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A Strategy for Implementation of Project-Based Learning in Civil Engineering Curriculum

Dr. Vikas Pratap Singh
Department of Civil Engineering, National Institute of Technology Uttarakhand, Srinagar Garhwal 246174, India
vpsingh@nituk.ac.in

Abstract: One of the prime objectives of Outcome Based Learning is to enable students with the capacity to think innovatively and confidently for the successful applications of academic concepts to solve real world problems. This article focusses on highlighting the role and significance of project-based learning in engineering education with the help of two case studies, wherein undergraduate students in Civil Engineering have taken project works as a part of their academic curriculum. In the first case study, a group of students undertook a problem to study the complex phenomena of liquefaction of soils, whereas in the second case study efficiency of stone columns as one of the ground improvement techniques was studied. The important and notable thing in both these studies was the innovative alternatives used by the students in lieu of the complex and costly test setup otherwise required. Also, the way students were able to communicate the test results and demonstrate their understanding of the underlying concepts of liquefaction and stone columns was praiseworthy. Further, taking the existing Civil Engineering curriculum of an Institution of National Importance as basis, a strategy is illustrated for the implementation of Project-Based Learning in undergraduate program leading to a Bachelor of Technology degree in Civil Engineering.

Keywords: Project-based learning, Case studies, Civil engineering, Curriculum strategy

1. Introduction

In India, the National Education Policy 2020 [1] has mandated a holistic change in the approach of educational system and conventional teaching-learning methodologies. It lays its focus on an education system that inches towards achieving attributes such as critical thinking, innovations, problem solving, multi-disciplinary approach etc. Every year, due to the demographic advantage, a considerable number of Indian students enroll in engineering and technology based academic programs at undergraduate level projecting India as a hub of technical talent and human resource. Though this situation is a matter of pride, but on the other hand the potential recruiters often raise concern on the employability quotient of our engineering graduates owing to the lack of basic technical knowledge & its application, communication & computing skills, and innovative thinking. One of the obvious reasons for the recruiters' concern is that even today academic curriculum in several engineering and technical institutes / universities is more oriented towards rote learning at the time of examination and scoring

Dr. Vikas Pratap Singh
Department of Civil Engineering, National Institute of Technology Uttarakhand, Srinagar Garhwal 246174, India
vpsingh@nituk.ac.in

grades. Thus, it is high time that both the academic curriculum and pedagogy in technical institutions need to be overhauled [1]. Project Based Learning (PBL) is one such step that must be promoted and accordingly, the overall scheme of evaluation for the award of a degree should be revisited. In this article, two simple cases are presented wherein it is demonstrated that PBL is an effective way to understand basic concepts and develop critical thinking & problem-solving attitude. Further, a model curriculum structure is also proposed and illustrated for the effective implementation of PBL in Civil Engineering curriculum.

2. PBL in Engineering Education

Chen et al. [2] presented a comprehensive review of literature, mostly from developed economies, on forms of implementation and challenges of PBL in engineering education. In Indian context, over the last few years, many academic institutes / universities offering undergraduate programs in engineering and technology are making efforts to practice PBL in their curriculum and pedagogy. A few of the common ways in which PBL is being proposed and practiced include introducing more project courses, inducting more laboratory courses, providing practical exposure in the form of field & industrial visits, internships, and training programs. However, most of these ways are focused on practical realization of the already learned concepts or pre-defined ideas, instead of allowing students to develop their own ideas, goals and strategies. PBL in engineering education must aim to allow students to identify a problem on their own, set their own rules & strategy, and apply multi-disciplinary knowledge for seeking solution [3-7]. The role of a teacher in PBL should be broadly limited to motivate, give direction, and evaluate the outcomes of the projects taken by the students. Also, the teacher must frame the learning objectives and outcomes for each project related course work.

In this article, the subsequent section presents two case studies to demonstrate the importance of PBL in engineering education, particularly focusing on Civil Engineering. Following this, a strategy for implementation of PBL in civil engineering curriculum at Institute / University level is illustrated. Both these aspects contribute significantly to the otherwise scarce information available in literature in public domain on significance and implementation of PBL in Civil Engineering education.

3. Case Study 1: Experimental Analysis And Evaluation Of Liquefaction Potential

Soil Liquefaction is a phenomenon where a partially or fully saturated sandy or silty soil loses its shear strength and stiffness completely under the application of cyclic stress. Evaluation of liquefaction potential or liquefaction susceptibility of soils is well established both in the literature and practice [8, 9]. However, for an undergraduate student, the topic of liquefaction is usually not a component of the core courses related to Soil Mechanics and Foundation Engineering. A group of three students from final year civil engineering opted to understand liquefaction phenomena through their final year project work [10].

A. Summary

In the project work, following the standard procedures using Standard Penetration Test (SPT) data, students conducted an analytical study to evaluate liquefaction potential of soils at two locations in India. Further, an experimental study was conducted in the laboratory to visualize & understand liquefaction phenomena. Both analytical and experimental studies were further used to study the influence of various parameters such magnitude of earthquake, water table, Bulk density etc. on the liquefaction potential of soils.

