Challenges in teaching engineering to the next generation: Some data from a geo-engineering perspective

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ABSTRACT: This paper looks at the changing attitudes amongst undergraduate students toward learning in engineering, in the context of teaching in geomechanics. On the basis of experiences in courses teaching introductory soil mechanics and geology in second year, and applied, project-based design in final year, a number of observations are made. The data underpinning these observations include course results, student survey results and anecdotes of interactions with students. It considers changes in the expectations of students as a function of generational attitudes and government and university policy. The experiences described point to a trend of students choosing to skip classes, becoming reluctant to think in order to learn, and failing to appreciate how much time they need to devote to their studies in order to achieve the necessary learning outcomes. Results presented show that course failure rates correlate strongly with non-attendance of lectures, and it is concluded that solutions to this problem are far from straightforward.

1 INTRODUCTION

The world, and life as we know it, continues to change at an ever-increasing rate. Many aspects of our lives, such as how we live, how we work and how we relax, have seen profound evolutions over the past 30 years or so. Despite our basic physiology remaining relatively unchanged during this time, the way we learn seems to have changed, driven largely by behavioural adjustments in response to changes in society, its expectations and its opportunities.

Whilst the expected outcomes of a university education in engineering have not shifted significantly, the aptitude of students presenting to study engineering, the educational environment and societal context of students have all changed markedly. This has resulted in a quantum shift in the university experience for both students and educators, that has thrown up many challenges (Vest, 2012) which as yet, are mostly unresolved.

2 GEOTECHNICAL ENGINEERING AT THE UNIVERSITY OF NEWCASTLE

Geotechnical engineering at the University of Newcastle sits within the Discipline of Civil, Surveying and Environmental engineering. The civil engineering program is made up of thirty-two 10 unit courses, of which 4 are geotechnical courses, taken in years 2, 3 and 4. These are described, as follows.

Geomechanics 1: The Geomechanics 1 course is made up of two compulsory parts, delivered simultaneously throughout a single semester. The engineering geology part provides the students with all of the geological knowledge they will receive whilst studying this programme. The soil mechanics part of Geomechanics 1 introduces soils, their fundamental properties and classification and their deformation behaviour. Geomechanics 1 has a heavy workload: it is assessed on the basis of 4 soil mechanics exercises, 3 soil mechanics assignments, one excursion, a geology practical exam, a reading exercise and a final exam.

Geomechanics 2: The Geomechanics 2 course covers the strength/stability aspects of soil behavior. It introduces soil strength models, methods of strength measurement, bearing capacity, lateral earth pressure, retaining walls and slope stability. It has 3 laboratory exercises and a number of assignments.

Geotechnical Engineering: Geotechnical Engineering takes the concepts of Geomechanics 1 and 2 and applies them to site investigation and foundation design. It introduces methods of subsurface sampling, in situ testing, types of shallow foundations, pile design, and a brief introduction to geoenvironmental engineering.

Geotechnical Project: The Geotechnical Design Project is capstone course of the geotechnical strand, providing students with a real, multifaceted design problem. It is devised by an experienced geotechnical consultant, based on a real project and supported by real field and laboratory data. The students work, in groups of 4 toward a solution, which they must present as a consulting report. The assessment for this course is derived from 50% based on the individual students’ efforts and 50% from the group effort, and it rewards conceptual understanding, aptness of the solution and the quality of the communication of the final outcomes.
The observations presented in this paper have been derived by the author from this involvement with Geomechanics 1 and Geotechnical Design Project courses over a period of more than 15 years.

3 PRIMARY FACTORS IN THE TEACHING AND LEARNING EXPERIENCE

The teaching and learning environment in Universities is controlled by a range of factors, including:

- Government tertiary education policy
- Institutional policy
- Educational policy in schools
- Societal norms and expectations
- Professional expectations

Whilst all of these are broad-ranging and distinct factors, aspects of one may have significant consequences for others in the university teaching and learning environment. Note that in the context of the present discussion, “teaching and learning environment” are taken to mean the broader environment that affects the student’s learning experience. Directly, it includes the university, its staff, its teaching spaces, its policies and procedures and its IT systems. Indirectly, it includes society, its expectations, its opportunities, and its constraints.

