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Trends in undergraduate environmental engineering training and integration strategy for civil engineering at the University of Pretoria

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Environmental engineering and information technology (IT) are growth areas in the civil engineering field. The South African Qualifications Authority (SAQA) (1998) and the Engineering Council of South Africa (ECSA) (1998) require that aspects of IT and environmental engineering be included in the curricula of engineering education. This is in line with a worldwide trend in engineering education. Recent SA environmental legislation elevated the issue of environment from one of 'general awareness' to a 'legal requirement' in the fields of planning, development and civil engineering practice. The University of Pretoria (UP) has, to date, offered environmental engineering and management modules primarily as postgraduate specialist studies. The Department of Civil Engineering and the Department of Agricultural and Food Processing Engineering recently merged as part of university-wide reorganisation and rationalisation of faculties and departments. The new Department of Civil and Biosystems Engineering thus formed utilised the strategic opportunity presented by the name change to investigate the extent to which environmental engineering can be accommodated as an independent undergraduate programme in the restructured Civil Engineering and Agricultural and Food Processing Engineering curricula. A phased approach was chosen, which included various electives in the new curricula from 2001.

INTRODUCTION

The civil engineering profession is going through major changes with associated paradigm shifts. It seems that civil engineering has from the start been the 'mother ship' from which a number of new disciplines have been 'spawned'. 'Initially, all engineering activities were subdivided as either "civil" engineering or "military" engineering, depending on its focus. As specific engineering disciplines developed, though, they often split off as new engineering fields: mechanical engineering, electrical engineering, chemical engineering and so on' (Bishop 2000). There has recently been an emphasis shift in the civil engineering industry towards a better appreciation of the whole life cycle of typical civil engineering infrastructure projects (Milford 1999). Figure 1 illustrates this shift in the civil engineering activities over the life cycle of a typical infrastructure facility, as described by Abbot (1996). Planning, design and construction activities have traditionally been the main focus. This focus on hard-core technical and analytical aspects has resulted in a historical bias towards design and analysis of structures in curricula. The 'upstream and downstream' engineering activities normally tend to be less analytical in nature than these hard-core historical focus areas.

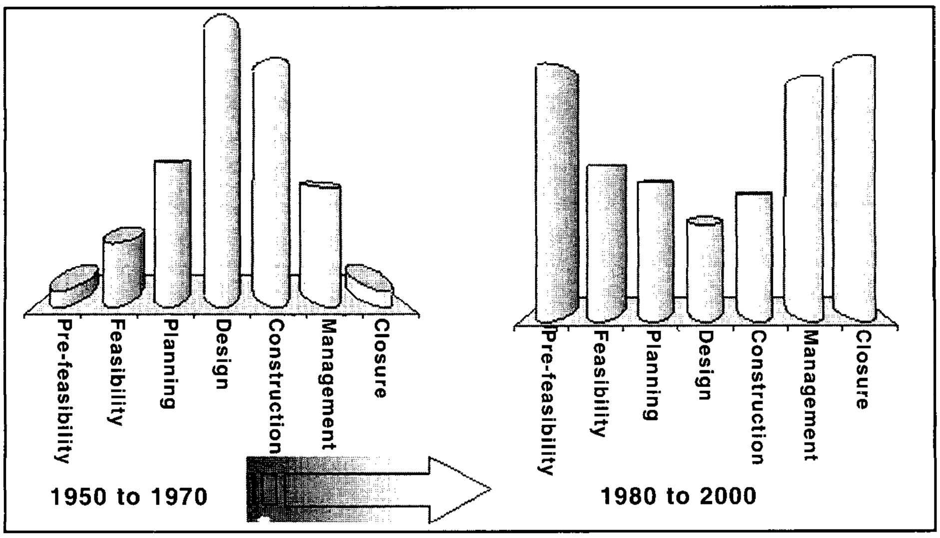

Figure 1 Shift in civil engineering activities over the life cycle of typical infrastructure facilities (Abbot 1996)

The recent shift in emphasis towards increased involvement in 'upstream activities' such as pre-feasibility and feasibility, and 'downstream activities' such as management and closure, is clearly illustrated in figure 1. This shift and need for 'soft skills' were observed even in the traditional hard-core civil construction industry (Theberge 2000). There is now an increased appreciation of the importance of 'upstream' activities on a project versus the traditional 'middle stream' activities such as design, tender and construction. The associated long-term cost implications and impact over the life cycle of a project are illustrated conceptually in figure 2 (Ahuje *et al* 1994). This figure clearly shows that the apparently less analytical issues, even prior to project conception, have the most significant impact on the whole life cycle cost of the project. The change from the traditional focus on design, tender and construction coincided with the IT revolution and the emergence of environmental awareness in civil engineering. Environmental engineering, as a less analytical focus area, finds high levels of applications in the 'upstream' and 'downstream' areas of engineering activity. Pre-feasibility, feasibility, management and closure phases of a project are areas where environmental engineering has lately come into its own right. This shift in emphasis requires integration of various fields of technical expertise and holistic thinking and therefore also calls for proficiency in the 'softer and communications skills' (Beder 1998a).

