Int. J. Engng Ed. Vol. 17, No. 3, pp. 255–260, 2001
Printed in Great Britain.

0949-149X/91 $3.00+0.00

A Student-centred Learning Approach to Teaching Soil Mechanics*

G. R. McDOWELL
School of Civil Engineering, University of Nottingham, Nottingham NG7 2RD, UK.
E-mail: glenn.mcdowell@nottingham.ac.uk

A project has been undertaken to establish the effectiveness of a student-centred learning approach to teaching students applications of Critical State Soil Mechanics taught more transmissively in lectures, and to determine whether such an approach significantly enhances learning of the theory itself. The project was undertaken as part of the new Postgraduate Certificate in Academic Practice at Nottingham University. A teach-yourself handout has been created, whereby students 'teach themselves' applications of the fundamentals, and it is found that by this approach, the students appear to learn better both the theory and the applications, developing high-level cognitive ability.

INTRODUCTION

THE AIM of this research project was to examine the effectiveness of a student-centred learning approach to teaching some applications of a very theoretical subject, namely Critical State Soil Mechanics, which is the subject of 'Advanced Soil Mechanics', a ten-credit module offered to third and fourth year undergraduates in Civil Engineering at Nottingham University (students must take 60 credits of modules in each of two semesters). The project was undertaken in the second semester of the 1998–99 academic year, as part of the new Postgraduate Certificate in Academic Practice at Nottingham University, which has been introduced primarily for new academics to provide them with a route to membership of the new Institute of Learning and Teaching. Critical State Soil Mechanics is not offered universally throughout British universities, and is often seen by the geotechnical industry as being too complicated to learn, and of limited use. Although it is true that the subject is complex, the perception that it is not useful is not true, and is due to ignorance, and in this project students are encouraged to teach themselves useful practical applications of this theory. This will be of great benefit to those who decide to become geotechnical engineers in the future, but of no less use to those who don't; the nature of the subject is such as to develop high level cognitive ability.

In previous years, students were asked to calculate stress changes and resulting deformations beneath a foundation. Problems with this previous coursework (according to previous lecturers) were that the analysis was over-simplified, the students did not understand the project, found the project too difficult, and did not learn from it. On the advice of the previous module lecturers, I, as the new lecturer of the module, decided to give the students several smaller tasks which illustrate the applications of the theory taught in the lectures. I therefore designed a 'teach-yourself document' to help the students learn more effectively how to apply the theory of Critical State Soil Mechanics to a wide range of unseen problems.

It is essential when helping students to learn, to specify clear learning objectives. These learning objectives are for the benefit of the students, and it is important to be clear which type of behaviour is being addressed (cognitive, psychomotor or affective domain), the level at which it is being addressed, and the conditions under which the objectives should be satisfied. For this coursework on applications of Critical State Soil Mechanics, it was desired that with the use of the lecture notes, students would be able to: *formulate* a number of relationships describing the behaviour of soil elements, *analyse* the stability of a shallow foundation under short and long-term conditions in normally consolidated and overconsolidated soils, and *critically assess* the Law laid down by the Health and Safety Executive that unsupported trenches should be no more than 1.2 m deep. These are high level (problem-solving) cognitive tasks. Ten percent of the overall module marks were available for the coursework. In order to assess the effectiveness of the project in helping students learn, a number of methods were used, namely a feedback questionnaire, the resulting coursework marks and the examination marks. There were fifteen students in the class.

FACILITATING STUDENT-CENTRED LEARNING

Research on learning no longer supports a transmissive style of lecturing [1]. It has been found that learning through memorisation and

* Accepted 5 August 2000.

reproduction does not result in knowledge that can be used to reason and to solve problems in new situations. Shuell [2] states that what the student does is actually more important in determining what is learned than what the teacher does. Thus, the teacher's role is not to lecture in an exclusively transmissive way, but to encourage active participation, dialogue and interaction by students with course materials and with each other [3]. The teacher is 'a facilitator of learning'.

According to Nicol [3], the concept of student-centred learning can be considered from within three perspectives:

- cognitive
- motivational
- social-contextual.