B. Learning Outcomes

During the project work, students demonstrated following learning outcomes:

1) Understanding of site conditions and real-world problems: For collecting the geotechnical data students visited two sites of major construction work. At one of the sites, construction of the Six-lane extradosed Cable Bridge over river Ganga was ongoing, and at the other site a flyover is proposed to be constructed on a junction. During the process of data collection, students interacted with site engineers and understood the extent & nature of subsurface investigations conducted at these sites.

2) Understanding theoretical background and evaluation procedures for soil liquefaction potential: For understanding basic concept of the liquefaction phenomenon and methods for evaluation of liquefaction potential of soils, students conducted a review of some of the relevant prominent journal papers and reference books. Through critical literature review, students demonstrated their research acumen

by formulating a research methodology for further study.

3) Innovative thinking in fabrication of test set-up and conduct of experiments: Shake-table is one of the most important equipment that is commonly used for the liquefaction related laboratory studies as it has the capacity of simulating earthquakes of varying magnitudes. Shake table basically consists of the test specimen and the platform it is fixed on, up to six servo-hydraulic actuators that apply load to the platform, and a controlling unit. The market cost of a typical commercially available shake table for research purposes is significant, ranging from 2-5 lakhs rupee. Considering the cost involved and limited time available for its procurement, students decided to fabricate a shake table on their own. A single degree of freedom shake table was fabricated using a 7HP, 1500 rpm A. C. motor with speed control and a foundation plate of size 600 mm x 600 mm made up of 25 mm hard plywood. The shake table has a payload capacity of 60 kg. For keeping the soil specimen, a watertight tank 300 mm x 200 mm x 300 mm dimensions was fabricated using acrylic glass frame with 3 mm thick sheets. For conducting experiments, soil specimens were prepared in the tank at different densities, percent fines etc. and the intensity of the earthquake was simulated with the speed (i.e., Revolutions Per Minute, RPM) of the motor. Time required for soil specimen to liquefy was noted down and used as a parameter to indicate liquefaction susceptibility of the soil specimen, Fig. 1 shows a photograph of the indigenously fabricated liquefaction test set-up.

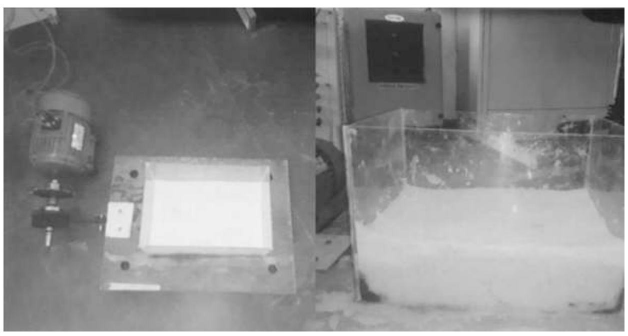

Fig.1:Indigenously Fabricated Liquefaction Test Set-up

4) Innovation using computing skills: The students developed a MATLAB code [11] with reference to the standard procedure for evaluation of liquefaction of soils. MATLAB is a popular programming and numeric computing platform to develop algorithms, modelling, and analysis of data. The liquefaction code developed by the students was versatile enough to account for the factors used in the parametric study such as depth of water, earthquake magnitude, soil density etc. It is yet another notable learning outcome as students understood MATLAB on their own and were able successfully apply to the problem in-hand.

5) Understanding of data analysis and interpretation: The data from the analytical and experimental study was presented in the form of several charts, tables, and figures. Most importantly, the interpretations from the analysis results were compared and correlated with those available in the existing literature. Students demonstrated an important trait of engineers to read and understand data effectively for its practical implementation.

6) Excellent report writing and presentation: One of the very common issues found with Indian students is related to their communication and technical writing skills. Consequently, despite good knowledge and quantum of work, students fail to achieve the desired success in their professional career. As author of this article also being the faculty mentor for the group of students in the case study on liquefaction analysis, can confidently rate the quality of project report as one of the best at undergraduate level. Also, all the three students presented their work in the form of PowerPoint presentations impressively to the evaluation panel. Professionally, it is one of the most relevant learning outcomes of project work.

C. Closing Remarks

Looking at the various learning outcomes of the project work as presented above, it is evident that PBL has not only significantly improved the overall understanding about the topic i.e., liquefaction of soils, but also improved the overall personality and confidence of the students. The project work also enabled students to find feasible alternatives to the infrastructural facilities required for experimentation. An important attitudinal change from “problem identifier” to “solution seeker” and teamwork was evident.

4. Case Study 2: Bearing Capacity Improvement Of Soft Soil Using Stone Columns

In practice, use of stone columns is one of the common techniques of ground improvement of soft clayey soils. A stone column is primarily a column of granular or coarser materials such as gravel and crushed stones compacted with the help of a vibrator. Relative to the adjoining soft soil, a stone column is stiffer and can bear heavy loads. Thus, a system of specifically designed stone columns improves the overall load carrying capacity and reduces settlement of the in-situ soil. A significant amount of literature is available [12, 13] in public domain on the analysis, design, & construction of stone columns for ground improvement of soft soils. Academically, the analysis and design of stone columns are usually taught at post graduate level. For undergraduate civil engineering students, the topic of stone columns is usually introductory. In the present case study, a group of three students from final year civil engineering opted for an experimental study on use of stone columns for the bearing capacity improvement of soft soils as topic of their final year project work [14].

