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Laboratory work in geo-engineering
The use of online resources to support laboratory classes in soil mechanics

D.W. Airey, P. Cafe & H. Drury

University of Sydney, Australia

ABSTRACT: During the introductory soil mechanics course at the University of Sydney students undertake five 2 hour laboratory exercises (300 students in groups of 10). This paper presents and discusses the benefits of introducing two on-line resources that have been introduced to support the laboratory experience. The first is a set of on-line pre-lab tasks that have been used to prepare students for the laboratory experiences. These have resulted in more motivated and curious students who have engaged more wholeheartedly in the laboratory work. The paper discusses the features of the program that we believe have been important in making this initiative a success: getting the right balance of certain components, making the tasks relatively easy, making it count, and supporting the on-line work with paper-based materials and direct contact. The second is an on-line resource (WRiSE, Writing Reports in Science and Engineering) which has been developed to support the writing of laboratory reports in science and engineering at the University of Sydney. This award winning resource is freely available externally, and one of its modules is focused on the soil mechanics course. The presentation introduces the main features of the WRiSE site: report writing content; language support; presentation; student examples, and lecturer input, and discusses how it is used in the course. This resource has made a significant difference to the written reports. Finally how these resources are used to support the administration and processing of the large student cohort and how they are linked to the development of writing across the civil engineering program is discussed.

1 INTRODUCTION

It is widely accepted that students in civil engineering courses should have exposure to the laboratory, and one of the requirements for accreditation is that students should be able to plan, design and interpret experimental data. In geotechnical engineering the importance of familiarity with materials and routine procedures is also often stressed. For most civil engineering students the need for familiarity with standard geotechnical tests is debatable, and the primary objectives of the soil mechanics laboratories for these students are improved conceptual understanding and helping to make soil mechanics “real”.

There has recently been considerable debate within the science and engineering communities about the effectiveness of laboratory instruction (Reid and Shah 2007, Adams 2009, Feisel and Rosa 2005). There is a general consensus that hands-on laboratory work is an essential component of undergraduate education in the sciences and engineering (Magin and Kanapathipillai 2000, Bhathal 2011) but more needs to be done to make laboratories more effective and better value for the costly equipment, dedicated technical staff, space and faculty time they require.

The educational literature stresses the importance of having clear justification and aims for the laboratory work. Reid and Shah (2007) suggest laboratory work should have 4 broad aims: skills related to learning the subject (soil mechanics), practical (professional) skills, scientific skills (observation, deduction, interpretation) and general skills (team working, reporting, problem solving).

What is common in all these discussions on the state of laboratory work in engineering and science, is that hands-on laboratories are essential, the objectives need to be ones that can only be met by hands-on activities, and there is a need to improve the effectiveness of the experience. The two main suggestions to improve the effectiveness are firstly to give students more involvement and responsibility in the design, planning and conduct of the experiments and secondly to make more effective use of students time in the laboratory by well planned pre and post laboratory exercises. The former approach has been used at the University of Sydney in an elective course with typically 50 students (Airey 2008) but its use with 300+ students would be difficult to manage. Thus the approach that we have been following has been to continue to refine and improve our existing laboratory exercises. For the last three years this has involved making use of on-line resources, and these developments are the subject of this paper.

1.1 Pre-laboratory work

Laboratory classes are costly and resource intensive and it is necessary to make effective use of the time spent in the laboratory. Traditionally, students were expected to prepare for laboratory sessions by reading through a paper-based document setting out theory,
aims and procedure of the experiments. However, most students turned up to the laboratories ill-prepared, and simply followed the directions of the demonstrator. Often the laboratory session ran out of time without reaching meaningful conclusions, and little learning took place. To improve this situation it is important that students come to the laboratory well-prepared, which makes the role of the pre-laboratory work critical. The objectives of pre-laboratory material, as described in Reid and Shah (2007), can include:

1. Stimulating students to think through the laboratory work
2. Encouraging students to recall facts related to terminology, formulae, safety, etc.
3. Checking that experimental procedures have been read, and giving practice in the calculations required during the laboratory
4. Leading the student into thinking about concepts, encouraging revision of prior knowledge
5. Offering experiences in planning
6. Bridging the gap between laboratory and lecture, experiment and application.