The increased emphasis on non-analytical activities described briefly in table 1 is confirming the concurrent changes in the perceptions of the environmental and civil engineering professions. There is also an increasing appreciation of the need to include non-technical and social skills in the education of both civil and environmental engineering professionals.

The American Accreditation Board for Engineering and Technology (ABET) (1998) recently developed a set of study requirements for engineering graduates which is intended to correct the historical bias towards hard-core technical and analytical skills by introducing more 'softer or non-technical skills' to curricula of engineering programmes (Grigg *et al* 1996). 'Industry is increasingly looking for employees who can think holistically, who can innovate, who can work in teams, who can synthesise and who can integrate environmental and societal values and ethics in their work – all activities that demand right-brain thinking skills' (Lumsdaine *et al* 1999). This view is also supported by surveys done in South Africa (Nasree 2000, De Lange 2000; FRD 1996). In line with this 'softer skills restoration' there is a global recognition that the involvement of the civil engineer in society and the environment has a definite ethical undertone (Vesilind & Gunn 1998). Beder (1998a) gives Australian comment as follows: 'A greater recognition of non-engineering inputs would certainly heighten the profession's standing in the community. With the depth of skills the engineering profession has to offer, it would probably go a long way to raising the public's awareness of the role of engineers in society, and as a bonus would certainly enhance the profession's status.' Engineers have often been portrayed as highly competent persons, but with limited social skills and a tendency to be environmentally insensitive. They were often even seen as 'nerd-like' and even partially 'autistic' in their behaviour (Beder 1998b). Environmental engineering projects tend to highlight the propensity for such insensitivities more than other engineering disciplines owing to the closer links with a number of diverse disciplines and integrated systems and often associated emotional content.

A number of environmental and planning laws and policy documents that came into effect in South Africa in the last few years have far-reaching effects on civil engineering practice (DEAT 2000). The National Environmental Management Act (NEMA) (No 107 of 1998) makes provision for the development of assessment procedures to ensure that the environmental consequences of policies, plans and programmes are considered. The legal framework in which civil engineers now have to operate has lifted the issue of environment from merely an 'awareness' level to a 'prerequisite' in engineering education, training and practice.

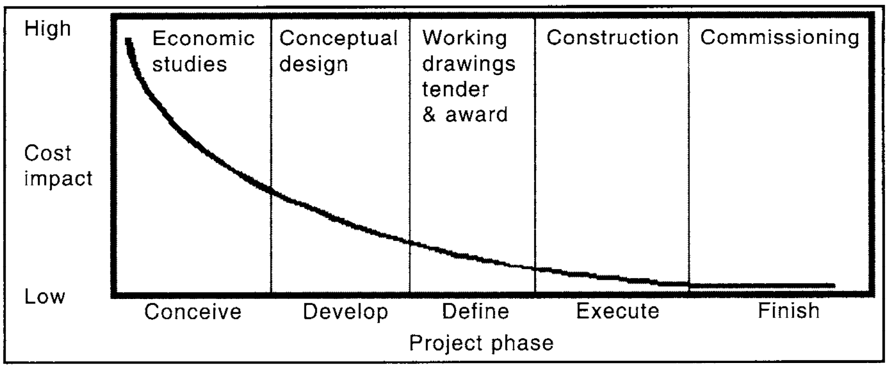

***Figure 2** Cost impact as a function of project phase (Ahuje* et al *1940)*

***Table 1** Environmental engineering paradigms (Bishop 2000; AAEE and ABET 1998)*

Period	Paradigm shift
Pre-1950	Focus on engineering practice; design according to codes and traditional rote procedures; public health emphasis
1950–1996	Focus on engineering sciences; fundamental understanding of natural phenomena and process simulations; reduced emphasis on practice, including design; breach in education/practice continuum; series of environmental education conferences
1996 to date	Focus on communication, teamwork impediments to holistic evaluation and design of environmental systems, partnering and global perspective; education/practice continuum; environmental engineering education relevance conferences

INSTITUTIONAL CHANGES AND STATUS QUO OF ENVIRONMENTAL ENGINEERING AT UP

Higher education in South Africa is currently undergoing far-reaching and fundamental change (CHE 2000). There is a need for rationalisation on a national basis and at the level of individual institutions, which requires major structural change and restructuring of institutions of higher education. The strategic objectives of the University of Pretoria to be an international centre of excellence and to be locally relevant have added to the pressure on the university to re-engineer itself. The result is that existing faculties have now become business units in new combined faculties to reduce overhead costs. The old Faculty of Engineering of UP has become the School of Engineering in the new Faculty of Engineering, Built Environment and Information Technology (EBIT).

