Use of case studies in geotechnical courses: Learning outcomes and suitable cases

T.L.L. Orr
Trinity College, Dublin, Ireland
M. Pantazidou
National Technical University of Athens, Greece

ABSTRACT: The accepted wisdom in engineering education is that the use of case studies in instruction has a number of benefits, as argued in several publications. Less attention has been devoted to identifying the type of learning outcomes that can be achieved when using cases in instruction. This topic is addressed in this paper specifically for geotechnical engineering instruction. Particular emphasis is placed on the relationship between specific learning outcomes and the corresponding suitable types of case studies and case data. The difficulties in locating suitable case data are discussed and possible actions that could be undertaken by the geotechnical engineering community to overcome these difficulties are suggested.

1 INTRODUCTION

The use of case studies in engineering has been advocated at an educational policy level for at least half a century, judging by the funding by the US National Science Foundation of the Engineering Case Program originated at Stanford University in 1964 (http://www.cee.carleton.ca/ECL/about.html). Since then, demands on engineering education have increased in terms of transparency in goals and accountability for results achieved. These increased demands are also related to the progress of educational research into learning in general and into learning at university level in particular. Hence, we are now in a better position than 50 years ago to answer the question “exactly what can be achieved by using cases in engineering instruction?” This paper attempts to address this question for geotechnical engineering by determining possible learning outcomes. It then considers the characteristics of case studies required to achieve different learning outcomes, before turning to the practical matters of locating or creating suitable case material for desired learning outcomes.

2 LEARNING OUTCOMES

Today, designing courses and study programmes on the basis of learning outcomes and competences is widely regarded as a good practice (ASCE 2008) and is often required by accreditation agencies (ABET 2011). On a European level, the aim of creating a European Higher Education Area, as described in the Bologna Declaration (European Ministers of Education 1999), requires cooperation between education institutions and a system for mutual recognition of qualifications. This has been achieved through the establishment of the European Credit Transfer and Accumulation System (ECTS) and the requirement to provide detailed descriptions of courses and programmes in terms of learning outcomes. In some institutions, this requirement has led to the rephrasing of course syllabuses to create learning outcomes, e.g. “understanding topic X, understanding topic Y, etc.” However, as Laurillard (2002) observes, “the point of having learning outcomes is to answer the question: how will you know if the students understand? What would count as evidence that they understand?” To this end, learning outcome statements are typically characterized by the use of active verbs expressing knowledge, comprehension, application, analysis, synthesis and evaluation. Jenkins & Unwin (1996) stress that the verb “do” is a key verb for stating learning outcomes and provide an extended list of active verbs suitable for each performance level, e.g. list (knowledge), classify (comprehension), interpret (application), compare (analysis), create (synthesis) and estimate (evaluation). Learning outcomes should be accompanied by assessment exercises capable of providing the evidence that outcomes have been achieved.

3 USING CASE STUDIES IN INSTRUCTION

3.1 Project-based learning & case-based teaching

Prince & Felder (2006) provide a comprehensive overview of inductive teaching and learning methods,
whereby specific observations, case studies or problems are presented first, in order to place theory in its applied context, thus motivating subsequent theory instruction. For the remainder of this section, the terms used by Prince & Felder (2006) will be used, without making any sharp distinction between teaching (what teachers do) and learning (what students do). Nevertheless, the use of “learning” instead of “teaching” does imply that students have more autonomy and hence, more responsibility for the performance level they achieve. Prince & Felder (2006) is the perfect paper for a skeptical reader who asks: “OK, we have heard that inductive methods, such as case-based teaching, are supposed to be good, but what specific claims can be supported by (a) educational theory and (b), most importantly, empirical evidence?” According to Prince & Felder, the use of inductive methods is supported by several educational theories. Moving from the familiar specific to the abstract general is consistent with prevailing ideas on how learners build up their knowledge. In addition, if new knowledge is presented in the context of real situations, then this new information is more likely to be connected to existing cognitive structures and be retained. Moreover, the use of cases involving real problems has the potential to motivate the students. What is more, dealing with open-ended problems and the uncertainties of real problems has the potential to help students develop intellectually and abandon immature beliefs about the certainty of knowledge and there being only one correct answer which is provided by the instructor.