3.1 Australian government policy

Over the past 10 to 20 years, the Australian tertiary education sector has seen significant and rapid change, driven by government policy. Most important amongst these were strategies to make the sector more cost effective, in response to assertions that increased funding cannot be readily justified (Marinova, 2006). The principal ways of achieving this were to increase the contribution to the costs of education borne by the student, and to exploit the quality and reputation of the Australian tertiary sector to raise income from full-fee-paying overseas students. DEEWR (2011) reports that this has been very successful, providing data to show that the overall government contribution to university education has decreased from 83% in 1987 to 42% in 2010. During this period, student contributions have risen from around 3% to 16%, and new income from overseas students of almost 18% has been achieved.

The incentive to universities to chase overseas student funding has largely been a simple financial one: reduced financial support from the government for universities to carry out their core business. The consequences of this, when translated into the institutions themselves, have been both direct and indirect. Directly, less funding has led to a need to either reduce costs, with consequent increases in student/staff ratios (Bradley et al, 2008), or increase income, through recruitment of overseas students, which has also lead to increased student/staff ratios. Less directly, the need to maximize student derived income has led to an increase in inter-institution competition for both domestic and overseas students, and an indirect increase in the cost and effort devoted to institutional marketing.

3.2 Institutional policy

In most cases, institutional policy formulation has been a direct reaction to government policy. Universities have striven to maximize both local and overseas enrolments in all disciplines. In real terms, universities only get ahead by doing this, if they keep staffing levels static. Increased marketing has been the principal tool for attracting more local and international students. However, to fill quotas of local students in an increasingly competitive market, universities have adopted policies of lower intake cutoff scores, more diverse entry paths and fewer academic prerequisites. As a result, student numbers in both Geomechanics 1 and Geotechnical Project have increased by around 50% over the past 10 years (Fig. 1). With increasing student cohorts in geomechanics courses come issues of teaching quality in field and laboratory exercises, which are hands-on and generally very teacher-student interactive. Without commensurate increases in experienced support staff, the practical learning experience is degraded.

A consequence of more aggressive marketing of universities is a greater emphasis on student satisfaction. Operational policies for encouraging improved student satisfaction incorporate increased scrutiny of course coordination and the perceived quality of

Figure 1. Student numbers and failed completion rates over the past 10 years for a) Geomechanics 1, and, b) Geotechnical project (Note that failed to complete data includes both failing final grades and students who abandoned the course).
teaching and course experiences, delivery of courses through more diverse and flexible modes, and a change in emphasis to assure students that their expectations and rights are important to the institution.

3.3 Educational policy in Schools

The preparedness of students entering university is a key factor in shaping the success of their university experience. In New South Wales, where the majority of the University of Newcastle’s students come from, the leaving qualification is the Higher School Certificate (HSC), and it includes a score, out of 100, that describes a student’s overall performance.

The range of around 85 courses available for inclusion in the HSC is very broad. Of these, there are 4 maths courses, 5 basic science courses and a course in Engineering Studies that are potentially suited to students wishing to become engineers. The remaining courses cover subjects of interest in broader society from retail and hospitality studies to dance life skills.

Student performance in each course is assessed using a standards-based reporting scale, on which the level of performance is judged according to predetermined benchmarks of understanding that might be displayed by a student (BOS, 2012). These differ for every course, but the relative depth of understanding they represent are set generically and equally for all courses. Most significantly, there is no recognition given to the level of intellectual challenge of different courses, so any course studied has equal weighting in the calculation of an HSC score.

3.4 Societal norms and expectations

These have arguably undergone the greatest and most profound changes over the past 20 years, and in general terms, there are far too many to consider in any comprehensive way here. Hence, the present discussion will be limited to a few observations that are pertinent to the discussion which follows.