From a cognitive perspective, students learn by interacting with and transforming received information so as to own it and make it personally meaningful. This leads to powerful understanding and useful knowledge. Within this perspective, Nicol outlines the constructivist view, whereby learning is facilitated by a range of tasks that involve students in active processing, such as questioning, explaining and discussion. Associated with this approach is 'metacognition': the idea that when the teacher 'thinks out loud', students develop critical thinking and learn how to learn [3].

The motivation for students to learn may be either inherent or determined by factors in the environment. Nicol states that student motivation is influenced by personal needs and values, what the students believe they can accomplish and expectations of success or failure. It is desirable that student motivation be increased, and this can be facilitated by giving the students relevant, authentic learning tasks, and increasing their expectancy of success. These aims have been undertaken in this project: the tasks set satisfy the requirements of relevance and authenticity, and pointers have been used to help the students along the way, where they may encounter difficulties. Thus, the students can expect to gain high marks if they simply spend the time necessary to complete the coursework. Nicol emphasises the importance of giving cues to the students at various stages to help them know how they are doing [3]. This increases motivation, and will be discussed later. Finally, regarding motivation, McKeachie [4] discusses the importance of people. Students can motivate one another, and working collaboratively can greatly increase motivation. I encouraged my students to actively participate in the set tasks with one another and to help one another.

The interaction of students with other students not only increases motivation, but actually facilitates learning. This is the social perspective of student learning [3]. How students learn depends on how they perceive and act out their relationships with teachers and with other students. Group learning can give students valuable experience in thinking and explaining and teaching each other. In such an environment, the teacher takes more of a paternal role, overseeing the activity of the class, and actively participating in the set tasks with the students at the appropriate times.

In summarising, it appears that it is mainly ideas from the cognitive perspective that have influenced teaching and learning in HE. However, Boekaerts [5] points out that how students feel about their studies (motivation) and how they interact socially while learning affects how they process information cognitively and their level of understanding.

In recent years, student-centred learning has unfortunately been seen by many to be synonymous with computer-aided learning (CAL). The use of CAL as a powerful student-centred teaching technique is discussed by Davison and Porritt [6], and with modern information technology CAL can now offer a real virtual alternative to transmissive lectures or laboratory classes. However, CAL should not be considered to be the only form of student-centred learning. Here, a simple interactive handout is shown to offer an effective student-centred approach to teaching and learning.

A TEACH-YOURSELF HANDOUT

The set coursework comprises five tasks, and is described in detail by McDowell [7]. The tasks are not described in detail here, but involve the derivation of well-established constitutive relations for soil elements, in addition to examining the stability of soil constructions, namely foundations and trenches. The five tasks are briefly described in the introduction to the coursework, and in more detail at the beginning of each task. The coursework contains blanks to be filled in by the students, and 'pointers' are given at appropriate stages to help the students revise the course theory, and to complete the next step of the current task. Examples of such pointers are 'Revise section 7.3 of the course', or 'Draw a Mohr circle of total stress . . .', as shown in Fig. 1, which is a typical extract from the teach-yourself handout. Thus the expectancy of the student's success is high, which produces motivation, but a large amount of work is required on the part of the student.

To increase motivation further, three hours of workshop time were allocated for the coursework, so that all students were able to interact with each other and with myself as the lecturer, where appropriate. This appeared to motivate the students in completing the assessed tasks, in agreement with the observation made by McKeachie [4] that a student's motivation is greatly influenced by other people. The collaborative approach stimulates learning because students are involved in active processing: questioning, explaining, discussion (the constructivist approach). It was decided that each individual would submit an individual coursework, however, since I have found that in