The key feature of project-based learning, according to Prince & Felder, is that the learning activity should lead to the production of a final product. In civil engineering, the final product often involves a design. A distinction must be made between project-based courses, where students mostly use projects to apply previously acquired knowledge, and project-based learning courses that use projects as an opportunity to introduce new knowledge. The evidence of the effectiveness of project-based learning compared to traditional instruction shows that students feel more motivated, and have a better understanding of issues of professional practice and of how to approach realistic problems. On the negative side, the comparison also shows that students taught on traditional courses may have a better understanding of engineering fundamentals, while students on project-based courses may be unhappy with the additional self-learning effort required by projects.

Case-based teaching is described by Prince & Felder as an instructional method whereby students analyze case studies that involve solving problems or making decisions. Often in engineering courses, the case is a failure and the problem to be solved involves diagnosis of the cause of failure. At the other end of the learner autonomy spectrum, the instructor may provide complete information on the problem and discuss how it was addressed, including the final outcome. Instruction with such cases cannot be considered as inductive nor suitable for learning outcomes at performance levels higher than application. On the contrary, when case specifics are given but the outcome is withheld, students can perform their own analysis and exercise decision-making skills. In other words, the same case can be used to achieve different learning outcomes, as shown by Papadimitriou (2011). Similar to project-based learning, empirical evidence shows that case-based teaching promotes transferable skills, such as reasoning and problem solving, but little or no evidence of increased subject-matter knowledge acquisition (Prince & Felder 2006). Yadav et al. (2010) arrived at the same conclusion using two carefully crafted case studies specifically constructed to improve conceptual understanding. Survey results indicated that, overall, students had a positive attitude towards the use of case studies. However, pre- and post-test results did not reveal any significant influence on conceptual understanding. From the above, it seems reasonable to posit that stating clear learning outcomes related to subject matter may improve the capacity of cases to promote knowledge acquisition.

3.2 Case studies in geotechnical instruction

Geotechnical engineering deals with a natural material. As a result, it is more difficult in geotechnical instruction to focus on the general and avoid addressing the particular, compared to in other engineering fields. In fact, experience is considered a constituent element of geotechnics (Burland 2008) and geotechnical design (Orr 2008).

Peck (2004) was very clear on the relationship between case studies and experience:

“Learning about the experience of others is where case histories play a vital role. Here is where one learns:

- What worked and what did not,
- What was practical and what was not,
- What is appropriate to the present situation and what is not.

Because practice changes with new procedures, new ideas and equipment, and even because of a new generation of engineers, yesterday’s case histories may not be adequate to improve today’s practices. Therefore, old, even classical case histories need to be supplemented by current ones.”

The key role of case studies is highlighted in several recent seminal papers on geotechnical education, e.g. Jaksa (2008), Phillips (2008), Rogers (2008), Jaksa et al. (2009). Case histories allow students to appreciate the complexity and full context of a real design situation which involves the ground, the structure and the construction method. Case histories show the simplifications and assumptions that need to be made in practice. They also show the tests that are used to obtain the different soil parameter values and how the values of soil parameters values are selected in practice. The selection of case histories for a particular course should respect the competencies of the students.
on the course. Case histories should be presented in appropriate detail and with appropriate models for the particular level. Simple models and straightforward design situations are required for bachelor level while more advanced models and more complex design situations are appropriate for master level. These distinctions can be made in a most transparent manner by defining suitable learning outcomes, as discussed below.

4 SPECIFIC LEARNING OUTCOMES FOR SPECIFIC GEOTECHNICAL COURSES

Case studies are valuable aids to the instructor for a variety of general purposes. These purposes may be affective, i.e. to produce a particular effect such as to spice up lectures and motivate students to study the subject matter through using case studies of local interest or with a dramatic element, e.g. failures. Other general purposes may be cognitive, i.e. to show the contribution of a particular analysis to the complete set of calculations and to explain the construction issues associated with particular design decisions.

