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Searching for a global model for environmental engineering education

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ABSTRACT: There has been a multitude of approaches to the development of curricula in environmental engineering education, mostly with the lack of comprehensive coverage of environmental issues and the integration of those issues with the engineering subject matter. Therefore, comprehensive research is required into the nature, design, development, implementation and effectiveness of a global environmental engineering curriculum. This is of tremendous importance in an era of rapid development, where sustainability, sustainable development and environmental engineering are the key issues to be tackled by modern engineering education, as they will determine the foundation of the knowledge, skills and attitudes essential for the formation of a global engineer for the 21st Century. The UNESCO International Centre for Engineering Education (UICEE) has recently undertaken a new research programme to fulfil this requirement. The paper presents an overview of the research programme, discussing the major deficiencies in environmental engineering education in the context of the current international situation. The adopted research methodology, which includes a wide range of research steps and activities, is also presented and discussed in the paper.

INTRODUCTION

The United Nations Environment Programme's Global Environment Outlook 2000 states that there are:

> *Two over-riding trends characterise the beginning of the third millennium. First, the global ecosystem is threatened by grave imbalances in productivity and in the distribution of goods and services. A significant proportion of humanity still lives in dire poverty, and projected trends are for an increasing divergence between those that benefit from economic and technological development, and those that do not. This unsustainable progression of extremes of wealth and poverty threatens the stability of society as a whole, and with it the global environment* [1].

The document continues on to state that:

> *Secondly, the world is undergoing accelerating change, with internationally coordinated environmental stewardship lagging behind economic and social development. Environmental gains from new technology and policies are being overtaken by the pace and scale of population growth and economic development. The processes of globalisation that are so strongly influencing social evolution need to be directed towards resolving, rather than aggravating, the serious imbalances that divide the world today* [1].

It is the author's strong belief that the resolution of these imbalances is the only way of ensuring a more sustainable future for the planet Earth and for society.

GLOBALISATION AND ITS EFFECT ON EDUCATION

One may be able to add another important overriding trend. The global economy continues to become increasingly interdependent, so that there will be a great need for well-trained engineers to cooperate closely with their overseas counterparts.

There is no doubt that the challenges presented by globalisation are great and the drive is exponential. Especially with the Geneva Agreement on Tariffs and Trade (GATT), to be implemented at the beginning of the 21st Century, more scientists and technologists will be working towards globalisation: working locally and thinking globally.

Universities will increasingly compete in two areas. The first is in the quality of education - the quality of their graduates - because the opportunities for graduates will be global. Large corporations will be hunting worldwide for the best graduates to incorporate them into their organisations. Secondly, competition will be in research and development (R&D). Research scientists and engineers will be increasingly involved in competing for R&D, for quality research that has a target. Badran once stated that the universities in particular, must think globally in terms of the education being offered in engineering [2].

Jensen strongly agrees that there is no way to avoid this strategic process of globalisation/internationalisation in today's world, where the competition is strong and global [3].

Already, the effect of globalisation is forcing many institutions in Germany to modernise and implement new curricula. Detert states that those who fail to meet this new challenge will be losing in the highly competitive global education market. One

important aspect of globalisation in education is the establishment of common standards [4].

Ramos states that we must internationalise national standards of engineering education if we want to have locally produced engineers to be able to compete with other engineers from other countries and to be able to survive in a highly competitive world [5].

It is vital that university education addresses this reality of globalisation and directs its students towards an internationally comprehensive approach that creates bridges to cultures throughout the world. This is where the internationalising of curricula becomes necessary [6].

Pudlowski sees that, because of the effect of globalisation, there is a distinct need for the development of a global curriculum in order to overcome some of the difficulties that are being faced by developing countries in coping with the recent advancements in technology and production processes. He advocates for the modernisation of engineering education, which would then have an overall positive effect on the process of globalisation. He also suggests that a global curriculum should be structured in a modular way and should consist of a large number of subjects (modules), both core and optional. This would then form a so-called *bank of subjects*. The core subjects would be recommended for the standard global curriculum, while the optional subjects may be selected by individual universities in order to satisfy their local and individual requirements [7].

GLOBAL MODEL

Such a global curriculum may offer a solution to achieving global accreditation standards and might even completely eliminate the need for any accreditation process. In this research project, the attempt will be made to design a global curriculum for environmental engineering education.