The following are some generalizations made in regard to the current generation of students:

- They see themselves as education customers.
- They have grown up with computers and the internet, and are undaunted by the learning curves associated with new technology.
- They have grown up with computer games and computer animated graphics are commonplace.
- Mobile phones/smart phones are essential personal items and additional accessories such as iPods, Tablets and Kindles, etc are commonplace.
- Students accept that their modern conveniences have a financial cost, and they are willing to work in paid jobs whilst studying to maintain them.
- Formalities in interpersonal interaction and communication have mostly been disregarded, and student-teacher interaction is casual.

In general, the world is now more “politically correct” than ever, and this has led to trends of student expectations, and institutional priorities, are more liberal than ever before.

3.5 Professional expectations

Expectations of the corporations and organizations employing graduates have not changed so rapidly, as they are controlled by people of older generations. If anything, there may be an expectation that, given the greater opportunity presented to the current generation of graduates, they might be somehow superior to their predecessors. Certainly, the basic knowledge and fundamental principles of most technical disciplines have not changed, and still as relevant. Also, problem solving and analytical skills are still required. However, the forefront of technology has advanced significantly, and there is an ever-increasing number of things to be familiar with.

4 OBSERVATIONS OF TEACHING AND LEARNING TRENDS AT THE UON

From 15 years of involvement with the Geomechanics 1 and Geotechnical Design courses, the following trends in the teaching and learning of civil engineering students in geomechanics have become apparent:

Students in engineering are increasingly less prepared for their studies. This occurs because of school education policy which does not discriminate between the value of courses on the basis of intellectual challenge, and university policy which does not enforce pre-requisites on the basis that it would discriminate on the basis of student choices rather than intellectual ability. Consequently, potential engineering students are being encouraged at school to study less challenging courses in place of maths and science, since this will improve their HSC score.

Students are increasingly choosing to “skip class”. In the Geomechanics 1 class of 2011 (140 enrolments), 140 copies of the course outline were taken for distribution in the first lecture: 45 were not distributed, as students did not attend. In a survey conducted in week 10, the average attendance of lectures was only 60. Typical weekly tutorial attendance (optional) is around 50 at the beginning of the hour and reduces to around 25 by the end of the session. There is also an increase in requests for the lectures to be taped and made available on the internet.

Students are no longer willing to write notes in class. Instead, they, expect to have notes presented to them in a professionally prepared form. Even examples in the notes, worked through in class by writing in spaces provided, are insufficient for many students, who request written copies to be uploaded after the class in which the answers were provided.

Students are increasingly reluctant to consult text books. In providing students with prepared notes, there is an expectation that these should serve as an extended syllabus, and that students should read more widely from texts to clarify their understanding, on an as-needs basis. The expectation of students, however, is
that the provided notes should be stand-alone, giving them all they will ever need to know about the subject matter.

**Students no longer ask questions during lectures, and make little use of timetabled tutorial sessions.**

**Students are reluctant to solve questions without worked solutions.** In Geomechanics 1, the students receive a list of tutorial problems weekly, with only numerical answers attached. Throughout the semester, there are repeated requests for full, worked solutions to the tutorial problems. When asked “why do you want them?” the students usually reply that they have insufficient time to work through all of the questions, and that having full worked solutions makes completing the tutorials more efficient.

**Students increasingly expect precise marking rubrics for all assessment items.** Also, they will analyse returned items against the rubric rigorously, when the items are returned, and challenge any perceived shortcoming in the assessment process.

**Students are increasingly seeking greater flexibility in the timing of submissions and attendance.** The two most common reasons given are that they must earn money to subsist, or that they are fulfilling an indispensible professional role in their workplace.

It should be noted that there are some aspects of student attitude that have not changed significantly, and most importantly, it seems that despite all of the changes noted above, students still enroll in courses with the sincere intention of learning enough to pass the course. For some students, the intention may be to learn just enough, though this is nothing new amongst students. Importantly, students still believe that it is important to have an amount of working knowledge in order to practice as an engineer. What is significant, however, is how the trends identified above are mostly working in opposition to the students desire to gain knowledge, and to the teacher’s responsibility to impart this knowledge. This is explored in the following section.

5 DISCUSSION

It is the opinion of the author that although most students enroll in their courses with every intention of learning what the teacher has set out to teach, many underestimate what it takes to fully appreciate the subject, and seem to undervalue and disregard the advice given at the beginning of the semester.