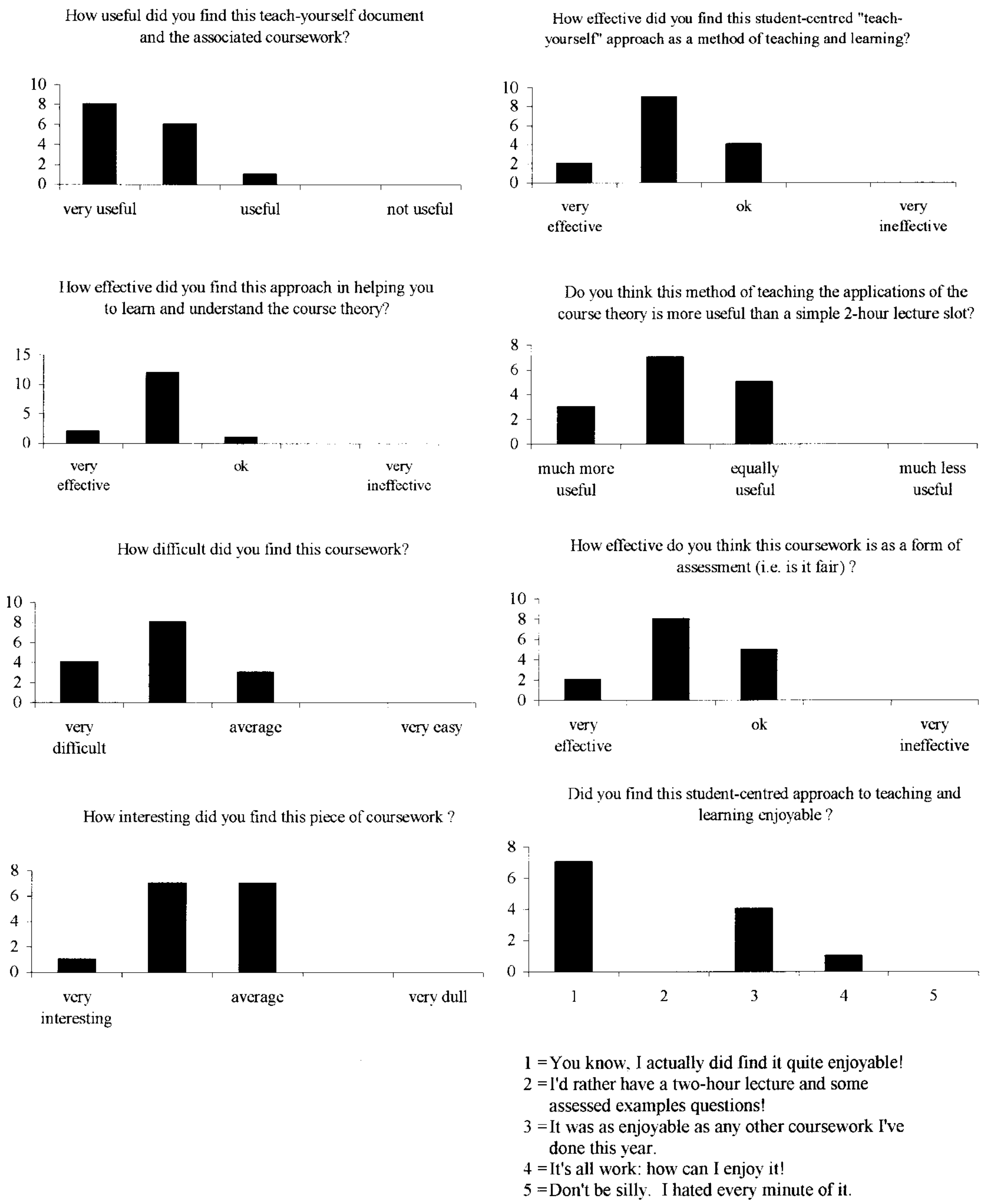


Fig. 1. Extract from an interactive handout.

group project submissions, less able students often take a back seat, and the stronger students do most of the work, because they wish for the group to obtain a good mark. By the approach adopted here, the emphasis of the coursework is on learning rather than assessment, so each and every student knows that by interacting with each other and myself, they are likely to succeed both in the coursework, and in any subsequent assessment.

The most interesting task is the most difficult one, which is to justify the law laid down by the Health and Safety Executive against digging unsupported trenches greater than 1.2 m deep. The vast majority of geotechnical engineers would simply adopt this approach without questioning why soil trenches deeper than this might unexpectedly fall in. In this project, students are asked to prove that the Law is wise. The task, I believe, gives the students great confidence in the fact that a somewhat abstract theory gives them the power to make sound engineering judgement.