The Department of Civil Engineering and the Department of Agricultural and Food Processing Engineering within the new School of Engineering were also rationalised. These departments were merged in the course of 2001 to become a single engineering department while continuing to offer the full degree programmes of Civil Engineering and Agricultural and Food Processing Engineering. The merger created an opportunity to respond to the emerging importance of environmental studies by exploiting the overlap between civil engineering and the broader field of Bio-engineering, Biosystems Engineering and Eco-systems, etc, which are the traditional field of Agricultural Engineering. The name Department of Civil and Biosystems Engineering was chosen to reinforce and underline this synergy.

Traditionally the Civil Engineering Department undergraduate curriculum included some environmental engineering input interwoven with subjects such as Town and Regional Planning, Traffic Engineering, Transportation Planning, Water Utilisation, Hydrology, Hydraulics and Geotechnical Engineering. However, these related subjects had the disadvantage that there was insufficient focus on environmental aspects. Consequently an environmental engineering focus could not easily be identified for education, marketing, research and publicity purposes.

Environmental engineering was viewed by the previous Faculty of Engineering as a specialist postgraduate programme. Honours and master's degrees were jointly presented by the Departments of Chemical and Civil Engineering. The focus of Chemical Engineering was mainly on water quality and utilisation. These specialist postgraduate degrees in environmental engineering were treated on a par with other more traditional postgraduate degrees in the fields of structural, transportation, geotechnical, water and urban engineering (Hahn 2000).

The Faculties of Natural and Agricultural Sciences, Medicine and even Law at UP have over the years developed specialist knowledge and degree programmes associated with environmental studies in the fields of Ecology, Geography, Zoology, Botany, etc. It was recognised that there was a need to combine these 'pockets' of environmental studies at UP to form an integrated and more visible entity around environmental studies. An inter-faculty and inter-department matrix-type School for Environmental Studies was formed in 1998. This school offers honours and master's degrees supported by diverse departments and faculties in a new cost-effective delivery approach. The success of this development provided clear guidelines for the design of an undergraduate curriculum which incorporates environmental engineering content in the new Department of Civil and Biosystems Engineering.

INTERNATIONAL TRENDS IN ENVIRONMENTAL ENGINEERING EDUCATION

The American Academy of Environmental Engineers (AAEE 1998) defines environmental engineering as 'the application of engineering principles to the management of the environment for the protection of human health, for the protection of nature's beneficial ecosystems, and for environment-related enhancement of quality of human life'. Environmental engineering is often also referred to as Resources Engineering, which by definition is 'a profession that provides real solutions to environmental problems and work with limited resources in a way that can be sustained for future generations' (Alha *et al* 2000).

'Environmental engineering, which was once traditionally viewed, with few exceptions, as being a subset of civil engineering, focusing on water sanitation, has mushroomed to include all aspects of the human and terrestrial environment – water and wastewater management, air quality, solid and hazardous waste management, noise and light pollution, and radioactive waste management, to name but a few' (Alha *et al* 2000). Or, in a very similar statement by Bishop (2000), 'Management of the environment has until recently been viewed, with a few exceptions, as a subset of civil engineering, but environmental engineering is now at the cross-roads where several programmes are spinning off from civil engineering and becoming independent disciplines or degree programmes.' In some European universities, Environmental Engineering Education (EEE) 'is offered as a full four to five year undergraduate and graduate curriculum; in others EEE is structured as graduate and post-graduate one to two year modules. It may also be available only as part of standard civil engineering programmes. In fact it is even argued that EEE ought to be part of any engineer's education and therefore separate degrees are not considered to be necessary' (Gujer & Henze 2000).

Environmental engineers are required to have a broad-based education. Alha *et al* (2000) concluded after the 1st European Seminar on Environmental Engineering Education that an environmental engineer 'must not only be skilled in the analysis and design of environmental processes and physical infrastructure, but must also have a profound understanding of the broader implications and benefits of the environment to society. Environmental engineers must be interested in people as well as engineering; an ability to work with, and lead, multi-disciplinary teams of architects, lawyers, scientists and environmental policy specialists, combined with an ability to communicate effectively, is a prerequisite.' The latter statement is supported by Grigg *et al* (1996) in the development of a new integrated curriculum for Colorado State University. Hahn (2000) argued at the European Seminar that environmental engineering education should be linked to or based on social sciences curricula. This is in line with the statements made by Beder (1998a) regarding the need for the new engineer to be more balanced in his/her education and professional conduct by incorporating softer skills acquired from the social sciences curricula.