The global curriculum would then have a wide range of implications on the following:

- The mobility of staff and students in the global arena.
- The accreditation of courses in the global marketplace.
- The recognition of qualifications in the global market-place.

It is anticipated that due to the development of the global curriculum, engineering education will benefit in a variety of ways by:

- Increasing the possibility of offering education at a distance.
- Ensuring a level of uniformity in the various curricula on offer.
- Sharing and transferring teaching facilities between institutions at a distance.
- Assisting developing countries worldwide.
- Building a bank of resources, eg courseware, teaching-ware, etc, which could be adopted and utilised by other institutions.
- Saving time and financial resources in the development of course materials.

THE CHALLENGE IN DEVELOPING A GLOBAL MODEL

The challenge in developing a global model for environmental engineering includes:

- Removing problems found in traditional environmental engineering programmes.
- Identifying core features for inclusion.
- Building a curriculum suitable for global application with minor adjustments to suit the local conditions.
- Creating a curriculum that is globally transferable and marketable.
- Providing subjects that will enhance students' knowledge and skills to solve environmental problems.

ENGINEERING AND THE ENVIRONMENT - AN OVERVIEW

The environmental debate has been going on for over four decades now and still continues to be a burning topic on the agenda, both politically and socially. Unfortunately, in engineering the environment has only been discussed about over a short period of time. There have been major discussions and talks about engineers needing to be educated about the environment, an area that has been neglected in past education.

Engineers are not only expected to have some form of environmental education but also to take an active role in helping to resolve environmental problems. This idea has come about because engineers are seen as the problem and also as the solution to the environmental problems. Travers gives a good example of how engineers can fall into both categories [8]. He states that many of these environmental problems of the present have been made possible by technical developments for which the engineering profession has been at least in part responsible. On the other hand, many of the solutions to these same problems are also technical and again within the responsibility of the engineer. Although this may sound simple in theory, it is harder to achieve in practice. According to Travers this is because environmental problems are complex and require the application of knowledge and experience from a wide range of disciplines. The current curricula are still very narrowly focused and little emphasis is placed on the environmental aspects. Although most agree and accept that engineers all need to be subjected to some form of environmental education, this requirement does not appear to be reflected strongly in existing curricula.

In addition to this, engineers of today are pressured and encouraged to think and practice along this path of sustainable development, cleaner production, greener technology, ecological design, waste prevention and recycling, energy efficiency, resource conservation and environmental protection. All of these are key topics in the future of engineering development and fall under this new study area of environmental engineering. A discipline introduced at Australian universities five years ago and was first made available in the United States of America. Environmental engineering is undoubtedly an important area and will expand in the future as the environmental problems worsen. If this is the likely scenario facing the planet in the future there will be a higher demand for more environmental specialists, namely: environmental engineers to find resolution to these problems.

Such achievements can only come about with proper education and training and through a well-structured and designed curriculum in environmental engineering.

The field of environmental engineering can make a huge contribution to the overall engineering profession. Some of these benefits include: increasing the number of female engineers, developing environmental technologies to solve environmental problems, improving the quality of life by conserving resources, improving efficiency for industry through recycling initiatives, raising the public image of engineers and finally contributing to global sustainability [9].

THE SUSTAINABILITY MODEL

A model outlining the challenge of sustainability for engineers was proposed by Don Roberts [10]. He pointed out the essential components requiring urgent attention by engineers if sustainability is to play an important role in engineering. These include issues ranging from resource development and recovery, processes, modification of resources and consumption patterns, environmental restoration, energy use and production and the transportation systems.

He also suggests two ways in which environmentally friendly approaches and sustainability can be achieved in engineering education. One way is to give all engineers some exposure to general education in the environment while retaining their specialist field of practice. The other suggestion was to take 25% of future engineers and train them as environmental generalists by providing them with a broader education, ranging from environmentalism, engineering, law, economics, humanities, etc.

Roberts' model of sustainability is shown in Figure 1 [11]. Thom stated that a new technical culture has emerged in engineering and this requires a major transition towards cleaner production, energy efficiency and sustainable technologies in engineering [12]. Messerle has also emphasised the importance of sustainable development in engineering education [13].