The effectiveness of this approach to teaching has been measured by assessing the coursework marks, the examination marks, and the results of a feedback questionnaire, which contained standard questions of the 'strongly agree. . . strongly disagree' type, in addition to allowing students to make their own comments. In brief, the average coursework mark was 8.9/10. Four students from the class of fifteen obtained full marks, and four

Step 1: Calculate the theoretical depth of unsupported soil in e.g. London clay

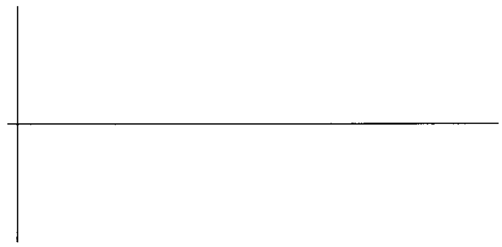
Consider a heavily overconsolidated clay such as London clay. Suppose the undrained strength of the clay is 100 kPa (i.e. stiff clay). Express the undrained strength criterion in terms of the vertical and horizontal total stresses

(5.1)

Pointer: Draw a Mohr circle of total stress. The size of the Mohr circle at limiting equilibrium will touch the undrained failure lines.

Hence for "active" soil (i.e. $\sigma_v > \sigma_h$) in equilibrium, use a Mohr circle construction to show that

$$\sigma_v - \sigma_h \leq 2c_u \tag{5.2}$$



Limiting Mohr envelope for total stresses

Fig. 2. Results of student feedback.

students 9.5/10. The lowest mark was 6/10 and every one else attained 8/10 or more. This demonstrates that the expectancy of success was made deliberately high. The examination (which carries 80% of the module mark) consisted of high-level problem solving tasks. It was a difficult exam, following the high-level type of questions set by Cambridge University, where Critical State Soil Mechanics was invented, and where I studied as an undergraduate and postgraduate. Despite the difficulty however, the average mark was 62%, and six students out of the fifteen candidates attained above 70%. Students had found that the set coursework had taken a long time, and felt that it ought to carry more than 10% of the module mark, but felt that it had prepared them well for problem-solving in the exam. This was indeed confirmed by the examination results.

Nowadays students regard themselves as consumers: they are paying for an education, and to spend a lot of time working hard to complete a coursework which only accounts for 10% of the module mark does not seem like good value. However, students often tend to plagiarise coursework which accounts for a significant percentage of a module mark, in order to gain a good initial mark before the exam. Coursework is therefore often not a reliable form of individual assessment. Plagiarism can be deterred by introducing group submissions, which can be used most effectively in design-based projects. In this case collaboration is expected, but as stated previously, this can often have the effect of encouraging weaker students to contribute less, and stronger students to contribute more than ought to be necessary. Furthermore, a group may still decide to plagiarise the work of a previous group in a previous year if the set problem is similar.

The teacher's philosophy ought to be that their students should develop high level cognitive ability. In this case they should be able to solve difficult unseen problems in new engineering contexts in examinations. That is not to say that examination is the best form of assessment, but simply that students with high level ability should be able to solve difficult problems under pressure. Some students find the stress of the examination room too much, and the 'exam' can actually bring out the worst in some students. However, examination skills can be taught to students, and it is important that the lecturer makes clear to the students how examinations will be assessed. This can have the positive effect of helping students make appropriate decisions and to perform difficult analyses under constraints of time and with limited information. These are valuable transferable skills. In this case, if coursework can be used as an effective revision and learning tool, and if in addition pointers are given to help the students complete the assignment, then the expectancy of success for each student is high, so the incentive to cheat is drastically reduced.

I have outlined a key problem associated with group submission, and the preferred approach here has been to encourage interaction and active processing amongst all students, so that the development of transferable skills such as teamworking and effective communication are also encouraged. For a very analytical and mathematical course, such as the module described here, it appears that the examination is an effective form of primary assessment, so long as students are given advice on to how to get the best results out of a difficult exam. Thus, a simple interactive handout, which serves to develop cognitive skills and help the students revise important principles, and for which a small number of module marks are available, encourages students to learn in an interactive way with colleagues and course materials, and with the lecturer, with a high degree of motivation. This academic year (1999–2000), in response to student feedback, I have increased the coursework mark only marginally from 10% to 15% of the module mark, to increase motivation even further.

