Undergraduate teaching of geotechnique in large-class environments: Experience at the University of British Columbia

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ABSTRACT
The current undergraduate curriculum in Civil and Geological Engineering at the University of British Columbia (UBC) includes core geotechnical courses in each of the 2nd, 3rd and 4th years. The recent increased demand for civil engineers has resulted in a gradual increase in class size, with more than two hundred students now taking the introductory soil mechanics course. The paper outlines strategies applied to improve student learning outcomes while accommodating increasing student numbers. The overall philosophy and objectives at UBC for the teaching of geotechnical engineering subjects, along with current class size data, are presented.

RÉSUMÉ
Le programme de premier cycle en génie civil et géologique de l'Université de la Columbie Britannique (UBC) inclut des cours de base en géotechnique dans chacune des 2e, 3e et 4e années. L'augmentation récente de la demande pour des ingénieurs civils a conduit à l'accroissement progressif du nombre d'étudiants par classe avec, par exemple, plus de deux cents étudiants présentement inscris au cours d'introduction à la mécanique des sols. Cet article expose les stratégies utilisées afin d'améliorer les résultats d'apprentissage tout en s'adaptant au nombre croissant d'étudiants. La philosophie générale, les objectifs d'enseignement ainsi que les plus récentes statistiques quant au nombre d'étudiants par classe pour le génie géotechnique à l'UBC sont présentés.

1 INTRODUCTION

The Faculty of Applied Science at University of British Columbia (UBC), Vancouver, Canada offers a range of four-year engineering undergraduate degree programs, where students follow a general applied science curriculum in the first year, with a specific field of specialization (e.g., civil, mechanical, mining, etc.) selected for the last three years. The current undergraduate curriculum in Civil includes core geotechnical courses in each of the 2nd, 3rd and 4th years. In addition to the students directly enrolled for Civil Engineering, traditionally, about 20% of the students studying geotechnical courses in a given second and third year class originate from other programs such as Mining and Geological Engineering.

Over the years, the class sizes at UBC have gradually increased, with class strengths in the order of 160 students noted in the years leading up to 2007-2008. As a result of increasing demand for civil engineers, many undergraduate students now select Civil Engineering as their first preference upon completion of the common first year of study. In recognition of this reality, the UBC Faculty of Applied Science has now decided to further increase the intake of Civil Engineering students, in turn, considerably increasing the class size of students taking geotechnical courses. For example, the total student enrolment in the second year soil mechanics class of 2007-2008 reached an unprecedented total of 225.

This presentation addresses attempts at UBC to improve student learning outcomes while facing the changing market place dynamics and increasing student numbers. Current class size data for geotechnical engineering subjects along with teaching philosophy and objectives are presented as background material. As instructors of the fourth and third year geotechnical courses, respectively, the authors share the challenges faced in the delivery of geotechnical engineering courses in large class environments.

2 TEACHING PHILOSOPHY

As all civil engineering works are built on or in the ground, civil engineering undergraduate students must learn something of the engineering behaviour of soils and rocks. As indicated by Alfaro et al. (2008) in the parallel paper in this special session on Geotechnical Education, the geotechnical engineering program presented at the undergraduate level is typically introductory and general, with professionally-oriented graduate programs required to produce specialist geotechnical engineers.

The undergraduate teaching philosophy in UBC Civil Engineering is based on the following key objectives: (i) provide adequate background in geology; (ii) develop a strong understanding of the fundamentals of soil mechanics; (iii) offer opportunity to gain "hands-on" geotechnical experience through laboratory testing; (iv) apply fundamental knowledge to engineering design and solution of real-life problems.

To accomplish these objectives, the civil engineering undergraduate program at UBC requires students to take the following courses: (i) an introductory course on geology to address the origins of earth materials (second year); (ii) two cascading courses on soil mechanics to provide the fundamental mechanics knowledge (second and third years); and (iii) a course on foundation

engineering to teach the application of fundamental soil mechanics to engineering design and solution of real-life problems (fourth year). In addition, students may select geotechnical electives such as a course on geotechnical case histories or geo-environmental engineering. Other geotechnical courses are available in the Earth and Ocean Sciences and Mining departments but there is little room in the curriculum for such electives. The geotechnical case histories course comprises guest lectures given by industry professionals sharing their experience. Because of the direct linkage that is made between the material learned in the classroom with real-life conditions, it has received appreciation both from the students and presenters who enjoy the opportunity to share their experience with potential future employees.

Laboratory classes are offered as an essential and integral part of the second and third year soil mechanics courses at UBC. Students undertake laboratory exercises on soil classification, compaction, hydraulic conductivity, shear strength, and consolidation. This is different from the approach that seems to have been increasingly adopted by many universities where laboratory classes are excluded from the geotechnical curriculum, primarily due to cost and logistical considerations.