Previous studies have reported that pre-laboratory exercises in Physics can improve student performance and improve student perceptions of the laboratory (Johnstone et al. 1998), however, the additional marking was seen as a potential disincentive (Reid and Shah, 2007). A number of studies have reported the use of computer based exercises to support the pre-laboratory work, particularly in Chemistry (e.g. McKelvey 2000) where it has been in use for over 10 years, and sophisticated online Dynamic Laboratory Manuals have been created incorporating video clips and interactive simulations (www.chemlabsbris.ac.uk). There are also a number of uses of computer assisted pre-laboratory work in the biosciences (Adams 2009). One of these (Dantas and Kemm 2008) points out the importance of including assessment, as simply making e-resources available will not itself motivate students. The use of online pre-laboratory work has not been reported in the engineering education literature.

In this paper we will describe how we have implemented on-line pre-laboratory work in soil mechanics, and discuss our observations of the effectiveness of this approach.

1.2 Post-laboratory report writing

Communication skills, both oral and written, are highly valued in engineering graduates, are essential for career progression (Tenopir & King 2004, King 2008), and writing is also important for the development of scientific and technical thinking. With the increasing diversity in the higher education student cohort, deficiencies in students’ writing competency have been noted, and universities and engineering faculty are under increasing pressure from the government, professional bodies and employers to address this issue (Commonwealth of Australia 2007, Nair & Patil 2008). For many engineering students, regardless of their background, report writing presents a challenge, and students need support and direction.

The approach in civil engineering at the University of Sydney has been to integrate writing tasks throughout the curriculum, and these include laboratory reports which are typically completed in the 3rd, 4th and 5th semesters of study. In the past, advice to students on content and presentation was provided in a series of paper documents. Students identified with particularly poor English skills were supported by the University’s Learning Centre but the resources were insufficient to the need. It was clear to the Learning Centre staff that many students needed much more advice on language and presentation skills than could be provided individually and this led to the development of some online resources, and ultimately to the development of the WRiSE site, discussed in more detail below.

Online or eLearning approaches for improving engineering students report writing skills have not been reported widely. However, there is a wealth of information on successful approaches for improving engineering students’ written communication in different higher education contexts. These approaches include collaboration with writing specialists, making assessment tasks and criteria more explicit, providing more realistic, work-related writing tasks, offering a draft/feedback cycle for submission of written assignments and clarifying learning outcomes for writing for engineering students (Boyd and Hassett 2000, Plumb and Scott 2002, Chirwa 2007, Flateby and Fehr 2008). These approaches draw on a number of pedagogical approaches such as situated learning or activity based learning, constructivist and knowledge transformation frameworks and genre based pedagogies (Walker 2000, Paretti 2008, Lord 2009).

Online environments offer students a flexible approach to learning as materials can be accessed at their own pace and according to their varied needs. Although a number of online programs support engineering students with advice and guidelines for report writing (e.g. Winckel et al. 2002) and some provide students with authentic examples and interactive exercises (Clerehan et al. 2003, Drury et al. 2005), they are not closely aligned with specific discipline course curricula and therefore remain largely generic in approach. This difficulty has been overcome in the approach described in this paper by embedding the report writing modules within the soil mechanics course material, and by designing the module from a student perspective with relevant and motivating content. The modules developed not only support students in understanding the structure and language, but also the process of writing their reports. In addition, learning activities to help students understand the concepts associated with the soil mechanics content of the report are included.

This paper will report on the approach and methodology used in the on-line modules, discuss the student
responses, and comment on the value of the online tool.

2 COURSE STRUCTURE

This paper is concerned with a series of 5 laboratory exercises that are integrated within a semester long introductory course in soil mechanics, which for most students is taken in the second semester of their 2nd year of study. The course covers the topics of: definitions and terminology; effective stress; flow of water; settlement and consolidation; and soil strength. The course involves three hours of lectures and a 1 hour tutorial each week for 13 weeks, and five 2 hour laboratory sessions. For the laboratories, students are organized in groups of ten, although each laboratory is organized so that two sub-groups of 5 work fairly independently.

In 2011, nearly 300 students completed the laboratory work. This has been achieved by having 5 sessions a week and running each laboratory over a period of 6 weeks.

The five laboratory exercises are Classification, Compaction, Flow Nets (including permeability), Consolidation, and Shear Box.