A. Summary

In the project work, students conducted an experimental study to understand the influence of stone columns on the load carrying capacity and settlement reduction of the soft soil. The study involved preliminary geotechnical laboratory testing (such as particle size analysis, consistency limits, and specific gravity) on the specimen of the locally available soil and granular material (i.e., crushed stone) to be used as in-situ soil and stone columns, respectively. This was followed with experimentation on determination of load carrying capacity of in-situ soil with or without stone columns.

B. Learning Outcomes

During the project work, students demonstrated following learning outcomes:

1) Understanding theoretical background on stone columns: For understanding the basic concept, analysis & design method, and in-situ construction techniques of the stone columns, students carried out a considerable review of the relevant prominent journal papers, reference books, and relevant Indian Standard codes. Students also studied and understood the potential of stone columns for ground improvement through several report case studies in literature. In the process of reviewing literature, students demonstrated their analytical capacity and research potential.

2) Innovative thinking in fabrication of test set-up and conduct of experiments: Stone columns are used in the field and therefore the best approach to study the load carrying capacity and settlement behaviour is by conducting initial load tests on test columns installed in the field. Another approach is to conduct model load tests in the laboratory. Given the scope of the current project work, students opted for conducting tests on model columns in the laboratory. For experimental investigation in the laboratory, a low-cost test set-up was indigenously and innovatively fabricated. Test set-up included a cylindrical tank of about 26 cm diameter with non-expandable side walls, a loading plate for which the base plate of compaction mould was used, and a loading mechanism which is alternatively represented by brick bats of known weights. Settlements were measured using two dial gauges placed on independent platforms. The set-up was used to test the soil samples prepared at specified water content and density without stone column and with one, two, three or four stone columns of diameter ranging between 5-10 cm and height 15 cm. The stone columns were placed centrally and in a systematic pattern. Fig. 2 shows a photograph of the innovatively fabricated test set-up for stone columns. The notable thing is that students demonstrated application of mind to overcome and solve practical problems such unavailability of fund, infrastructure facility, assess to field projects etc.

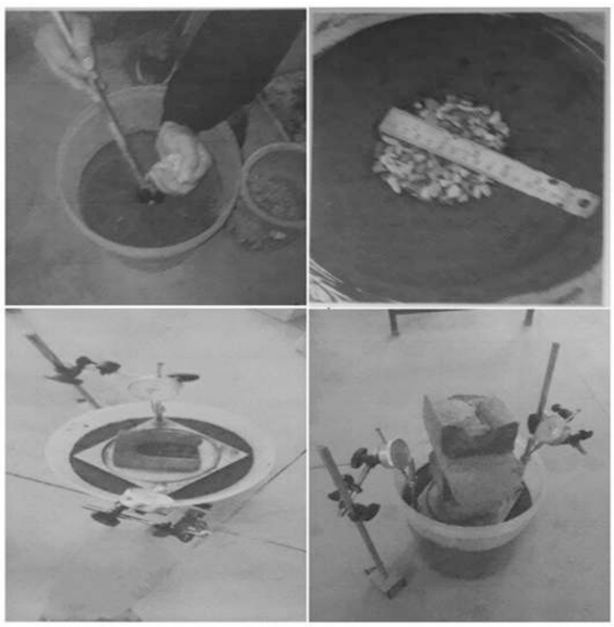

Fig.2: Innovative Test Set-up for Stone Column Testing

3) Understanding of data analysis and interpretation: The results of the experimentation were presented in the form of figures and tables. Students were able to clearly bring out the influence of installing columns on increasing load carrying capacity and reducing settlement of in situ soft soil. Also, the study clearly highlighted the significance of installing one, two, three, or four stone columns.

4) Teamwork, report writing and presentation skills: The project report submitted by the students was comprehensive and reasonably well written. During continuous evaluation, a significant improvement in the presentation skills and teamwork was also demonstrated.

C. Closing Remarks

The performance, quantum, and overall quality of work done by the students in the project is testimony to the fact that project-based learning has efficiently taught students several technical aspects related to stone columns. PBL has also groomed their personality by enhancing their oral and written communication skills. Like case study 1, in this case study too students demonstrated an attitudinal change as “solution seeker”.

The above two case studies showed the importance of project-based courses in engineering curriculum. These case studies are not unique but representative of several similar studies [e.g. 15, 16] routinely being carried out by students at their undergraduate level in the form of minor / major or final year projects. It means that our education system is already promoting PBL, but to a limited extent vis-à-vis entire curriculum requirements. Also, another issue is the subjectiveness involved in the evaluation and implementation of these project-based courses.

