spain, Japan and Canada were reviewed as an example.

Environmental Engineering Education in Spain

Similar to other European countries, there is a growing demand in Spain for environmental engineers and technologists but, ironically, no formal environmental engineering degree programmes actually exists at universities in Spain to meet this demand [6]. The word *formal*, in this case, means that those programmes are non-official and not recognised by the Spanish Council of Universities as being environmental. However, universities in Spain are working towards finding a solution due to this demand for environmental engineering professionals and specialists, and are adapting old programmes to include environmental engineering education.

There is great diversity in the educational requirements and needs of environmental engineering across Europe [7]. Roriguez-Roda et al believe the solution is to establish a new common framework for education and research in environmental engineering as there are no standard core curricula implemented [6]. The authors of this paper also support the idea of a common framework and have proposed elsewhere a common, or so-called global environmental engineering curriculum, with the fundamental body of knowledge being identified and developed strongly in this proposed curriculum. Such a curriculum may be shared and utilised globally. In a comparative study of engineering educators and environmental engineering educators, the authors found there is general support for the development of such a global curriculum and only a few, mostly from developed countries, have opposed the idea [8].

There appears to be another problem in Spain concerning the actual definition of an environmental engineer. The situation seems to be that everyone is claiming to be an environmental engineer but no-one appears to really understand or truly know the meaning of this profession. In its attempt to propose a degree in environmental engineering to meet the growing demand of this profession, two working groups, mainly from science and engineering, put forward their ideas to the Council of Universities. However, the two groups could not agree or reach a consensus on what should constitute the general curricular options, causing a delay in this process. The result is that students in Spain have only one available option, and that is to enrol for intensive courses, specialised in other degree programmes, and choose subjects related to environmental engineering. The related programme in environmental engineering is divided into two major groups, one majoring in environmental sciences and the other in traditional engineering. The approach adopted here is referred to as the *add-on approach:* that is, taking environmental engineering subjects and adding them on to existing programmes [6].

The same approach also was widely adopted by many engineering schools in earlier times to incorporate the environment into engineering curricula. Many have started integrating the environment into traditional engineering subjects, offering more specialised environmental subjects as optional units in engineering curricula and developing environmental engineering undergraduate programmes.

For many educators, this approach may be seen as a positive initiative by engineering schools to make the environment a common part of engineering curricula; in particular, with the increasing numbers of environmental engineering programmes that have eventuated over the past decade. However, there are problems with existing environmental engineering programmes that still need to be resolved. The authors are not in favour of this approach because there are many problems resulting from this method. Some of the problems have been addressed and presented by the authors in a separate article [9].

The status of environmental engineering education remains unclear in Spain and more progress is required to improve the future education and profile of the environmental engineers.

Environmental Engineering Education in Japan

The status of environmental engineering education at major universities in Japan appears to be well developed and the profile of the environmental engineering profession is clearly defined when compared to universities in Spain.

Environmental engineering education is offered by universities in Japan, for example, the University of Tokyo (UT). Students enrolled for the undergraduate programmes in Sanitary and Environmental Engineering (SEE) are expected to spend 1.5 years studying general and fundamental subjects in the arts and sciences, before moving to more specialised subjects offered by the Department of Urban Engineering [10].

The Japanese Ministry of Education released a policy calling for universities in Japan to restructure and renew their education and research to reflect public concerns and societal needs. The following three universities in Japan namely, the University of Tokyo, Hokkaido University and Kyoto University responded to this challenge by restructuring their environmental engineering curricula.

A comparative study of the environmental engineering curricula from the three universities in Japan shows that at the University of Tokyo sanitary engineering subjects form a major part of the curriculum, while at Hokkaido University applied chemistry and chemical engineering is the primary focus. The main concern within the environmental engineering curriculum at Kyoto University is toxicology and radioactive waste management [10]. All curricula offer units from the basic subjects, general environmental subjects, water-related subjects, other environmental subjects, global environmental subjects, etc. Mino pointed out that important environmental subjects are lacking in all three curricula. These subjects include environmental impact assessment, environmental auditing, environmental ethics, environmental economics, ecological engineering and ecology [10]. In addition, the authors of this paper also observed some emerging subjects such as cleaner production; sustainable development and environmental design that were not included in the curricula.

Environmental Engineering Education in Canada

An interesting observation about environmental engineering education in Canada is that, at the graduate level, it has been a visible and widely available study option in the past five decades. However, the development of environmental engineering education has been slower at the undergraduate level. It was not until the mid-1980s that undergraduate programmes in environmental engineering started to experience fast change and development [11].

According to Smith et al the knowledge and interest in environmental engineering programmes may vary across universities but the basic components remain the same. The basic components of environmental engineering programmes found across universities in Canada include subjects from the following fields:

- Science (e.g. chemistry, maths, biology);
- Applied science (e.g. environmental chemistry, thermodynamics);
- Engineering (e.g. engineering design, hydrology, etc);
- Environmental engineering (e.g. principles of environmental engineering, waste-water treatment, etc);
- Public and environmental health (e.g. water quality, environmental protection);
- Environmental law and policy (e.g. environmental impact assessment, resource management) [11].

Despite undergraduate environmental engineering being relatively a new discipline in engineering, the Canadian Engineering Accreditation Board (CEAB) has recognised environmental engineering as a separate discipline in engineering with its own identity and merits.

The first undergraduate programme to receive accreditation by CEAB in 1990 was the Regional Environmental Systems Engineering Program at the University of Regina, followed by the University of Windsor, which received accreditation in 1991, and slowly the number of undergraduate environmental engineering programmes began to emerge and evolve in Canada. Overall, there has been great progress, with the evolution and development of environmental engineering at the undergraduate level across universities in Canada in the past decade.

CONCLUSIONS

Environmental engineering education has grown, expanded and evolved into a unique area of engineering over the past decade, particularly across universities in Canada, Japan and USA. However, in many countries it still lacks identity as a discipline and as a profession within universities (e.g. in Spain). At present, there is no formal degree programme in environmental engineering in Spain, despite the fact there is a growing demand for environmental professionals and technologists in the job market. The add-on approach is adopted by universities in Spain to bring environmental engineering education forward. This approach is one of taking an existing programme, for example, degree in environmental sciences, and adding to it subjects in environmental engineering.

Environmental engineering is different from any classical engineering discipline because it is multidisciplinary in nature, covering a broad range of topics from engineering and science, to economics and humanities, etc. It is not enough to take an existing programme and add on environmental units, and then call it environmental engineering. This method may appear to be the quickest and most economical way of developing a new programme but, according to the authors, it has resulted in many problems and failures.

It is pleasing to observe that environmental engineering education has by now started to grow and spread across universities in the developing countries. This new discipline within engineering has become so popular over the past decade that courses in environmental engineering are widely available at almost all universities in the developing countries. However, many courses and programmes are still being taught and delivered as part of civil engineering

programmes. The authors strongly believe that environmental engineering education would be better delivered in a more specialised programme rather than within the traditional civil engineering programmes.

The criteria used to measure environmental engineering education in developing countries depend very much on the various communities and regions investigated. The regions are classified into slow-industrialising, industrialised and fast-industrialising countries. The findings also show that the focus on technology and research programmes at universities in developing countries was on less expensive, cheaper technology and basic management systems. This is due to the lack of available resources. The authors believe this is where a collaborative programme with universities in a developed country or a global curriculum on environmental engineering would be particularly beneficial to universities in the developing world, where resources are obviously scarce and substantial costs of higher education would have been reduced by sharing the developed courseware, software, laboratory procedures, methodologies, etc, already available. The education of today will help shape and determine the future of the environmental engineering profession.

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