These general purposes, affective and cognitive, must be distinguished from the specific learning outcomes as defined in Section 2. Table 1 proposes a set of 10 broad outcomes covering a wide spectrum of performance levels for a study programme in geotechnical engineering. These outcomes are chosen to be complex enough, a characteristic that makes them prime candidates to be achieved through using case studies. Table 1 contains horizontal outcomes, i.e. they concern almost all geotechnical courses, and should further be specified in more detail for an individual course, e.g. see Kunberger (2012). The “safety elements” of outcome 7, which include choosing suitably cautious parameter values, applying partial/safety factors and making suitable geometric allowances (e.g. overdig allowances), exemplify the notion of a horizontal outcome, which is relevant to many geotechnical problems and courses. In relation to the 24 outcome types proposed by ASCE (2008), outcomes 1 to 8 are “technical”, whereas outcomes 9 and 10 are classified as “professional”.

Learning outcomes 1 to 4 are appropriate for all geotechnical courses, but particularly for introductory and undergraduate level courses, while learning outcomes 5 to 7 and, to a limited extent 8, are particularly appropriate for master-level courses. It is understood that learning outcomes 8 to 10 are only likely to be fully achieved after personal involvement in practice (ASCE 2008). However, it is important that all geotechnical students, including undergraduate and master level, are introduced to the complexities, professional responsibilities and ethical dilemmas that are involved in many geotechnical design situations. Case studies are ideally suited for introducing these concepts and achieving the required learning outcomes at different performance levels. Indeed, stating specific learning outcomes makes discrimination between performance levels possible. For example, without personal practical experience, it is difficult for a student to fully achieve the high level outcome 10 in Table 1 “Appreciate the ethical dilemmas in geotechnical practice”. Nevertheless, a lower performance level outcome is achievable, such as being able to “Describe the ethical dilemmas in geotechnical practice”.

Table 1 is intended to serve as an invitation to the wider geotechnical community to define key learning outcomes and suggest how these may be linked to appropriate courses. For example, soil parameter selection (outcome 6) may be more appropriate for a geotechnical design course rather than a soils laboratory course, where result evaluation often has as an end point the result itself and not its use for a particular design situation. On the other hand, if the goal is to evaluate data obtained from real soils, it is perhaps advisable that students first get some experience with high quality results from field research experiments (Gavin 2012). Then, students can progress to evaluating data from consulting projects, where it is possible that some data may be of such low quality that students have to judge that these data should be rejected, e.g. data obtained from severely disturbed samples (Lo Presti 2011).

5 EXAMPLES OF SUITABLE CASES FOR SPECIFIC LEARNING OUTCOMES

It follows from the above that part of the input required from the wider geotechnical community is, ideally, published case histories that are usable in class, accompanied by details of the desired learning outcomes and examples of the assessment exercises confirming that the outcomes were achieved. This section describes
some indicative examples drawn from the personal experiences of the authors and from a workshop with the theme “Case histories in geotechnical instruction: Appropriate cases for each educational level”. The workshop took place during the XV European Conference on Soil Mechanics and Geotechnical Engineering (ECSMGE) in September 2011 in Athens, Greece, and was organized by the European Regional Technical Committee on Geotechnical Engineering Education (ERTC 16).

Due to the large size of the classes at undergraduate level, exceeding 100 until the recent financial crisis, the first author mainly uses published cases, such as the Transcoma grain elevator failure and liquefaction due to the Christchurch earthquake, for teaching. The aim of these case studies is to show different geotechnical failure mechanisms and the appropriate parameter values and analytical methods. Hence the focus is on achieving learning outcomes 1 to 3. At master level, where the class size is usually less than 20, the author gives students data from his consulting or research experience, for a design, e.g. students are given a number of borehole logs and asked to design a foundation. The aim of these case studies is so that students can appreciate the variability of geotechnical data and can select appropriate parameters and design methods. Hence the focus is on achieving learning outcomes 4 to 8.

The experience of the second author of this paper, whose expertise is environmental geotechnics, was chosen to highlight teaching needs inside and outside the instructor’s area of consulting expertise. In her course “Environmental Geotechnics”, the second author uses primarily case studies of contaminated site characterization and remediation from her own consulting experience. The cases serve the general purposes of motivating instruction and showing how topics taught in the course fit within a real project. In terms of specific learning outcomes, the use of cases contributes towards achieving the stated learning outcome “Students are able to take initiatives related to modelling, i.e. related to the formulation of a simplified problem that admits solution” (Pantazidou 2010). To this end, subsets of the case data are given to students who are asked to calculate input parameters and make decisions with regard to possible simplifications, e.g. calculate hydraulic gradient by approximating groundwater flow as one-dimensional. The second author also teaches part of a slope stability course, for which she had to ask geotechnical colleagues who are consultants to share their records with her. Again she sought a case for the general purpose of demonstrating the contribution of a slope stability calculation to the entire project (design of a portal for a highway tunnel). In order to develop the case material for use in instruction and build the confidence to present the case without first-hand experience, she interviewed the project consultant, after reading the geotechnical investigation and geotechnical design reports. The educational case material produced includes a PowerPoint presentation and a bullet-like case narrative (in Greek). However, it is questionable whether this material can be used by another instructor. The transferability of case material is considered further in Section 7.