5. Proposal For PBL in Civil Engineering Curriculum

National Institute of Technology Uttarakhand (NITUK) is one of the thirty-one Institutes of National Importance in the country established by an Act of Parliament under the aegis of Ministry of Education, Government of India. The Institute aims to constantly provide an encouraging environment for education and training of technical professionals as well as grooming the skills of the students through impeccable learning. The Department of Civil Engineering, NIT Uttarakhand was established in 2013 with an intake of 60 students. The vision statement of the department reads as “To achieve recognition through academic excellence and exemplary research for sustainable infrastructure development with special emphasis on hilly terrains” In line with the vision statement, the department offers a four-year course leading to the Bachelor of Technology (B.Tech.) degree in Civil Engineering.

A. Overview of Existing Curriculum for Civil Engineering

The existing curriculum provides broad based knowledge and simultaneously builds a temper for the lifelong process of learning and exploring. At undergraduate level, a student needs to do compulsory foundation courses in the areas of engineering sciences, basic sciences, humanities, and social sciences apart from the departmental requirements. Departmental courses (core and electives) constitute a minimum of 50% of the total curriculum. Further, students are required to study open category electives to develop inter-disciplinary knowledge base or to specialize significantly in an area outside the parent discipline. The B.Tech. degree program at NITUK is a 4-year program with a total of 8 semesters (i.e., two semesters per academic year) numbered herein as semester I to VIII.

Fig. 3 shows the overall credit structure and the list of courses in the existing civil engineering curriculum [17]. A student aspiring for a B.Tech. degree in Civil Engineering is required to complete courses with a minimum overall 160 credit hours (or simply credits). Each course is assigned credits in Lecture (L) - Tutorial (T) - Laboratory / Practice (P) pattern with each one-hour lecture equivalent to 1 credit, and two hours tutorial or laboratory / field practice equivalent to 1 credit. For example, all courses with L-T-P as 3-2-0 or 3-0-2 have 4 credits and courses with L-T-P as 3-0-0 have 3 credits.

The total credits required for the award of degree are divided into two broad categories as Undergraduate Core (UC) with courses equal to 113 credits and Undergraduate Elective (UE) with courses equal to 47 credits. As shown in the Fig. 3, the UC credit requirements are further subdivided into Departmental Core (DC), Basic Science (BS), and Humanities & Management (Core) (HMC). Likewise, UE credit requirements are further subdivided into Departmental Elective (DE), Humanities and Management (Electives) (HME), Open Course (OC) & a special category of Non-Credit requirements (UN).

Referring to Fig. 3, Table 1 shows the summary of credits that can be earned by a student through practical (i.e., laboratory / practice) and project-oriented courses in the existing Civil Engineering curriculum.

A. Overall Credit Structure			
Undergraduate Core (UC)		**Undergraduate Elective (UE)**	
Category	***Credit***	***Category***	***Credit***
DC	67	DE	23 (minimum)
BS	19	HM	06 (minimum)
ES	22	OC	18 (Balance)
HM	05	UN	0 (03 Courses)
Total	113	Total	47
Grand Total (UC + UE)			160

A1. Departmental Core Courses (DC)

Course Code	Course	L-T-P	Credit
CEL251	Fluid Mechanics	3-0-0	03
CEP251	Fluid Mechanics Lab	0-0-2	01
CEL252	Engineering Geology	2-0-0	02
CEP252	Engineering Geology Lab	0-0-2	01
CEL253	Building Mat. and Construc. Techno.	3-0-0	03
CEP253	Building Materials Testing Lab	0-0-2	01
CEL254	Environmental Engineering-I	3-0-0	03
CEP254	Environmental Engineering-I Lab	0-0-2	01
CEL255	Transportation Engineering	3-0-0	03
CEP255	Transportation Engineering Lab	0-0-2	01
CEL256	Surveying	3-0-0	03
CEP256	Surveying Lab	0-0-2	01
CEL257	Strength of Materials	3-2-0	04
CEL351	Geotechnical Engineering-I	3-0-0	03
CEP351	Geotechnical Engineering Lab	0-0-2	01
CEL352	Environmental Engineering-II	3-0-0	03
CEP352	Environmental Engineering-II Lab	0-0-2	01
CEL353	Structural Analysis	3-0-0	03
CEL354	Geotechnical Engineering-II	3-2-0	04
CEL355	Hydrology and Irrigation Engineering	3-2-0	04
CEL356	Indeterminate Structural Analysis	3-2-0	04
CEL357	Design of RCC Structures	3-2-0	04
CEL358	Design of Steel Structures	3-2-0	04
CEL359	Railway and Airport Engineering	3-0-0	03
CEL360	Estimation and Costing	3-0-0	03
CED351	Minor project	-	01
CED451	Major Project	-	02
Total			67

A2. Basic Science Courses (BS)

Course Code	Course	L-T-P	Credit
SCL152	Applied Mathematics-I	3-2-0	04
SCL153	Applied Mathematics-II	3-2-0	04
SCL251	Applied Mathematics-III	3-0-0	03
SCL154	Applied Physics	3-0-0	03
SCP154	Applied Physics Lab	0-0-2	01
SCL155	Applied Chemistry	3-0-0	03
SCP155	Applied Chemistry Lab	0-0-2	01
Total			19