Many institutions in Europe and North America offer master's degrees in environmental engineering or environmental science. These programmes are typically of one to two years' duration following the awarding of a bachelor's degree. In some cases undergraduate degree programmes are offered as an integrated five-year master's degree programme. The programmes may lead either to the awarding of an environmental engineering degree or a more traditional engineering degree with emphasis on environmental engineering (Alha *et al* 2000).

A summary of the situation regarding environmental engineering programmes offered in Europe, based on the report by Alha *et al* (2000), is given in table 2.

Table 2 Summary of the European situation regarding environmental engineering education

Country	Situation regarding university programmes
Denmark	Have been established for considerable time with well-accepted degree and graduates find work easily
Netherlands	Same as for Denmark, but recently there has been a movement to revert to integrating environmental engineering education into civil and chemical engineering programmes
Switzerland	The Swiss Federal Institute of Technology of Zurich recently launched environmental engineering programme as only one in country
Finland	Tampere University of Technology offers environmental engineering degree programme. University of Oulu and Helsinki University of Technology integrated environmental engineering in the programmes of chemical and civil engineering
Germany	Traditionally it was part of civil engineering. At least one dedicated degree programme in environmental engineering in Berlin and others is under development. Otherwise, environmental engineering is integrated into civil engineering programmes
Spain	Environmental engineering degree does not yet exist
Portugal	Five-year undergraduate programme or specialised final branch within undergraduate curriculum of civil, chemical and biological engineering or specialised lectures within classical programmes

Alha *et al* (2000) concluded that there are significant differences in curricular content and educational philosophy in environmental engineering programmes across Europe. In most cases, environmental engineering is offered in conjunction with, or as part of, a traditional civil engineering programme, but there are also institutions which offer specific degree programmes designated as environmental engineering.

Bishop (2000) reports that 'there has also been a change from a belief that environmental engineering education should begin at graduate level, after receiving a solid engineering foundation in one of the more traditional engineering disciplines, to the development of specialised undergraduate environmental programmes. This is still quite controversial in the United States, but more Bachelor of Science in Environmental Engineering programmes are continually being added each year.' He further reports that of the about 220 universities offering civil engineering programmes in the United States, only about 26 offer a separate accredited undergraduate degree in environmental engineering. 'Thus most universities in the United States are still only offering environmental engineering as an option within civil engineering programmes.' Alha *et al* (2000) concluded that during the 1st European seminar it was evident that there was no consensus on what constitutes a minimum environmental engineering curriculum. Bishop (2000) on the other hand concluded that 'environmental engineering programmes in North America are quite uniformly structured as a result of the ABET accreditation process'. The ABET environmental engineering programme criteria as developed by the American Academy of Environmental Engineers (AAEE) are summarised in table 3.

Bishop (2000) reports that the ABET accreditation recently changed to be more outcomes focused. 'Environmental engineering programmes are no longer constrained to offer a set curriculum. They can now experiment with new teaching approaches; the only requirement is that well qualified environmental engineering graduates are the result. The Association of Environmental Engineering and Science Professors is actively involved in ensuring that these new teaching strategies are successful.' ABET (1998) reviewed the relevancy of general fundamentals to the major environmental engineering focus areas. The results, as reported in table 4, clearly show that some of the subjects often found in civil engineering curricula, such as electrical circuits, are not appropriate for environmental engineering education.

There seems to be growing demand for specialists trained in environmental engineering and clearly most engineering schools worldwide are in a state of change. 'In some cases, environmental engineering degree programmes attract higher student uptake than traditional engineering disciplines' (Alha *et al* 2000). Alha *et al* (2000) ascribes the apparent slow development of independent undergraduate environmental engineering programmes in Europe and North America to the observation that once a new education programme has started, it typically takes about five to ten years for the new degree to become established and accepted by employer organisations and the engineering profession. Grigg *et al* (1996) also report that 'most of the discussion around curriculum innovation has been about concepts, but management issues must be solved if we are to implement workable innovations'. He concluded that several major management and organisational problems are faced once a new integrated undergraduate programme is embarked upon.

Official enrolment figures at American universities for undergraduate

Table 3 Outcomes for an environmental engineering graduate programme

- Knowledge of fundamental concepts of waste minimisation and pollution prevention
- Understanding the roles and responsibilities of public institutions and private organisations in environmental management
- Capability to apply environmental systems and process modelling techniques
- Ability to conduct laboratory experiments and to critically analyse and interpret data in more than one of the recognised environmental engineering focus areas
- Proficiency in mathematics through differential equations, probability and statistics, calculus-based physics, general chemistry, an earth science (eg geology, meteorology, soil science) relevant to the programme of study, a biological science (eg microbiology, aquatic biology) relevant to the programme of study, and fluid mechanics relevant to the programme of study
- Knowledge of introductory level fundamentals in the following major focus areas: water supply and resources, environmental systems modelling, environmental chemistry, wastewater management, solid waste management and occupational health
- Proficiency in advanced principles and practice in a minimum of three of the major focus areas listed above
- Ability to perform environmental engineering design by means of design experiences integrated throughout the professional component of the curriculum
- Understanding of concepts of professional practice, such as procurement, bidding versus quality-based selection processes, interaction of project design and construction professionals, and the importance of professional licensing and continued education