The objectives of the laboratory work are to introduce students to soil as an engineering material (to make it real), particularly Compaction and Classification, which support the basic definitions, but importantly allow students to touch and visualize the materials. The later experiments are more sophisticated and their primary objectives are to aid in conceptual understanding. In all cases, students are introduced to the technical and procedural skills that provide a link to the professional practice of geotechnical engineering.

The following activities are completed in each of the 2 hour laboratories:

Classification: Liquid and Plastic Limits by Casagrande and Fall-Cone methods, Sieving and Hydrometer.
Compaction: 4 point Standard and Modified Compaction tests
Flow Net: Flow visualization for dam and drain models, Falling head permeameter test
Consolidation: Use of Oedometer, Construction of void ratio, effective stress relation, Time dependent consolidation for one increment, Hydraulic oedometer to show pore pressure changes
Shear Box: Six tests on dry sand, three normal stresses, two relative densities.

Moisture content analysis by oven drying (both conventional and microwave) is included in compaction, classification and consolidation.

As the students are not required to provide a write-up of each experiment, the necessary recording of data, calculations, interpretation and conclusions have to occur during the laboratory session. This is achieved with the aid of a laboratory manual to assist students in recording the necessary information and directing them to the necessary calculations. In the case of the consolidation and shear box experiments, data are entered into pre-prepared spreadsheets to assist with data manipulation.

The assessment weighting for the laboratory component of the course is 10%, and this is split 2% for the pre-laboratory exercises and 8% for the laboratory report. Attendance and satisfactory completion of the laboratory work are course requirements.

3 PRE-LABORATORY EXERCISES

The pre-laboratory exercises are provided to students online and have been designed to address most of the objectives suggested by Reid and Shah (2007) listed above. In addition we have included three on-line modules discussing safety in the laboratory and instituted an online safety quiz for which all students are required to obtain 100% before being allowed to undertake the practical exercises. It is intended that a typical student will spend 30–60 minutes doing each pre-lab.

There are seven on-line modules for each particular laboratory session (lab), and of these the first five are intended for use prior to the laboratory. The seven modules are as follows:

1. Introduction
2. Theory
3. Method
4. Movie
5. Pre-Lab Quiz
6. Report
7. Worksheet.

Prior to each lab, students are required to attempt the appropriate Pre-Lab Quiz. They are allowed 2 attempts with the highest score contributing 0.4% towards their assessment. The quiz is based on the Theory module and has 10 questions which may ask about theoretical concepts or numerical calculations based upon theoretical formulae. The questions are not difficult but do require some careful focus on the theory. Although called a “Quiz”, these are intended as learning tasks, not assessment tasks, and the questions are intended be within the capabilities of all students. To minimize student collaboration, each question is randomly drawn from a bank of similar questions, questions are randomly ordered and for multiple choice questions the choices are randomly presented so that effectively no two quizzes are the same. Marking of the quizzes is handled automatically in the learning management system (Blackboard) and the marks can be emailed to the laboratory supervisor so that it is known who has attempted the pre-lab work.

The Theory is supported by the Introduction, which is a very simple probing exercise designed to raise their level of curiosity about the lab, and by the Movie which is typically about 3–5 minutes and shows why and how the lab is done.

The Method and Worksheet are reproduced in hard copy and compiled with the safety rules to produce a
Laboratory Book which each student receives at their first laboratory class. The Method describes the steps that need to be followed during the lab and has tables for recording raw data and some basic calculations. The Worksheet is a 2-page interpretative exercise which the students must complete during the lab and is signed by the supervisor on completion. It typically asks students to draw graphs or make conclusions based upon the experimental data, to explain the meaning of some concepts, to compare experiment to theory, or to consider the experiment in a broader context. For most students the completion of the Worksheet is the end of their experiment.

However, 2 students in each group of ten must write a formal laboratory report (students are notified which lab they must write up at the start of the semester). The module Report outlines for each lab what are the report requirements for that lab and has links to various other documents and sites giving guidelines for writing lab reports (including the WRiSE site – See 6 below).

Students who do not attempt the pre-lab quiz prior to the lab receive assessment result of zero for that lab. Five of the seven pre-lab modules are simple documents with images and links (written in MS Word with embedded hyperlinks and saved as web pages). The pre-lab quizzes were written using the University’s On-Line Learning Software (LMS BlackBoard). The movies were compiled by 2 students for an undergraduate final year project, and were originally intended to be shown at the start of the laboratory sessions.