A3. Engineering Arts and Science Courses (ES)

Course Code	Course	L-T-P	Credit
MEL152	Elementary Mechanical Engineering	3-0-0	03
EEL151	Elementary Electrical Engineering	3-0-0	03
EEP151	Elementary Electrical Engineering Lab	0-0-2	01
ECL151	Basic Electronics Engineering	3-0-0	03
ECP151	Basic Electronics Engineering Lab	0-0-2	01
MEL151	Engineering Drawing	3-0-0	03
MEP151	Engineering Drawing Lab	0-0-2	01
CSL151	Computer Programming and Problem Solving	3-0-0	03
CSP151	Computer Programming Lab	0-0-2	01
MEP152	Mechanical Workshop	0-0-2	01
CEL151	Environmental Science	2-0-0	02
Total			22

A4. Humanities and Management (Core Courses) (HMC)

Course Code	Course	L-T-P	Credit
HML151	Social Science	2-0-0	02
HMP152	Technical Communication	2-0-2	03
Total			05

A5. Departmental Elective Courses (DE)

Course Code	Course	L-T-P	Credit
SCL453	Probability Theory and Statistics	3-0-0	03
CEL451	Geomatics Engineering	3-0-0	03
CEP451	Geomatics Engineering Lab	0-0-2	01
CEL452	Non-Destructive Testing of Materials	3-0-0	03
CEP452	Non-Destructive Testing of Materials Lab	0-0-2	01
CEL453	Structural Dynamics	3-0-0	03
CEP453	Structural Dynamics Lab	0-0-2	01
CEL454	Design of Hydraulic Structures	3-2-0	04
CEL455	Rock Engineering	3-0-0	03
CEL456	Industrial Waste Management	3-0-0	03
CEL457	Environmental Impact and Risk Assessment	3-0-0	03
CEL458	Advanced Concrete Design	3-2-0	04
CEL459	River Mechanics	3-0-0	03
CEL460	Traffic Engineering	3-0-0	03
CEL461	Construction Planning and management	3-0-0	03
CEL462	Advanced Foundation Engineering	3-0-0	03
CEL463	Design of Prestressed Concrete Structures	3-0-0	03
CEL464	Urban Water and Environmental Management	3-0-0	03
CEL465	Advanced Structural Analysis	3-0-0	03
CEL466	Advanced Highway Engineering	3-0-0	03
CEL467	Groundwater Engineering	3-0-0	03
CEL468	Hydraulic and Hydraulic Machines	3-0-0	03
CEL469	Bridge Engineering	3-0-0	03
CEL470	Design of Earth Retaining Structures	3-0-0	03
CEL471	Architectural Planning and Design of Buildings	2-2-0	03
CEP481	RCC Structures Detailing Lab	0-0-2	01

A6. Humanities and Management (Elective Courses) (HME)

Course Code	Course	L-T-P	Credit
HML152	Principles of Industrial Management and Psychology	3-0-0	03
HML153	Industrial Psychology and HR Mgmt.	3-0-0	03
HML154	Industrial Economics	3-0-0	03
HML155	Industry and Society	3-0-0	03
HML156	Personnel Management and Industrial Relation	3-0-0	03
HMP151	Preparatory English	3-0-0	03
HMP153	Urban Sociology	0-1-0	01
HML351	Industrial Management	3-0-0	03
HML451	Social Demography	3-0-0	03
HML452	Economics for Engineers	3-0-0	03
HML453	Studies in Contemporary Indian English Literature	3-0-0	03
HML454	Creative Writing in English	3-0-0	03
HML455	Corporate Communication for Technocrats	3-0-0	03
HML456	Screenwriting and Documentary Filmmaking	3-0-0	03
HML457	Interpreting Literature, Theater and Cinema	3-0-0	03

A7. Non-Credit Requirement (UN)

Course Code	Course	L-T-P	Credit
NCN151	NCC#	-	0
NCN152	NSS#	-	0
NCN153	NSO#	-	0
SPB151	Sports-I#	0-0-4	0
SPB152	Sports-II#	0-0-4	0
HMD251	Community Project	-	0
CET251	Practical Training	-	0

#-A student has to opt at least one from NCC, NSS, NSO and Sports (I & II).

Fig. 3: Existing Civil Engineering Curriculum at NITUK [17].

From Table 1, it is evident that the existing Civil Engineering curriculum has only 16.88 percent of credits that can be earned through either practical or project-oriented courses. The percentage will reduce drastically to merely about 2% if only project-based courses are considered. Thus, undoubtedly the existing curriculum needs to be revised holistically to implement PBL. In the subsequent section, a strategy to implement PBL in the Civil Engineering at NITUK is illustrated.