The reasons for this are complex, but two principle reasons are apparent: students’ priorities have shifted in response to societal changes, and their secondary school training is not imparting the learning and time-management skills necessary for studying engineering at university.

5.1 Learning skills

Students are being trained in their HSC studies in secondary school to expect a highly structured and predictable curriculum, which is designed to help them maximize their final HSC score. For their teachers, and the broader community, the focus is on achieving the highest HSC score they can. This leads to the selection of less appropriate courses to achieve higher marks, instead of the traditionally more difficult courses of math and science which better prepare students for geotechnical design.

The current HSC system is designed to take a student to a superficial level of understanding, with very clearly defined expectations and outcomes. Students are encouraged to learn by completing questions from past exam papers, which are structured according to tightly constrained plans, so as to consistently conform to the expectations of students and their teachers. Past exam papers and solutions are widely available to all students on the internet. The expectation of students and their teachers is that if they have done all of past exam papers, then they have learned enough to achieve a high mark. This comes at the expense of deeper understanding and it trains students to study to pass an exam rather than to master a subject. These students arrive at university with this approach to learning, and many struggle to adjust to an environment where they are expected to understand broad theoretical concepts and apply them to open-ended, applied problems.

In Geomechanics 1, this leads them to a sense of insecurity when they are given tutorial material in soil mechanics without fully worked solutions. Many are either reluctant, unwilling or unable to read the course material and interpret it in order to solve the tutorial questions. It is commonplace to field questions about assignments from students who have not yet attempted any of the associated tutorial questions, and which have answers that are readily and directly found in their course notes.

In the Geotechnical Design Project, students struggle with the open-endedness of geotechnical design problems and that there can be many solutions with varying degrees of suitability to any particular design situation. Fortunately, by their final semester, most have come to appreciate the way engineers handle uncertainty in the design process, from their earlier studies in geomechanics and water engineering, although the leap of understanding required is daunting for many. Some students complete the course, comfortable with designing for natural variability, whilst others remain unconvinced.

5.2 Evolving expectations

Perhaps the most significant impediments to student learning arise from the expectations of students in modern society, and they manifest in the balance between what the students expect to receive, what they expect to have and what they expect to give.

As noted earlier, students are now well aware of their status as customers, and they expect that they should have some say in how the service they are buying is delivered. Sometimes what they want is inconsistent with what teachers think is best for them, and this
leads to dissatisfaction. University policy, in response to government pressure to increase student numbers, has exacerbated this situation by creating a learning environment where student satisfaction is given far more attention than staff satisfaction or learning outcomes. Students are now surveyed intensively and staff are leveraged on the basis of the results, to do whatever it takes to make students happy with their experience.

What students are willing to give to gain an understanding of applied engineering is largely determined by how they allocate their time. What emerges from interacting with students in course coordination, is that the amount of time devoted to recreation and personal time has not changed significantly. However, there seems to have been a shift from time devoted to outside study to time spent in employment. Students are now more heavily committed to part time work, and in extreme cases, are trying to juggle full time work with full time study.

A primary factor in increasing work commitments is the need to fund a lifestyle in the technological age, which offers unprecedented opportunities for communication and information, but at a cost. It is now almost unheard-of that a student would not have the latest mobile phone and personal computer devices, with subscriptions that give them comprehensive access to the electronic services that most of society has. The costs of this are additional to the everyday costs (rent, car, food, clothes, sport and entertainment) that students of the past had to manage.

A secondary factor is the shortage of engineering professionals, causing companies turn to undergraduates to accommodate an increasing workload. There are now frequent requests from students for extensions of time and for rescheduling of laboratories etc. on the basis of work commitments. Many companies who employ undergraduates in professional capacities, through necessity, leverage a greater commitment from students than they can afford to give.

It seems that this trend is at the heart of declining class attendances. There is a tendency for students to plan their semesters by blocking-out class times in their schedules, and then filling the spaces in between with work commitments. Increasingly, additional self-directed study time is something that students expect will just happen in unspecified times between lectures and work. This behavior explains the gradual decline in attendance observed throughout a semester, where as a course proceeds, students begin to receive assessment tasks, and they feel compelled to skip class in order to work on them.