3 TEACHING CHALLENGES IN LARGE-CLASS ENVIRONMENT

The opportunities for mutual interaction between the instructor and students reduce in a significant manner with increasing number of students, particularly when the class size increases, say, beyond sixty. Large-class environments present instructors with formidable challenges in almost all of the following key activities of the teaching process: (i) management of administrative processes; (ii) securing classrooms with adequate capacity; (iii) effective conveyance of course material; (iv) providing adequate periodic feedback; and (v) conducting laboratory classes with small-size groups. As a result of experience gathered over many years with large class-sizes, UBC Civil Engineering has undertaken several approaches and initiatives with the objective of enhancing the learning experience of students.

An obvious first step to reduce class sizes is to section the course. The second year soil mechanics course is now taught in two sections. This approach has been followed in other civil engineering courses such as Fluid Mechanics and may be considered soon for the third year course in soil mechanics. The main challenge herein lies in ensuring availability of faculty and staff to meet the teaching requirements. The question must also be posed whether learning outcomes are significantly improved when class size reduces from 200 to 100. In 2007-2008, both sections were taught by the same instructor in consecutive sessions. This ensures consistency of delivery but takes a heavy toll of the faculty member, especially during marking of examinations.

In an attempt to engage students in class and to provide instantaneous feedback, a Student Response System (InterWrite PRS™ - "clickers") has been in use since 2007 in the third year soil mechanics class. Students are required to purchase a hand-calculator-size "clicker" at the start of the term. The clickers allow the students to participate in answering questions posed by the instructor during classes. Multiple choice questions are posed by the instructor. Students respond by activating the clickers. The software allows the instructors to digitally collect the student input, and then instantaneously display the aggregate responses from the class. The participation with the clicker counts towards the student's final grade for the course which also serves as an encouragement to participate. In an overall sense, the clickers seem to be effective as a means of communication between the student and instructor, and providing a more active lecture environment with increased student participation.

Civil engineering covers a broad range of specialties. Consequently, it is common to encounter students who are taking geotechnical courses under duress rather than by choice. While this is not a new phenomenon, the influence of disinterested students can be greater in the case of a large class, particularly if they are inclined to be disruptive. This increases the challenge to engage the students and to impress upon them the relevance of soil mechanics and geotechnical engineering to their future civil engineering endeavours. It appears that there is a need to emphasize the value of the wide range of courses offered and their relevance to the real-life professional practice as an integral part of introducing the undergraduate program in the first year.

In the fourth year, students take Foundation Engineering. This course requires students to apply the material from earlier courses to the design of foundations and retaining structures. Little new material is delivered but the students are exposed to the uncertainties involved in the selection of representative material parameters and in the application of existing design approaches.

At this stage of their education, most students are looking forward to joining professional engineering practice. Experience shows that few civil engineering students will become geotechnical engineers but almost all will interact with or procure work from geotechnical engineers. Alternatively, the approximately 20% of the class that are in the geological engineering program will usually take employment in the geotechnical sector. This diversity in interest level presents a challenge to the instructor.

In its current form, the course incorporates aspects of Team-Based Learning or TBL (Michaelson et al. 2004). This approach encourages students to read prescribed material in preparation for team based exercises in the form of more open ended design problems than they have encountered earlier in the program. The advantages of team learning are emphasized by requiring students to take quizzes in each module where they first take the quiz as an individual and then retake the same quiz in their teams. Their score on the team quiz is always higher than on the individual one and the animated debate during the latter is a welcome departure from the passive learning environment of a conventional lecture.

The course modules are sequenced to follow the stages that would be included in a typical geotechnical evaluation in practice. Student teams prepare proposals for site characterization, interpret site characterization

data, and are required to select input parameters for their designs rather than having them prescribed as has been the case in earlier years. As a final exercise, teams are required to synthesize the results of their designs into a recommended foundation scheme and construction sequence. At the end of the course, students are familiar with the process and products of a geotechnical site evaluation. They have experienced the joys and sorrows of working in design teams, have faced the dilemma of selecting design parameters from variable soil conditions and have compared alternative design solutions to a problem with due consideration of the construction sequence required to implement the design.

The process of implementing the above changes has posed many challenges and has highlighted the need to consider the training of civil engineering graduates as an integrated process. In particular, there is increasing demand from employers for students to graduate already adept in the communication and other "soft" skills required in the modern industrial environment. The Civil Engineering program aims to meet this requirement by giving students the opportunity to practise their skills in a range of courses. In Foundation Engineering, open-ended design problems force students to confront the uncertainty inherent in the design process. Also, the team work and writing required for the submission of deliverables contribute to the overall strategy on communication skills. We also emphasize the multidisciplinary nature of civil engineering design by emphasizing links between design courses and by requiring integration of design disciplines in the capstone design course taken by all fourth year students.

4 SUMMARY

Classes exceeding 100 students and growing in size annually combined with limited availability of department resources requires innovation in the delivery of geotechnical courses in order to engage students and enhance the learning environment. The paper describes some measures implemented within the civil engineering program at UBC to address this challenge and to meet the changing needs of civil engineering education.

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