Table 1: Summary of Credits Earned through Practical & Project-Oriented Courses in Civil Engineering Curriculum

Sl. no.	Course category	Credits requirements (a)	Credits for practical and project courses			Credits percentage, 100* [(b)/(a)]
			Practical courses	Project-oriented courses	Total (b)	
1	DC	67	8	3	11	16.42
2	BS	19	2	0	2	10.53
3	ES	22	5	0	5	22.73
4	HMC	5	1	0	1	20.00
5	DE	23	4	0	4	17.39
6	HME	6	0	0	0	0.00
7	OC - #	18	4	0	4	22.22
8	UN - $	0	0	0	0	-
	Total	**160**	**24**	**3**	**27**	**16.88**

- Calculation for OC category assumes that a student opts for 04 number of practical courses as OC.
$ - In UN category, student must take HMD251 Community Project & CET251 Practical Training as two zero credit courses.

B. Proposed Strategy for Implementing PBL in Curriculum for Civil Engineering at NITUK

The Indian higher education system must focus on skill building and practical training along with academics to give students an edge [18]. However, for the developing countries like India, the implementation of PBL in technical institutions needs to be done in a careful and thoughtful manner. It can never be a replica in toto of its form in developed countries [2] but should be designed by taking into consideration the ground realities such as faculty-student ratio, socio-economic status of the students having a direct influence on their academic background, employability scenario in the country, and available infrastructural facilities & funding with the Institutes. Therefore, the proposal for the implementation of PBL in this illustration is based on the following premises:

a) It should fit-in to the existing approved overall credit structure requirements of the Bachelor of Technology (B.Tech.) degree course in Civil Engineering at NITUK.

b) It should maintain the essence and flexibility of the existing choice-based credit system at NITUK.

c) It should cover maximum syllabus as per the requirement of the competitive examinations such as Graduate Aptitude Test in Engineering (GATE) and Engineering Services (ES).

d) It should not compromise significantly with the requirements of the practical / laboratory courses.

e) It should provide ample opportunities for students to learn and enhance their inter-disciplinary knowledge.

Given the above premises, the target implementation of PBL is chosen as 40% by raising the percentage of laboratory / practical and project-oriented courses from existing 16.88%. To provide opportunity to the students to earn 40% credits through PBL, a total of 64 credits out of 160 credits required for the degree should be obtained from laboratory / practical courses and project-oriented courses. Since, curriculum already has provision of about 24 credits through laboratory / practical courses, the remaining 40 credits are intended to be obtained from project-oriented courses.

Table 2 shows the types of project-oriented courses proposed to be included in the curriculum of B.Tech. Civil Engineering to achieve a target of 40% inclusion of courses leading to PBL. Table 2 also indicates the other basic details such as project acronym & category, credits, and tentative semester for completion during the four years of the B.Tech. degree program.

Table 2: Types of Projects Proposed to be Implemented

Sl. no.	Proposed project type	Acronym	Project category	Proposed credits	Proposed semester
1	Science Project – I	SCP-I	BS / ES	04	I/II
2	Science Project – II	SCP-II	BS / ES / HMC	04	II/I
3	Civil Engineering Design Project-I	CEDP-I	DC	06	IV or V
4	Civil Engineering Design Project-II	CEDP-II	DC	06	V or VI
5	Civil Engineering Research Project	CERP	DE	08	VII or VIII
6	Civil Engineering Industry Interaction Project	CEIP	DE	12	VIII or VII
			Total Credits	**40**	

A brief description on the implementation strategy and expectations from each of the project type mentioned in the Table 2 is discussed below:

a) Science Project-I and II (SCP-I & SCP-II): From Fig. 3 it can be noted that the total credit under BS, ES and HMC category courses adds up to 46. It is a standard practice at NITUK that out of these 46 credits, a student is expected to earn 43 credits (except SCL251) during the first year (i.e., I and II semesters) of their degree course. Since, first year courses are common for all branches of engineering, for administrative reasons, all newly admitted students are normally divided into two groups (say Group A and Group B) of nearly equal strength. During Semester I, a fixed number of courses are floated to Group A students and another set of fixed number of courses are floated to Group B. In semester II, swapping of the courses is done between Groups A & B. Following the same pattern, Tables 3 and 4 show courses to be offered to the first-year Group A (say) students with the inclusion of two project-based courses, namely SCP-I and SCP-II, each having 04 credits during semester I and II, respectively.

Table 3: First Year Common Courses Offered to Group-A Students During Semester I and Group-B Students in Semester II

First Year - Semester I/II Courses (Total Credits: 22)			
Course code	Course	L-T-P	Credit
Cluster – 1: Primary Core BS / ES Courses (Maximum Credits to be Earned: 14)			
CEL151	Environmental Science	2-0-0	02
ECL151	Basic Electronics Engineering	3-0-0	03
ECP151	Basic Electronics Engineering Lab	0-0-2	01
MEL152	Elementary Mechanical Engineering	3-0-0	03
MEP152	Mechanical Workshop	0-0-2	01
PBL101	Science Project – I (SCP-I)	-	04
Cluster –2: Secondary Core BS / ES Courses (Maximum Credits to be Earned: 08)			
SCL152	Applied Mathematics-I	3-2-0	04
SCL155	Applied Chemistry	3-0-0	03
SCP155	Applied Chemistry Lab	0-0-2	01
CSL151	Computer Programming and Problem Solving	3-0-0	03
CSP151	Computer Programming Lab	0-0-2	01
Strategic steps: (a) SCP -I shall be based on any one discipline among mathematics, chemistry, and computer programming. (b) Student / group of students may be allotted a mentor from the concerned discipline department for overall supervision. (c) Students shall be allowed to skip the secondary core BS or ES course depending upon the discipline in which project is chosen. For example, if a student undertakes SCP-I based on chemistry, he/she shall skip courses SCL155 & SCP 155, and so on. (d) Flexibility be given to take a secondary core theory course in cluster-2 with or without corresponding practical course, however, reverse shall not be allowed.			