Two more instances of using cases in courses, which were presented in the education workshop of the Athens XV ECSMGE, are now discussed briefly. Lo Presti (2011), drawing on material from his own consulting experience, presented the case of a flood-plain bank that, over the years, developed several failure surfaces. The basic characteristic of this case exemplifies the idea of case-based teaching: some problem is presented (cracking) and the students have to diagnose its origin by thinking of and evaluating possible alternatives (a problem with the bank? a problem with its foundation material?). In order to evaluate alternatives, students perform slope stability calculations covered in previous courses. Apart from the application of slope stability methods, the learning outcomes of the course also include determining the soil profile and the soil parameters used in the calculations. The paper provides the key features of geotechnical investigation, while the entire data set is available on the internet (in Italian: www.ing.unipi.it/geotecnica). It remains to be seen if this material can be used by another instructor.

Bouazza (2011) presented details of an environmental geotechnics course designed in the tradition of project-based learning, whereby projects are used both to motivate learning and to give students opportunities to apply taught material. The teaching format alternates between traditional lectures on groundwater, solute transport, clay barriers, etc. and practicals dedicated to the project design. Bouazza has taught the course in this format since 1998, using every year a different project, mostly from his own consulting experience. The case study referred to in the paper was a landfill site, but there was minimal information on the case itself.

6 LOCATING SUITABLE CASES

As mentioned in Section 4, the goals of geotechnical instructors using case studies in their courses may be either affective or cognitive, or both. Locating published case studies to motivate instruction is relatively easy for two reasons. First, almost by definition, published case studies have some unusual characteristics that make them interesting and therefore publishable: they often refer to failures, sometimes dramatic, the investigations of which involve a level of soil characterization that is not customary at the pre-design, pre-construction stage. Second, when cases are used to motivate the presentation of theory, the instructor does not need all the existing documentation available: some key features of the case are adequate and these are typically presented in case study papers from the literature. Jaksa (2008) and Orr (2011) discuss possibilities for locating case studies, placing particular emphasis on geotechnical failures.
A general-purpose motivational case needs less documentation than a case allowing students to select their own, a project-based course. Few people can afford complete teaching and consulting experience from a multifaceted project to transferable educational material. However, smaller-scale projects or parts of projects may offer suitable input to develop into educational case material.

Yadav et al. (2010) provide ideas for educational case material with their two examples of cases in the form of a narrative accompanied by drawings, which provide the pertinent information for students to start thinking “what is going on here”? These type of cases are the tradition in other disciplines, e.g. ethics, law, management, where a case is written up in a few pages, often with a quality justifying a purchase fee (e.g. http://www.ksgcase.harvard.edu/). Geotechnical engineering has the additional difficulty of requiring data in the form of site maps, borelogs, and other data obtained in the field. Nevertheless, it is feasible to limit the scope of a case study. For example, a failure helps focus a case on the data relevant to the cause of the failure.

One way to satisfy the requirements of easy perusal and completeness is by assembling educational case material with the aid of a template. One such template was suggested by Pantazidou et al. (2008), who argued that together with high-profile cases, there is a need to compile straightforward, undistinguished case studies suitable for undergraduate geotechnical instruction. The basic categories of the template are summarized in Table 2, whereas detailed information on each entry is given by Pantazidou et al. (2008). As an example of using the template, Pantazidou and co-workers provided detailed documentation of the case study of a reinforced earth wall (in English), which is available on the internet (http://users.ntua.gr/mpanta/TeachingEN.htm).