Table 4 Relevancy of general fundamentals to the major environmental engineering focus areas

	Major focus areas of environmental engineering							
General fundamentals	Water supply and resources	Environmental system model	Environmental chemistry	Wastewater management	Solid waste management	Hazardous waste management	Atmospheric systems of air pollution	Environmental and occupational health
Probability and risk assessment	1	1	1	1	1	1	1	1
Statics/dynamics	1	1	1	1	1	1	1	1
Fluid mechanics	1	1	1	1	1	1	1	1
Chemical thermodynamics	2	1	2	2	1	1	1	2
Chemical kinetics	1	1	1	1	1	1	1	2
Solution chemistry	1	1	1	1	1	1	1	1
Mass transfer	1	1	1	1	1	1	1	2
Heat transfer	2	1	2	2	2	2	1	2
Material balance	1	1	1	1	1	1	1	1
Energy balance	2	1	1	2	2	2	1	2
Population dynamics	2	1	2	1	2	2	2	1
Computer science	1	1	1	1	1	1	1	2
Graphics	1	1	1	1	1	1	1	1
Geology	2	1	3	2	1	1	3	3
Meteorology	1	3	3	1	1	1	1	1
Hydrology	1	1	1	1	1	1	1	2
Microbiology	1	1	1	1	1	1	1	2
Ecology and resource use	1	1	1	1	1	1	1	1
Regulatory systems	1	1	1	1	1	1	1	1
Electrical circuits	2	1	2	2	2	2	2	3

1 Applicable and important
2 Moderately applicable or important
3 Not very applicable or important

environmental engineering programmes showed a 1,2% decline in 1999. Enrolment has dropped steadily since 1995 when environmental enrolment was at 3 611 and enrolment stood at 2 373 in 1999 (ASCE 1999). In its fifth straight year of decline, environmental engineering master's enrolment has been at 852 – a decrease of 13,5% from the previous year – and enrolment for doctorates has dropped by 6,7% since 1998 (ASCE 1999).

POTENTIAL FOR AN ENVIRONMENTAL ENGINEERING UNDERGRADUATE DEGREE PROGRAMME

It has been indicated that at postgraduate level there is adequate provision for specialist modules in environmental engineering at UP. The ultimate objective is to establish an independent environmental engineering undergraduate degree programme as well. The outcomes listed in table 3 and the evaluation of the relevance of general fundamentals to the major environmental engineering focus areas in table 4 give a clear indication that an independent environmental engineering undergraduate programme needs fundamental rethinking. It is common knowledge that the existing civil engineering curricula lack exposure to the fields of biochemistry, fauna, flora and vertebrates (Hahn 2000). These fields of knowledge are typically associated with the environmental fields the civil engineer is increasingly confronted with in practice. They already form part of bachelor degree programmes offered by the Natural and Agricultural Sciences Faculty in Environment and Ecology at UP. An attempt was made to investigate the extent to which the requirements listed in tables 3 and 6 could be met by 're-packaging' the existing civil engineering curriculum. In order to include these environmental subjects, the current over-emphasis on analytical course work, such as structural analysis and design, was addressed by replacing certain analytical modules with 'off the shelf' subjects from the Faculty of Natural and Agricultural Sciences.

The resulting proposal for an independent environmental engineering curriculum is shown in table 5, in which proposed subject credits are also indicated. The new ECSA and SAQA determined outcomes for engineering curricula are fulfilled by this proposal. The aim was to achieve, on average, 80 credits per semester and 160 credits per year for each of the four years of study. Typically, engineering subjects are packaged as 8-credit or 16-credit semester modules throughout. This approach is significantly different to the way the Faculty of Natural and Agricultural Sciences calculate their credits, as their modules are structured around three-year degrees. As can be seen from the results in table 5, the target of 80 credits on average per semester can be achieved.

In this proposal, the existing civil engineering subject fields of water engineering/hydrology, geotechnology and soil mechanics were maintained and even expanded as they traditionally address the natural resources of water and soil. Exposure to transportation engineering, project management, engineering economy and building materials were kept to an introductory level up to third year. The 'capstone design project' in the final year normally builds strongly on the integration of the disciplines of transportation engineering, geotechnical and structural engineering. In this case, Environmental Design Project as 'capstone project' was redirected towards an environmental engineering focus.

