Designing Civil Engineering Curriculum In Developing Countries

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ABSTRACT: Civil Engineering discipline is very vast, and has around 15 subsets of specialized training areas, each having around 10-15 core subjects of their own. The undergraduate degree course is normally of four years duration after school and it is becoming difficult for curriculum designers to cover the whole spectrum of subjects within this limited period. In this paper the authors highlight some of theissues being faced in developing countries and suggest a rational procedure for designing degree curriculum for providing holistic training at undergraduate level. The suggested protocol is also at the same time up to speed with the leading civil engineering training providers in andaround the world as it meets the requirements of the 'Washington Accord'.
Index Terms: Civil Engineering training, Curriculum design, Washington Accord, Sustainable development, Holistic teaching

I.INTRODUCTION

Civil Engineering (CE) is the oldest profession after military engineering. Its first training was conceived around 270 years ago (1). This branch of engineering deals with planning, design, construction and maintenance of natural and built environment. With the developments in society the needs are changing and civil engineering training has become broader. Civil engineering currently has around 125-150 core subjects. The undergraduate degree course is normally of four years duration after school and it is becoming difficult for curriculum designers to cover such vast number of subjects within this limited period. There is yet another dimension to this scenario. Peers (other engineering training providers) around the world are making structural adjustments in their curricula by bringing in courses from other associated disciplines like social sciences, human values, management, economics, ecology, environment and even sustainable development, etc. and embedding them in their engineering teaching to provide holistic training to students in line with the current trends and needs of the society. With no guidelines available from anywhere for designing a realistic and worthwhile curriculum, the training providers in developing country environment find themselves placed at a disadvantage. There is obviously a need to look at this picture in its totality and provide some direction to training providers, so they are better placed to design and facilitate an effective and meaningful training to their students, and at the same time win an edge over others as being one of the best undergraduate civil engineering training providers in the country and abroad.

II.STAKEHOLDER'S EXPECTATIONS

In an attempt to design a worthwhile curriculum it is best to look first at the stakeholders and their expectations. When it comes to teaching and learning, obviously the stakeholders are students, the tertiary providers and the employers in the country and abroad. Let us identify what their expectations are and how best we can accommodate them in the new curricula.

A. Student's Perspective

From students (in developing countries) perspective the training should be innovative in a way that it is recognised for work placement and higher education within the country and abroad. And also when it comes to looking at which countries abroad, student's choice falls upon developed countries likeAustralia, Canada, Hong Kong, Ireland, Japan, New Zealand, Singapore, UK and USA etc.; which will offer them better prospects for personal and professional growth.

B. Tertiary Providers and Employers in the Developing Country's perspective

Here the providers shall like the curriculum to be customer focused. They would also like training should be such that it is in line with the appropriate technology and meets the needs of the country so students can find employment easily and be useful to the society. They would also like the students to be able to beneficially use appropriate technology to improve the living standards of the community around. The faculty should also feel inspired to carry out appropriate research and translate it into their delivery thereby enhancing their teaching capabilities. The curriculum at the same time should give the students enough exposure of the state of the art technology in the desired discipline so students are not disadvantaged when venturing opportunities overseas.

C. Tertiary Providers and Employers in the Developed Countries

The curricula should be in line with the terms of reference as set out in the 'Washington Accord'.

III.THE WASHINGTON ACCORD

The Washington Accord (2) signed in 1989, is an international agreement among bodies responsible for accrediting engineering degree programs. It recognizes the substantial equivalency of programs accredited by those bodies and recommends that graduates of programs accredited by any of the signatory bodies be recognized by the other bodies as having met the academic requirements for entry to the practice of engineering. 16-developed (and/or semi-developed) countries e.g. Australia, Canada, China, Taipei, Hong Kong, India, Ireland, Japan, Korea, Malaysia, New Zealand, Russia, Singapore, South Africa, Turkey, UK and USA, which are incidentally Permanent members of Washington accord, have together agreed for generic 'Program Outcome's (PO's) and have adopted them for their under-graduate degrees in Engineering and Technology. PO's state the skills expected from graduating students. Since these

guidelines are same, the undergraduate degree in Science and Technology from one permanent member (PM) of the Washington Accord is recognized in another PM of Washington Accord for higher education and placement. It therefore becomes imperative that the curriculum in developing countries addresses the degree program outcomes as identified by these developing countries. Because when once these PO's are adapted in teaching and learning of the curricula of a developing country then their training program also gets accredited and recognized in these member countries and this opens doors for students in the developed countries too. So it is imperative with the PO's of the Washington Accord.