The idea of a template was discussed in the education workshop and the opinions were divided: a consultant offering case material for educational purposes was in a favour of a template, whereas an academic expressed the opinion that a template stifles creativity. On retrospect, it is realized that one template cannot fit all case studies. The template presented in Table 2 is suitable for students to work on a manageable design project and corresponds to a specific

### Table 2. Case template with project information grouped in categories (Pantazidou et al. 2008).

<table>
<thead>
<tr>
<th>Category</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Project introduction</strong></td>
<td>Type of project, location of project, photographs</td>
</tr>
<tr>
<td><strong>2. Geological information</strong></td>
<td>Map with borehole locations, soil profile</td>
</tr>
<tr>
<td><strong>3. Relevant analyses</strong></td>
<td>Characteristic cross-section(s), analysis types</td>
</tr>
<tr>
<td><strong>4. Geotechnical investigation &amp; evaluation of test results</strong></td>
<td>Soil tests performed and results, soil profile and soil parameters used in analysis</td>
</tr>
<tr>
<td><strong>5. Construction – design considerations</strong></td>
<td>Constraints and data known prior to analysis</td>
</tr>
<tr>
<td><strong>6. Geotechnical analyses performed</strong></td>
<td>Basic steps of each type of analysis + results</td>
</tr>
<tr>
<td><strong>7. Key points/messages</strong></td>
<td></td>
</tr>
</tbody>
</table>

---

Orr (2011) also discusses the difficulties in locating suitable case studies for instructional use to achieve cognitive goals and specific learning outcomes. The characteristic that makes some case histories publishable is their complexity, and, as a result, these cases may be too complicated to be presented in detail in most geotechnical courses. In addition, many published case histories do not provide all the information required for the students to engage meaningfully, i.e. with some degree of responsibility and autonomy. Finally, and again related to the partial documentation of published case studies, it can be difficult for the instructor to present confidently in a classroom situation case histories in which there has been no personal involvement. As a result, when it comes to the use of case studies to achieve specific cognitive learning outcomes in geotechnical engineering, personal experience is perhaps the most common source of case histories, as shown in Section 5. The advantages of using case studies in which the instructor has been involved cannot be overstated (Orr 2011). Hence, the challenge for the geotechnical community is to make the personal communal, by facilitating the compilation of suitable case study material for use in instruction. To paraphrase Peck (2004), learning from the combined teaching and consulting experience of others is where case study material plays a vital role.

### 7 SUGGESTIONS FOR FUTURE WORK

Building a repository of case study material suitable for use in instruction (from now on referred to as, “educational case material”) will be meaningful provided it satisfies three basic requirements. First, the educational case material should address clearly the stated needs of the user. To achieve this, compilers of case studies should clearly state the intended purpose of the case and the corresponding learning outcomes. This presupposes the development of a taxonomy for learning outcomes in geotechnical instruction, perhaps starting with a list such as that in Table 1. Second, the users should be able to search on-line for material suitable to their needs with relative ease. To fulfill this requirement, cases should be cross-referenced and searchable using both learning outcomes (e.g. determine soil parameters) and geotechnical topic (e.g. consolidation settlement). Third, the case material assembled should be deemed by the user to be complete. This is not a straightforward requirement to fulfill, since completeness is judged against the intended use of the case material. A general-purpose motivational case needs less documentation than a case allowing students to select appropriate calculation models for solving geotechnical problems. Moreover, completeness is judged against the scale of the case. It is unlikely that the repository will include cases able to support, on their own, a project-based course. Few people can afford to dedicate the time needed to transform personal
learning outcome: enabling undergraduate students to practice calculation methods on real cases instead of on idealized, textbook-type problems. Because a template makes it easy to both assemble and then review case material, it appears desirable to have available a few alternative templates and examples of educational case material assembled with each template.

8 CONCLUDING REMARKS

The use of case studies has been a staple component in geotechnical engineering education for decades, for a combination of affective and cognitive purposes. More recently, increased awareness of accountability requirements and the progress made in engineering education research have enabled geotechnical instructors to be more transparent in how they use case studies in instruction by defining specific learning outcomes. This paper proposed a set of learning outcomes for a geotechnical study programme.

Unlike other disciplines that also share an appreciation of the educational value of case studies, the geotechnical community has not developed a tradition of compiling suitable educational case material. In order to increase the repertoire of case studies available to geotechnical instructors for teaching, this paper suggests some actions to be undertaken by the geotechnical engineering community, including the development of alternative case templates and examples of educational case material.

REFERENCES