It is concluded from this desk study that it is viable to implement an independent undergraduate environmental engineering degree programme that complies with ECSA and ABET requirements by using 'off the shelf' subjects. The current European situation and subject relevancy, as described in tables 2 and 4, can be used as a guide in adapting curricula in South Africa. The development of new subjects is tempered by a number of hurdles. The fact that a new degree programme will take about two years to get approval and accreditation and five to ten years for acceptance by the industry makes it a doubtful starter. Furthermore, there is currently no overwhelming need expressed by the market in South Africa for such specialised professionals. Coupled to this is the fact that higher education institutions are increasingly under threat of diminishing numbers and related doubtful financial viability (CHE 2000).

Civil engineering and agricultural engineering professions are currently experiencing low student intakes for many reasons. This makes any alternative degree programme a financial risk to start with. The previously quoted downwards trend in environmental engineering studies in America (ASCE 1999) is worsened when coupled with the further decline in enrolments for civil engineering that has been observed in South Africa for a number of years (Onsongo 2000). It is concluded, therefore, that it would be more

Table 5 Independent environmental engineering degree curriculum

Study year	Credits	Semester 1	Credits	Semester 2
Year 1	16	Mathematics	16	Mathematics
	16	Physics	16	Physics
	16	Chemistry	16	Mechanics/Statics
	8	Information Technology	16	Land Surveying
	8	Innovation and Problem Solving	16	***General Chemistry***
	16	Graphics		
	Total 80		Total 80	
Year 2	16	Introduction to Structural Design	16	Mathematics
	8	Engineering Statistics	8	***Biochemical Engineering***
	8	Town and Regional Planning	16	Structural Analysis
	8	Communication	16	Soil Mechanics
	8	Engineering Economy	16	Geomaterials and Processes
	16	Mathematics	8	**Physical Geography**
	16	Strength of Materials		
	Total 80		Total 80	
Year 3	16	Hydrology	16	Water Utilisation (320)
	16	Geotechnical Engineering	16	***Environmental Geotechnology****
	8	Ethics and Engineering Practice	12	***African Vertebrates***
	8	Building Materials	7	***Environmental Geomorphology***
	8	Traffic Engineering	16	***Environmental Engineering***
	7	***Process Geomorphology***	7	***Natural Resource Management***
	7	***Geographic Information Systems***	8	Transportation Planning
	12	***SA Flora and Vegetation***	Total 84	
	Total 82			
Year 4	16	Hydrology (410)	16	Water Resource Planning
	16	***Geohydrology****	16	***Solid Waste Management****
	16	***Research Project****	18	***Conservation Biology****
	16	***Environmental Management****	30	***Environmental Design Project****
	16	***Water and Effluent Treatment****		
	Total 80		Total 80	

* Subjects are either new to civil engineering or sourced from other engineering departments to suit the environmental engineering desired outcomes. All other subjects are sourced from other faculties 'off the shelf'.

Table 6 Environmental electives in the civil engineering curriculum

Credits	Semester 1	Credits	Semester 2
	Year 1		**Year 1**
16	Mathematics	16	Mathematics
16	Physics	16	Physics
16	Chemistry	16	Mechanics/Statics
8	Information Technology	16	Land Surveying
8	Innovation and Problem Solving	16	Civil Engineering Design
16	Graphics		
Total 80		Total 80	
	Year 2		**Year 2**
16	Introduction to Structural Design	16	Mathematics
8	Engineering Statistics	16	Pavement Materials and Design
8	Town and Regional Planning	16	Structural Analysis
8	Communication	16	Soil Mechanics
8	Engineering Economy	16	Geomaterials and Processes
16	Mathematics	8	Engineering Statistics
16	Strength of Materials	8	Engineering Economy
Total 80		Total 80	
	Year 3		**Year 3**
16	Hydraulics	16	Water Utilisation
16	Soil Mechanics	16	Geotechnical Engineering
8	Timber Design	8	Building Materials
8	Building Materials	8	Reinforced Concrete Design
8	Trafffic Engineering	8	Steel Design
8	Structural Analysis	8	Traffic Engineering
16	Mathematics ***or Geographic***	8	Transportation Planning
8	***Information Systems (GIS)****	8	Construction Management
8	***and Society and Space***		and Equipment
Total 80		Total 80	
	Year 4		**Year 4**
8	Technological Entrepreneurship	16	***Environmental Engineering****
16	Hydrology	16	Water Resource Planning
8	Steel Design ***or Geohydrology***	8	Geographic Information Systems (GIS) ***or***
8	Concrete Design ***or***	8	***Physical Geography or***
	Environmental Geotechnology	8	***Biochemical Engineering***
8	Ethics and Engineering Practice	40	***Design Project or***
8	Transportation Planning		***Solid Waste Management and***
		16	
8	Project Management	24	Design Project (reduced in scope)
Total 80		Total 80	

* Environmental Engineering electives

Table 7 Calculation of minimum ECSA and SAQA study fields

	Percentage of total comprehension hours (according to knowledge areas)						
	Mathematics	Basic Science	Engineering Science	Design and Synthesis	Computing and IT	Complementary studies	Discretionary
SAQA prescribed minimums	10	10	30	12	3	10	25
A Normal civil engineering degree	12,5	11,5	39,6	23,1	3,3	10	
B Environmental engineering electives	10	11,5	39,9	20,5	3,9	13,6	

prudent to follow a phased approach in incorporating environmental engineering into the civil engineering curriculum. The study does indicate though that it is possible to meet a demand if it should transpire in future.