5.3 Teaching considerations

The focus so far has been on the changes which have occurred in the students’ learning environment. The other, equally important side of this complicated equation is what is happening in the teaching environment.

In many cases, teaching staff have not sought to change their approach to teaching, finding it hard to justify changing what has worked effectively for previous generations. In other cases, teachers have embraced technological and pedagogical change and attempted to adapt and innovate in response to the challenges that have arisen. Innovations such as on-line course delivery (Kim and Bonk, 2006), videoed lectures (on demand) and virtual laboratory exercises have all been tried (Ertugrul, 2000), though there would seem to be no clear evidence that they have been more effective.

There is one school of argument that supports giving students what they want, because they have already learned at school how study in their own way, and traditional views on what makes effective study may not apply to them. It is difficult to accept however, that deeper levels of understanding can be gained from non-attendance of lectures and practice doing fully worked solutions (in place of taking more time to read the course material and assimilate it in order to be able to solve the problems from scratch).

One way to evaluate whether the change in student study patterns is having a detrimental effect is to look at the failure rates of students in courses. The graphs presented in Figure 1 show that, on average, failure rates in Geomechanics 1 have risen consistently over the past 10 years, whilst failure rates in Geotechnical project are changing less consistently, though higher now than ever before. Note that the higher rates of failure in Geotechnical Project may reflect both student behaviour in that course, and also student behavior in the earlier Geomechanics courses that feed into the design course.

Evidence has indicated that attendance of lectures is of benefits to students (Massingham and Herrington, 2006). To get a clearer indication of whether there is a correlation between non attendance and likelihood of course failure, a simple survey of attendance in the two Geomechanics 1 lectures was arbitrarily conducted in week 10 of semester in 2011. The students were not told that the surveys would be carried out, and the results of the survey were not analysed until the course marks were finalised. Figure 2 shows the frequency of final grades for students who attended

Figure 2. Frequency of final grades for Geomechanics 1 students who attended two lectures, one lecture or no lectures in week 10.
both, one or neither of the lectures in week 10. Figure 2 shows clearly that students who do not attend lectures are significantly more likely to fail to complete courses successfully, and feature less frequently amongst the higher grades achieved. Students who attended at least one class in the week of the survey achieved significantly better results, with attendance of both, correlating to slightly better grades and a greater proportion of the highest grades.

Interestingly, there were 2 students who did not attend class in week 10 who achieved marks greater than 90%, and students who attended both classes who failed, though relatively few and not by much.

6 CONCLUSIONS

Achieving good pass rates and satisfactory learning outcomes in geomechanics courses at the University of Newcastle has become increasingly difficult over the past 10 years. This is partly due to a combination of government and institutional policies aimed at increasing productivity in Australian universities, and to a shift in attitudes and study patterns amongst undergraduate engineering students.

Government policies to encourage universities to attract more students, and university policies to attract and admit more students, have seen significant increases in the numbers of less well prepared students undertaking engineering studies without a commensurate increase in teaching resources. At the same time, student commitment to study has reduced in response to increased commitment to part time work, leading to a trend of student non-attendance of classes and incomplete attempts of tutorial questions and assessment tasks.

Whilst it would be reassuring to find that students’ study effectiveness has adapted along with their study patterns to achieve suitable learning outcomes with reduced investment of time, the evidence is to the contrary: it seems that failure to attend class correlates to a significantly greater frequency of failure. It would also be reassuring to believe that teachers can adopt more flexible and innovative delivery modes to complement the study-time constraints and modern lifestyles of “Gen Y” students (Mc Crindle, 2011), and enhance their learning efficiency, but it is the author’s opinion that flexible delivery modes can only compensate so far.

The reality is that the knowledge base for geomechanics is only broadening, and there is an amount of knowledge that must be acquired in a professional degree program, which cannot be compromised if graduates are going to meet the expectations of employers. This leaves geo-engineering teachers with a challenge, for which this author has few answers.

REFERENCES