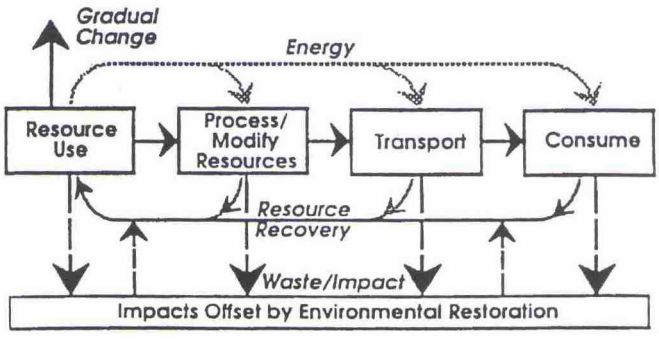

Figure 1: The model of sustainability proposed by Roberts.

Varcoe elaborates on the important issue of global sustainability and how engineers can contribute to this new challenge [9]. To achieve this, engineers need to take the following issues into consideration:

- Resource consumption/process efficiency.
- Energy resource availability - renewable versus non-renewable.
- Material resource availability - recyclable versus consumable.
- Life of the item or project.
- Ultimate disposal, completion or closure.
- Future use.
- Impact on the present community.
- Impact on future generations.
- Pollution and waste products.
- Recyclables.

In recent years, there has been a proliferation in the number of environmental engineering courses developed worldwide. This is evident by the growing demand and importance for the disciplinary area. However, there are a number of problems and issues regarding the structure, quality and methods employed in the development of environmental engineering curricula that have been overlooked.

Some of the more obvious problems are that there is no uniformity in the existing educational structure with too many impositions of particular views and influences from other engineering disciplines, which may overshadow the environmental topics that otherwise should be properly addressed and delivered in the course. Many of the existing environmental engineering programmes have stemmed from the civil or chemical engineering fields and there may be a strong influence from these core disciplines found in these programmes.

Several of the existing environmental engineering programmes examined are designed to focus on a particular field, eg environmental management. Hence, a broad-based coverage of the many environmental fields has not been met in the current curricula to give students a broad understanding of, and the exposure to, a wide range of issues.

Research Hypotheses

The research project attempts to test and verify the following hypotheses:

- A global curriculum for environmental engineering is needed to remedy the current problems encountered with existing environmental engineering courses.
- Environmental contents are not strongly brought out in existing environmental engineering curricula.
- Many of the existing environmental engineering courses are designed to focus on the general technical subjects rather than non-technical subjects.
- There is no uniformity and consistency in existing educational structures.
- There is no broad coverage of environmental topics in existing curricula.

Project Objectives

The main objective of the study is to investigate the need, nature, design, structure, development, implementation and evaluation of a global curriculum for environmental engineering. The most challenging task is to design a curriculum that addresses and takes into account possible solutions to many global problems, as well as removes some of the barriers experienced in existing programmes as mentioned above. An additional objective to this is to

develop a curriculum that would enhance students' awareness, attitudes, values and skills towards the resolution of environmental problems, and that it would reflect the global scene.

The specific project objectives are being carried out in the following sequence:

1. Literature review

- Review of existing literature and research on various models of environmental engineering education and the strengths and weaknesses of those programmes.
- Review of literature, exploring the current global environmental problems, the impact of science, technology and engineering on the environment and the inclusion of the principles of sustainable development in these courses.

2. Review of environmental engineering courses

This involves the analysis and review of different educational models and systems applied in the courses offered in environmental engineering in a number of leading international educational institutions, in order to determine:

- The status and quality of environmental engineering courses.
- The evolution of environmental engineering courses.
- The coverage of the key issues in the current environmental engineering curricula.
- The problems and barriers experienced by international institutions in the successful implementation of their environmental engineering courses.
- The similarities and differences existing among environmental engineering curricula, using data gathered from leading tertiary institutions worldwide, with regard to their natures, structures and methods.
- The essential components in which existing environmental engineering programmes are built upon.

3. Review of industrial practice and education systems

To better understand the effectiveness of existing environmental engineering courses, the industry and education for which graduates are being prepared needs to be identified and investigated, namely to:

- Find out what specialised skills and qualities environmental engineering graduates are expected to have, taking into account the point of view of industrial representatives.
- Explore how the education process of environmental engineering graduates should be structured in a global curriculum to match industry's requirements.