ELECTIVES IN THE UNDERGRADUATE CIVIL ENGINEERING DEGREE PROGRAMME

The merging of the Department of Agricultural and Food Processing Engineering and the Department of Civil Engineering into a new Department of Civil and Biosystems Engineering has created a strategic opportunity to introduce environmental engineering subjects to the basic civil engineering curriculum. As part of the reduction of overhead costs, the Agricultural and Food Processing Engineering degree programme was deliberately tailored to function with subjects currently offered by Mechanical Engineering and Civil Engineering degree programmes, with Agricultural Engineering specialist electives in the 3rd and 4th years. This integration and phasing in are in line with the ECSA and ABET requirements, with the flexibility to ultimately be transformed into an independent environmental engineering degree programme in future.

The normal four-year civil engineering curriculum is very full and compact, making it difficult to include elective subjects. One of the reasons is the prerequisite of subjects which should be passed sequentially as building blocks. This results in a rigid curriculum order. However, the over-emphasis of mathematics and analytical skills in the traditional civil engineering curricula creates the opportunity to correct the bias by substituting environmental engineering modules as electives.

All the SAQA and ECSA requirements for a civil engineering degree had to be met in this exercise. Therefore environmental engineering subjects, offered as electives, had to comply with these same requirements. To achieve this objective, the existing strengths of the Civil Engineering degree programme had to be utilised. Geotechnical and Hydraulic Engineering study fields are examples of such subjects of strength. In table 6 it is shown that environmental engineering subjects can be sourced from other departments in the School of Engineering, with limited development work needed. Such new or 'off the shelf' subjects are indicated in bold italics. In the case of the environmental engineering stream, the research project and the capstone design project will also have an environmental engineering focus. A new introduction is Geographic Information Systems (GIS), which is a perfect example of the integration of the IT and Environmental

Table 8 Pros and cons of alternative curricula

ALTERNATIVE	PROS	CONS
1 Full environmental engineering degree	• Meet SAQA and ECSA quotas • Mainly sourced from off-the-shelf subjects • Covers all aspects of environmental engineering	• Long process to register a new degree programme • Doubt about industry support and sustained work for graduates • Potential erosion of successful postgraduate specialist programme in environmental engineering • Traditional management problems with complex cross matrix organisations
2 Civil engineering degree with environmental electives	• Meet SAQA and ECSA quota requirements • Sourced from existing subjects or resources • Protect successful postgraduate programmes • Immediate implementation with increased environmental bias possible • Industry accepted broad-based civil engineering degree which has sustainable employment potential	• Focus on water and soil aspects while air quality is only addressed at postgraduate level • Do not cover aspects of botany and zoology • Can be seen as less analytical

Engineering focus areas mentioned at the start. Georgia Tech refers to such a subject in combination with surveying, as Geomatics and it is seen as a basic component of the Civil and Environmental Engineering degree (Meyer & Jacobs 2000).

The calculation of the percentages per study field for the normal civil engineering curriculum and the environmental engineering electives curriculum is summarised in table 7. It shows that, in both cases, the minimum SAQA and ECSA requirements could be met to qualify as a bachelors civil engineering degree. The result is that environmental engineering subjects could be offered to an even greater extent than required by ECSA, but obviously not to the extent described earlier for the ABET and AAEE full environmental engineering degree programmes in tables 3 and 4. It does provide a significant positioning for future specialisation in environmental engineering from the basis of a civil engineering degree.

At least 40–50% of engineering students complete their studies in five to six years. Such 'slow' students who start off on a four-year programme normally develop unbalanced gaps in their lecturing schedules. These students are now offered the opportunity to take additional environmental modules for enrichment. Typically these would include subjects from the full environmental engineering curriculum sourced from the Faculty of Natural and Agricultural Sciences described earlier.