A.Program Outcomes (PO's)

Washington Accord specifies 12 PO's and states that the graduates should be able to:

1) Apply knowledge of mathematics, science and engineering fundamentals to conceptualize engineering models.
2) Submit solutions for complex situations that meet specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental issues.
3) Conduct investigations to design experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.
4) Create, select and apply appropriate techniques, resources, and modern engineering tools, to complex engineering activities, with an understanding of the limitations.
5) Function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings.
7) Communicate effectively with the engineering community and with society at large and be able to comprehend and write effective reports, make effective presentations, and give and receive clear instructions.
8) Demonstrate understanding of the societal, health, safety, legal and cultural issues and their relevance to engineering practice.
9) Understand and commit to professional ethics and responsibilities and norms of engineering practice.
10) Understand the impact of engineering solutions in a societal context and demonstrate knowledge of and need for sustainable development.
11) Demonstrate a knowledge and understanding of management and business practices, such as risk management, and understand their limitations.
12) Recognize the need for, and have the ability to engage in independent and life-long learning.

It should be recognized that the PO's mentioned above are very generic and some skills are overlapping in them.

A. Program Learning Outcomes (PEO's)

In author's opinion for the development of curriculum for CE training, one is best placed to generate concise Program Educational Objectives (PEO's), which students shall have upon graduating in a way that each of these PEO's can be mapped with the PO's of the Washington Accord so that it all converges into holistic development of the trainees. Keeping that in mind 7-concise PEO's have been developed for civil engineering training as under:

1) To be able to plan, construct, operate and maintain the natural environment and manmade infrastructure.
2) To be able to analyze and design systems, specify project methods and materials, perform cost estimates and manage technical activities in civil engineering project.
3) To apply technical and managerial skills and be a competent and engaged engineering professional.
4) To exhibit oral, written, and visual communication skills when engaged as a team member or a leader in community and professional work.
5) To establish an understanding of professionalism, ethics, quality performance, public policy, safety and sustainability and contribute to society when solving engineering problems and producing civil engineering solutions.
6) To be well versed in using latest civil engineering software(s) and equipment and achieve desired project objectives.
7) Pursue life-long learning as a means of enhancing personal knowledge and skills.

The next task then is to conceive a flexible program that suits different types of learners in a given tertiary environment and at the same time is holistic. Thereafter the courses needed under each PEO's, the course outline, the level of their coverage, and the competencies etc. may be developed. However in this paper we have limited our discussions to the course titles and flexibilities only. It must be emphasized that in this curriculum the teaching and learning is proposed to be: (a) made simple and interesting which shall be achieved with the use of a variety of teaching methodologies, (b) teaching process shall adapt interactive pedagogy, (c) students' learning shall be strengthened by laboratory work which shall be project based and not experiment based, and (d) students' assessment shall be for all important competencies, e.g.: recall, understand, analyze, design, and create etc.

IV.HOLISTIC DEVELOPMENT

For holistic development it is necessary that the taught program has inputs not only from engineering but also from allied fields. A survey of more than 50 universities all over the word reveals that the program may comprise of not more than 50 credit-courses spreading to earn around 170 credits. The program should also need to have appropriate number of audit courses which focus on extracurricular activities. The number of courses (in brackets) and the percentage of coverage of credits from each field are shown below:

Field of Study, number of courses and % total credits

Humanities and Social Sciences (7)	15%
Basic Sciences (5)	11%
Engineering Sciences (8)	17%
Core Civil Courses (16)	34%
Professional Electives (5)	11%
Management Electives (1)	1%
Open Electives (2)	3%

Practice School/ Research Project/ (4) 8%
Audit courses (2) -

Following is the list of courses proposed under each of the above category. It is suggested that credits of each subjects under any given category may be decided at the respective institution level subject to total weighted credits within any given category remaining as specified above.