4. Review of quality and skills of graduates

The understanding of the qualities and skills that graduates of environmental engineering courses possess adds another dimension to the assessment of existing courses. It should provide useful information about the potential barriers, as well as the opportunity to implement environmental and sustainable practice.

It is anticipated that graduates will provide insight information into the relevance of their education in this area and whether the education system prepared for them and provided to them has facilitated the necessary skills to take up this challenge.

5. Review teaching methodology

To examine the best and most effective method used in the teaching of these courses (eg lectures, tutorials, laboratory classes, assignments, research projects, Web-based instructions, etc) in order to maximise learning, develop and enhance these skills in students, so that they satisfy and match the industry requirements and expectations of global environmental engineers.

6. Research methodology

The research methodology consists of:

- Comprehensive literature review.
- Internet search.
- Development of survey questionnaires.
- Testing the effectiveness of this global curriculum.
- Design of a global curriculum in environmental engineering.

7. Research on the effectiveness of the global curriculum in environmental engineering

- Based on the information gathered from various institutions a best model for the development of a global environmental engineering curriculum will be developed and presented.
- It is envisaged that the experimental work, involving the implementation of the designed curriculum, as well as research on the effectiveness of this curriculum, will be carried out in a suitable engineering education institution.
- The model will be verified through testing and expert review.
- Comprehensive research on the strengths and weakness of the global curriculum will be conducted.

8. Discussion

Presentation and discussion of all educational and practical aspects of the global curriculum for environmental engineering will be carried out.

CONCLUSIONS

Earlier research into the existing environmental courses carried out with Australian higher education institutions shows that there is an unsatisfactory level of treatment of important concepts, topics and issues dealing with the environment and environmental protection [14]. Also, most of the courses examined so far demonstrate emphasis on such issues as environmental science, natural resources management and environmental management. It is therefore imperative that a future curriculum provides the coverage of a wide spectrum of topics integrating all the environmental fields within environmental education.

The huge proliferation of concepts can only be avoided if there is a global curriculum in environmental education designed,

developed and implemented. Obviously, it would have been much better to establish a global engineering education curriculum, which would cater for all engineering specialities, including environmental engineering. However, at this stage, the task is too great for a small institution like the UICEE to be able to undertake this exercise, without considerable financial and human resources to be made available.

Attempts have been made to establish a consortium of several international universities to tackle this task. But the scope of the project, resources required and conflict of interest amongst the institutions approached, has made it impossible to undertake this project, at least at this stage. Therefore, the UICEE has alone undertaken research and development activities to design, implement and test a global curriculum in environmental engineering education. If successful, the UICEE will expand the project in order to devise a global curriculum for engineering education.

Although, it is recognised that the design, development and implementation of a global environmental curriculum itself is a mammoth task, it is believed that the research methodology with its clearly defined steps, and in particular the Modelling Method, which will be used in this project, are sound and should form an excellent basis and guidelines in this work.

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Conference Proceedings of the *5th UICEE Annual Conference on Engineering Education* under the theme: *Student-centred Engineering Education*

edited by Zenon J. Pudlowski

The *5th UICEE Annual Conference on Engineering Education*, under the theme of *Student-centred Engineering Education*, was organised by the UNESCO International Centre for Engineering Education (UICEE) and was held over the Internet and in person at Anna University, Chennai, India, between 6 and 9 February 2002. This volume of Proceedings includes papers submitted to the Conference and offers a manifold collection of almost 50 papers detailing various international approaches to engineering education and specific activities.

The Conference theme, *Student-centred Engineering Education*, was chosen to identify and present best projects, programmes and examples relevant to the main theme and to discuss their impact on the status and quality of global engineering education. Although the Conference's emphasis was on this theme, the papers included in these Proceedings present many aspects of engineering education and industrial training, addressing topics of vital importance to engineering education. These have been placed into various groups, namely:

- Innovation and alternatives in engineering education
- Important issues and challenges in engineering education
- New trends and approaches to engineering education
- Quality issues and improvements in engineering education
- Learning strategies and methods in engineering education
- Course development in engineering education
- International examples of engineering education and training
- Multimedia and the Internet in engineering education
- Case studies

Several papers in the Proceedings demonstrate research and development activities from within India and illustrate that the global debate on engineering education and the international expansion of interest in engineering education has grown and is having an increasing influence on the host nation.

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