A student successfully clearing both Semester I and Semester II, would be left with only one 03 credit course i.e., SCL251 Applied Mathematics-III among the courses & credits requirements for BS, ES, and HMC categories under undergraduate core (UC) requirements. It can be studied in any of the higher semesters.

Table 4: First Year Common Courses Offered to Group-A Students During Semester II and Group-B Students in Semester I

First Year - Semester II/I Courses (Total Credits: 21)			
Course code	Course	L-T-P	Credit
Cluster – 1: Primary Core BS / ES / HMC Courses (Maximum Credits to be Earned: 14)			
HML151	Social Science	2-0-0	02
SCL153	Applied Mathematics-II	3-2-0	04
EEL151	Elementary Electrical Engineering	3-0-0	03
EEP151	Elementary Electrical Engineering Lab	0-0-2	01
PBL102	Science Project – II (SCP-II)	-	04
Cluster – 2: Secondary Core BS / ES / HMC Courses (Maximum Credits to be Earned: 07)			
MEL151	Engineering Drawing	3-0-0	03
MEP151	Engineering Drawing Lab	0-0-2	01
SCL154	Applied Physics	3-0-0	03
SCP154	Applied Physics Lab	0-0-2	01
HMP152	Technical Communication	3-0-2	03
Strategic steps: (a) SCP -II shall be based on any one discipline among engineering drawing, physics, and technical communications. (b) Student / group of students may be allotted a mentor from the concerned discipline department for overall supervision (c) Students shall be allowed to skip the secondary core BS or ES or HMC course depending upon the discipline in which project is chosen. For example, if a student undertakes SCP -II based on physics, he/she shall skip courses SCL154 & SCP 154, and so on. (d) Flexibility be given to take a secondary core theory course in cluster-2 with or without corresponding practical course, however, reverse shall not be allowed.			

b) Civil Engineering Design Project-I and II (CEDP-I & CEDP-II): From Fig. 3 it can be noted that the total credits under departmental core courses (DC) is 67. The list of DC courses given in Fig. 3 is divided into cluster-1 with primary courses and cluster-2 with secondary courses. Table 5 shows the list of departmental core courses alongwith proposed inclusion of CEDP-I and CEDP-II. In Table 5, CEDP-I and CEDP-II, each having 06 credits, are also introduced in the DC category under cluster-3 i.e., project-oriented courses. It is suggested that the topics for CEDP-I and CEDP-II should be based on the application, case study, technological development, and innovation related to the courses or combination of secondary core courses listed under cluster-2. For example, CEDP-I could be a combination of the courses CL357 and CEL358 with topic "Design of Multi-level Car parking Facility", and for CEDP-II could be a combination of courses CEL354 and CEL359 with topic "Design of Subgrade for a Runway Pavement". It is to be noted that a student must take courses corresponding to earn maximum 24 credits from cluster-2 to accommodate CEDP-I and CEDP-II.

c) Civil Engineering Research Project (CERP): In this category of project, students either individually or in groups of two or three contribute to the development of technical knowledge in one or more core areas of Civil Engineering. In CERP students are also expected to identify, assess, and synthesize existing literature and research findings on an unfamiliar problem. Student / group of students may be allotted a mentor from the department for overall supervision. At the end of the project students shall submit a research dissertation of professional and academic standards, and showcase their findings through deliverables such as a conference or journal paper, working model etc.

d) Civil Engineering Industry Interaction Project (CEIP): The objective of CEIP is to focus on the application of technical knowledge to address engineering problems, communications, group work, professional and social ethics, sustainability, risk assessment and engineering design practice. For implementation of CEIP, suitable industry partners dealing with Civil Engineering analysis, design, and construction be identified, preferably by the Institute, and on mutual agreement students be allowed to take part in their ongoing construction projects for a duration of say 6 months or 1 semester. Mentors from both Industry partner and the Institute shall be allotted to the students for monitoring the progress of the work. CEIP is recommended to be offered in the 7th semester of the degree programme. At the end of the project students shall submit a project report of professional and academic standards.

Both CERP and CEIP are proposed to be included in DE category to give flexibility to the department to offer it to a particular student or students group depending upon their academic performance and credits requirements for degree completion.