A. Humanities and Social Sciences
1) English
2 Language and Reasoning Skills
3) Energy and Society
4) Ecology and Environment
5) Human Values
6) Employability Skills
7) Professional Communication and Ethics

B. Basic Sciences
1) Engineering Mathematics I
2) Engineering Mathematics II
3) Engineering Physics
4) Engineering Chemistry
5) Engineering Mathematics III

C. Engineering Sciences
1) Engineering Materials
2) Measurements
3) Engineering Graphics with CAD
4) Workshop Practice
5) Problem Solving through Programming
6) Engineering Mechanics
7) Construction Materials
8) Fluid Mechanics

D. Core Civil Courses
1) Engineering Geology
2) Building Planning, Construction & Management
3) Surveying
4) Mechanics of Materials
5) Hydraulics and Hydraulic Machines
6) Geotechnical Engineering
7) Environmental Engineering
8) Structural Analysis
9) Foundation Engineering
10) Water Resources Engineering
11) Transportation Engineering
12) Design of Concrete Structures
13) Design of Steel Structures
14) Project Estimation and Contracts
15) Quality Management and Safety in Construction Industry
16) Civil Engineering Systems Design

E. Professional Electives – one course to be selected from each sub-area

Structural Engineering
1) Green Buildings
2) Low Cost Housing
3) Structural Dynamics
4) Pre-stressed Concrete
5) Bridge Engineering

Construction Technology
1) Value Engineering
2) Project Scheduling and Analysis
3) Construction Quality Management
4) Repair and rehabilitation works
5) Construction Equipment and Machinery

Geotechnical Engineering
1) Ground Improvement Techniques
2) Geo-synthetics
3) Geotechnical and Earthquake Engineering
4) Design of Earth Retaining Structures
5) Rock Mechanics

Transportation Engineering
1) Railway, airport, docks and harbor Engineering
2) Pavement Engineering
3) Traffic Engineering
4) Urban Transportation System Planning
5) Low Cost Service Roads

Environmental and Water Resources Engineering
1) Rural water supply and Sanitation
2) Solid Waste management and Landfills
3) Air pollution Control Engineering
4) Groundwater Engineering
5) Watershed Management

F. Management Electives
1) Basics of Marketing for Management
2) Risk Management
3) Self-Management
4) Emotional Intelligence
5) Management Electives

G. Open Electives

These are courses offered by different engineering departments. Following courses may be offered by Civil Engineering Department for engineering students all across the entire institution.
1) Remote Sensing and GIS
2) Environmental Impact Assessment
3) Environmental Pollution Control
4) Spatial data analysis and Modeling
5) Disaster Management

H. Practice School/ Research Project

The aim of this is to expose students' to hands on training. Each student is expected to undertake 6-month intensive live training at a worksite during 7 or 8th semester. This shall be worth 4-courses equivalent. In case student is not able to find a suitable training venue, he/she may do a research project which shall have the same weightage as the practice school.

I. Audit Courses

These may include:
1) Sport club
2) Hobby club
3) Robotics club
4) Mechatronics club
5) Debating club
6) +++++

V. FLEXIBILITIES

As discussed earlier the program shall be made flexible to suit varied group of students, including the slow learners. This curriculum comes with the following flexibilities:

A. Change of Program:

Top 1% of students who successfully pass all courses of first and 2nd semester can apply, subject to strength of any program does not exceed by 5% of its intake strength.

B. *Degrees to be offered in three categories:*

(a) B.Sc. Engineering (Civil)

(b) B.Sc. Engineering (Civil) with specialization in:

- Structural Engineering and Construction Tech.
- Geo Technical and Transportation Engineering
- Environmental and Water Resources Eng.

To be able to qualify for the specialized degree the students need to pass 4 professional electives (out of a total of 5) from the chosen specialization.

(c) Honors degree – Students who get A grade or above in minimum of 75% of the credit courses shall be awarded an honors degree in the respective category.

C. *Integrated Degree - B.Sc. and M.Sc. degrees in 6-years:*

Students who get 'A' grade in a minimum of 75% of all the credit courses shall be required to register at start of 4th year of study and to complete additional courses in summers after 4th and 5th year of study.

D. Summer School

This shall provide coaching to slow learners (students with backlogs) and give them opportunity to qualify the courses prior to start of new academic year. This school shall also offer courses for the integrated degree program(s).

E. Community Service and participation in public projects

Students shall participate in blood donation camps, basic computer training courses for unemployed youths, English speaking courses for locals, implementation of green bus shelters, low cost roads, tree plantation, community washrooms, household composts and septic tanks with soakage arrangement (as replacement of insanitary pit latrines) etc.

VI. CONCLUSIONS

The above guidelines provide a state of the art technology for advancing curriculum for civil engineering training in developing country environment. They address the interests of key stakeholders and especially offer students a choice to obtain specialization even at undergraduate level, if they so desire.

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