The results of the feedback questionnaire are given in Fig. 2, and show that the students found the coursework very useful, effective as method of teaching and learning, and effective in helping them to learn and understand the course theory. The results also show that they felt this approach to be more useful than transmissive lecturing on the same material would have been. This serves as an acid-test of the effectiveness of the approach. The students found the coursework difficult, but considered it effective as a form of assessment. They found it interesting and enjoyable! However, improvements can be made. The students expressed the desire for more 'cues' to help them see how they are doing at various stages. The new (1999–2000) edition of the coursework contains the eventual equations they need to work towards in order to increase further the expectancy of success and motivation. The new coursework contains more guidance in the text (i.e. more hints or 'pointers'), and some useful references to relevant literature. Despite these deficiencies, however, the evidence, described in detail by McDowell [7] demonstrates the effectiveness of the adopted student-centred learning approach. It appears that the set tasks stimulated motivation, interaction with one another, the coursework materials and myself, and greatly increased the students' ability to solve difficult unseen problems. Furthermore the number of students taking the course has increased from 15 to 40 this academic year, and it is thought that this can largely be attributed to the student-centred approach described, which gives students a high expectancy of success in the examination.

CONCLUSIONS

The psychology of student-centred learning has been examined in order to undertake a research project into the effectiveness of a student-centred approach in teaching Soil Mechanics. A teach-yourself coursework handout has been designed in order to facilitate learning of applications of a difficult theoretical subject. The coursework aims to address the cognitive, motivational and social perspectives of learning, and the effectiveness of the technique has been measured by means of a feedback questionnaire, the coursework marks and the examination marks. Evidence suggests that students benefited from the new 'teach-yourself' approach, and have an enhanced ability to apply fundamental principles to high level unseen problem-solving.

The average mark for the coursework was very high (about 89%). Thus, if students expend considerable effort, they will learn much, and gain a high mark. This high expectancy of success increases motivation and thus stimulates learning. However, feedback shows that students felt that the coursework ought to be worth more than 10% of the overall module mark. This is more than compensated for by the increased aptitude for problem-solving under examination conditions. Some thought has been given to the weighting of the marks for the coursework: an extra 5% of the overall module mark has been made available for this academic year to increase further student motivation and thus the ability to solve problems in new contexts. The coursework remains an important part of the module, and more pointers and 'cues' have now been included to help the students see how they are progressing at various stages of the coursework.

There is strong evidence to show that the students believe they have learnt more from this exercise than what they would have done if the material had been lectured in the traditional transmissive way. This can only be based on their personal past experience, but serves as a useful acid-test of the effectiveness of the adopted approach.

REFERENCES

1. P. Ramsden, *Learning to teach in Higher Education*, Routledge (1992).
2. T. J. Shuell, *Designing instructional computing systems for meaningful learning, Adaptive Learning Environments: Foundations and Frontiers* (eds M. Jones and P. H. Winne), Berlin: Springer-Verlag (1992).
3. D. J. Nicol, *Research on Learning and Higher Education Teaching.* UCoSDA Briefing Paper Forty-five, April (1997).
4. W. J. McKeachie, Recent Research on University Teaching and Learning: Implications for Practice and Future Research. *Academic Medicine* **67 (10),** 584–587 (1992).
5. M. Boekaerts, Being concerned with Well-being and with Learning. *Educational Psychologist* **28 (2),** 149–167 (1993).
6. L. R. Davison and N. Porritt, Using computers to teach. *Proc. Instn. Civ. Engnrs, Civ. Engng.* **132,** Feb, 24–30 (1999).
7. G. R. McDowell, *Developing reflective practice.* Portfolio, Postgraduate Certificate in Academic Practice, University of Nottingham (1999).

Glenn McDowell graduated from the University of Cambridge with a first class BA (Hons.) in Engineering in 1993. He remained at Cambridge University Engineering Department to take a Ph.D. in soil mechanics and graduated in 1997. He was awarded the Goldsmith Junior Research Fellowship in Materials by Churchill College in September 1996, and he remained at Cambridge until May 1998, when he took up his current position as a lecturer at the University of Nottingham. He has recently been awarded the Postgraduate Certificate in Academic Practice, which is a new teaching qualification set up by the University of Nottingham, and is to be awarded a University of Nottingham Lord Dearing Award for Teaching and Learning by Lord Dearing in October 2000.