C. Limitations

The proposed strategy for the implementation of PBL in civil engineering curriculum at NITUK apparently satisfies all the premises mentioned earlier, but its successful implementation would depend on various constraints such as administrative will (e.g., orientation of the institute vision, faculty strength, academic ordinances, etc.), financial independence (e.g., availability of funds for student projects,

Table 5: Departmental Core (DC) Courses alongwith Proposed Inclusion of CEDP-I and CEDP-II

Course code	Course	L-T-P	Credit
Cluster – 1: Primary DC Courses (Maximum Credits to be Earned: 31+3[a] = 34)			
CEL251	Fluid Mechanics	3-0-0	03
CEP251	Fluid Mechanics Lab	0-0-2	01
CEL252	Engineering Geology	2-0-0	02
CEP252	Engineering Geology Lab	0-0-2	01
CEL253	Building Mat. and Construction Technology	3-0-0	03
CEP253	Building Materials Testing Lab	0-0-2	01
CEL254	Environmental Engineering-I	3-0-0	03
CEP254	Environmental Engineering-I Lab	0-0-2	01
CEL255	Transportation Engineering	3-0-0	03
CEP255	Transportation Engineering Lab	0-0-2	01
CEL256	Surveying	3-0-0	03
CEP256	Surveying Lab	0-0-2	01
CEL257	Strength of Materials	3-2-0	04
CEL351	Geotechnical Engineering-I	3-0-0	03
CEP351	Geotechnical Engineering Lab	0-0-2	01
SCL251[a]	Applied Mathematics-III	3-0-0	03
Cluster – 2: Secondary DC Courses (Maximum Credits to be Earned: 24)			
CEL352	Environmental Engineering-II	3-0-0	03
CEP352	Environmental Engineering-II Lab	0-0-2	01
CEL353	Structural Analysis	3-0-0	03
CEL354	Geotechnical Engineering-II	3-2-0	04
CEL355	Hydrology and Irrigation Engineering	3-2-0	04
CEL356	Indeterminate Structural Analysis	3-2-0	04
CEL357	Design of RCC Structures	3-2-0	04
CEL358	Design of Steel Structures	3-2-0	04
CEL359	Railway and Airport Engineering	3-0-0	03
CEL360	Estimation and Costing	3-0-0	03
Cluster – 3: Project Oriented Courses (Maximum Credits to be Earned: 12 credits)			
CEDxxx	Civil Engineering Design Project-I (CEDP-I)	-	06
CEDxxx	Civil Engineering Design Project-II (CEDP-II)	-	06

Strategic steps:
(a) CEDP-I & II may indirectly cover via project work the broad knowledge of courses not studied by the student from the list of secondary core courses in the cluster -2.
(b) Student / group of students may be allotted a mentor from the department for overall supervision.
(c) Students shall be allowed to skip the secondary DC course listed under cluster -2 depending upon the discipline in which CEDP-I & CEDP-II are chosen. For example, if a student undertakes CEDP-I based on design of RCC structures, he/she shall skip course CEL357, and so on.
(d) List of secondary core courses under cluster -2 can be made more exhaustive by addition of new core courses. This would offer both flexibility and choice for project topics under CEDP-I and CEDP-II.
(e) Flexibility be given to take a secondary core theory course in cluster-2 with or without corresponding practical course, however, reverse shall not be allowed.
[a]SCL251 Applied Mathematics-III is a BS core course to be offered by Mathematics Department, added under DC list as an exception.

research, technical events etc.), and infrastructural facilities (e.g., state-of-the-art laboratories & library, computing facilities etc.). Additionally, a holistic qualitative and quantitative evaluation strategy for the project-oriented courses would play a key role in achieving the desired objectives of introducing PBL in the curriculum.

6. Evaluation Strategy For Pbl Courses

The effectiveness of PBL implementation in engineering education would certainly depend upon the evaluation strategy vis-à-vis learning outcomes. For each of the project types mentioned in Table 2, specific course objectives and learning outcomes need to be defined. The evaluation strategy for project-based courses shall give due weightage to the several factors including application of basic concepts of science and technology, innovative element, proximity of the project work to the real-world problems, teamwork, deliverables in the form of working models or technical papers, skills acquired, and inter-disciplinary nature. It is important that on one hand, the academic regulations shall make suitable provisions to identify & motivate good projects, and on the other hand discourage below par projects.

7. Concluding Remarks

Project-based learning is the way forward for the education in India. This article highlights the significance of PBL in engineering education with the help of two cases wherein it is evident that the learning outcomes from project-based courses are widespread, including understanding of basic concepts, enhancement of computational experimental and computational skills, development of communication and inter-personal skills, teamwork, attitudinal changes, etc., and directly addresses the concerns of potential recruiters. The study also illustrated a proposal for implementation of PBL in Civil Engineering curriculum with reference to the existing curriculum for B.Tech. degree program in civil engineering at NITUK. A total of six different types of projects are proposed to be introduced and strategies for their implementation are presented. The concept of course clustering has been utilized to accommodate the PBL courses without deviating from the overall structure and credit requirements in the existing curriculum.

Finally, it can be concluded that the PBL implementation strategy in higher education system in developing countries like India shall stand at par with those in the developed countries, but with due consideration to the premises such as those highlighted in this article. It is recommended that slowly and steadily, the PBL shall either replace or at least dominate the engineering education curricula of Indian technical institutes and universities.

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