CONCLUSIONS

The pros and cons of the two environmental engineering bachelors degree curricula are summarised in table 8. One of the main concerns is the aspect of sustainable jobs for graduates in environmental engineering. This was the main focus of discussions at the 1st European Seminar on Environmental Engineering (Alha *et al* 2000). Market response to date indicate that contracts still tend to be of the traditional civil or chemical engineering type, with environmental engineering aspects linked to it. Personal feedback from Australia and New Zealand confirmed the validity of this sustainability concern for specialist environmental engineering bachelors degrees. The conclusion reached is that clients and young graduate engineers are served better with basic bachelors degrees in chemical and civil engineering with an environmental engineering bias. Specialist postgraduate degrees in environmental engineering help to differentiate such civil or chemical graduate engineers in the employment market. The environmental engineering curriculum within the civil engineering degree programme was selected as the most logical route to follow. It addresses and exceeds the ECSA objective of increased environmental engineering content and is cost effective in the short to medium term with potential for later expansion into an independent undergraduate environmental engineering degree, if the market requires it.

References

AAEE 1998. *Guide for Administrators and Faculty to ABET Accreditation in Environmental Engineering.* American Academy of Environmental Engineers, Annapolis, MD.

ABET 1998. *ABET accreditation yearbook.* Accreditation Board for Engineering and Technology, Baltimore, MD.

Abbot, J 1996. *Urban engineering: defining the future of civil engineering in South Africa.* Seventh Annual SAICE Congress, Cape Town, South Africa.

Ahuje, H N, Dozzi, S P & Abourzik, S M 1994. *Project management: techniques in planning and controlling projects.* Second edition. New York: John Wiley and Sons.

Alha, K, Hollinger, C, Larsen, B G, Purcell, P & Rauch, W 2000. Environmental engineering education – summary report of the 1st European Seminar. *Water Science & Technology, Environmental Engineering Education in Europe,* 41(02):1–8.

ASCE 1999. 1999 Civil & Environmental Engineering Enrollment Data. American Society of Civil Engineers (ASCE) Report compiled from the reports of the Engineering Workforce Commission (EWC) of the American Association of Engineering Societies (AAES).

Beder, S 1998a. *The new engineer: management and professional responsibility in a changing world.* Sydney: Macmillan.

Beder, S 1998b. The new engineer: a bit of the rain man in every engineer? *Civil Engineers Australia,* April.

Bishop, P L 2000. Environmental engineering education in North America. *Water Science & Technology, Environmental Engineering Education in Europe,* 41(02):9–16.

CHE 2000. Towards a new higher education landscape. *Meeting the equity, quality and social development imperatives of South Africa in the 21st Century.* Council on the Higher Education (CHE). Shape and Size of Higher Education Task Team, Pretoria.

De Lange, G 2000. The identification of the most important non-technical skills required by entry-level engineering students when they assume employment. *Proceedings* of the 2nd Southern African Conference on Engineering Education, Vanderbijlpark, South Africa, 28–29 September 2000.

Department of Environmental Affairs and Tourism (DEAT) 2000. Strategic environmental assessment in South Africa: guideline document. Pretoria, February 2000.

Engineering Council of South Africa (ECSA) 1998. Standards for Accredited University Engineering Bachelors Degrees. Document PE-61. Midrand.

FRD 1991. *Survey into engineering education.* Foundation for Research and Development.

Grigg, N S, Criswell, M E & Siller, T J 1996. Integrated civil engineering curriculum: implementation and management. *Journal of Professional Issues in Engineering Education and Practice.* New York: American Society of Civil Engineers.

Gujer, W & Henze, M 2000. Preface to environmental engineering education in Europe. *Water Science & Technology, Environmental Engineering Education in Europe,* 41(02).

Hahn, H H 2000. Environmental engineering education in conjunction with or as part of social science curricula. *Water Science & Technology, Environmental Engineering Education in Europe,* 41(02).

Meyer, M D & Jacobs, L J 2000. A civil engineering curriculum for the future: the Georgia Tech case. *Journal of Professional Issues in Engineering Education and Practice.* New York: American Society of Civil Engineers, April.

Milford, R 1999. The past, the present and the future of the institution – 1999 presidential address. *Civil Engineering*, May 1999. Magazine of the South African Institution of Civil Engineering.

Nasree, S 2000. Beyond a shadow of a doubt: making a case for humanities and social sciences in the engineering curriculum. *Proceedings* of the 2nd Southern African Conference on Engineering Education, Vanderbijlpark, South Africa, 28–29 September 2000.

Onsongo, W 2000. Is there a demand for more civil engineering graduates in South Africa? *Civil Engineering*, February. Magazine of the South African Institution of Civil Engineering.

Lumbsdaine, E, Lumbsdaine, M & Shelnutt, J W 1999. *Creative problem solving and engineering design*. McGraw-Hill.

Theberge, P E 2000. Changing role of engineers in construction management. *Transportation Research (TR) News*, January-February 2000, Washington, USA.

UA 2000. *School of Engineering Guide 2000*. University of Auckland, New Zealand.

Vesilind, P A & Gunn, A S 1998. *Engineering, ethics, and the environment*. Cambridge: University Press.