4 INTEGRATION OF ONLINE, HARD COPY AND PERSONAL CONTACT

The online material is supported by written lab materials (The Lab Book) and direct contact with the laboratory staff.

At their first lab session the students receive a short talk from the lab technical manager (mainly concerning safety and tardiness), and a short talk from the pre-lab designer explaining how the pre-lab program works, stressing the expectation of a professional approach to the laboratory and their report, and warning of the consequences of not doing what is required.

Students who do not attempt the pre-lab quiz prior to the laboratory, or who do not get more than 6/10 for a pre-lab quiz (information easily obtained from the LMS) are questioned individually during the laboratory and encouraged to take the pre-lab work more seriously. This approach has been very successful in obtaining near full compliance with completing the pre-lab quizzes.

5 LABORATORY CONTENT

The content of each laboratory and the tasks actually performed during the class have remained essentially unchanged despite the introduction of the online material. We are still using old equipment with weights on hangers, and dial gauges, the only exception being the hydraulic oedometer where a pore pressure transducer and associated voltmeter are used. Although the civil engineering laboratory exercises were suffering from an appearance of old-fashionedness, neglect and irrelevance, this was not in content, but in style and delivery. The soil mechanics laboratory exercises were designed over 30 years ago in a very different student environment, but are still relevant to today’s laboratory objectives. We concur with the comment by Reid and Shah (2007) “to change the experience, you don’t need to change the experiment, just what you do with it”.

Minor changes to the laboratory content were made:

- to simplify some processes to ensure that the laboratory sessions could be completed in a compact 2 hours, and
- to provide computers in the laboratory with prepared spreadsheets to remove the onerous calculating and graphing which were always prone to errors and detracted from the learning purposes of the Consolidation and Shear box laboratories.

6 POST-LABORATORY

When the first author joined the University of Sydney, students were required to produce a write up for all five laboratories, and this was repeated in other courses which also had a laboratory component. One of the results of this was that students generally made little effort to produce a good report and copying from previous years was rife. The report writing was initially reduced to two of the exercises with the idea that students would receive feedback on the first to improve on the next. While this reduced plagiarism it did not entirely eliminate it, and the step was taken, also driven by increasing student numbers, to reduce the number of required reports to one. Feedback in this course would then be expected to be used in producing a laboratory report in a fluid mechanics course the following semester. It became evident during this process that the appropriate objective for the write up of the soil mechanics report was to learn the skills and process of presenting a professional style report. This built on writing tasks in earlier semesters (in other subjects), but involved a substantial advance in the presentation aspects. The structure of the laboratory write up in the fluids course in the next semester is similar. However, a heavier weighting is given to the data interpretation. The intention is to assist the students to develop their writing skills by raising the expectations from one semester to the next.

The current arrangement is that for each sub-group of 5 in the soil mechanics course, only one student will be responsible for the writing up of any laboratory session. The objective of the writing exercise is primarily to get the students to write a well-structured
and professionally presented report, with appropriate language. To assist the report writing task an online module WRiSE (http://learningcentre.usyd.edu.au/wrise/home-B.html) has been created through collaboration with language and learning specialists and technical and eLearning specialists. Language and learning specialists have created learning materials to address the structure and language of a typical soil mechanics report based on their analysis of a corpus of student reports from previous years. Technical and eLearning specialists converted these learning materials into online modules. A student and the first author also provided audio interviews for the site. The student commented on the process of report writing and the difficulties he encountered and the lecturer explained his expectations of students’ report writing, student difficulties and how to improve. The on-line module also contains a quiz to help with understanding the content of the laboratory exercise.

The WRiSE site contains 9 modules designed to support writing across science and engineering. The Civil engineering module is based on the requirements of the soil mechanics course. The design of each module is based on a model of learning which takes into consideration students prior writing experiences, their current perceptions and approaches and their interaction with the learning environment designed to support their written assignments (Prosser and Trigwell 1999, Laurillard 2002). The online approach to teaching writing is supported by a theory of language (Systemic Functional Linguistics after Halliday 1985, Martin 1999) and a genre based pedagogy which emphasises the influence of context and purpose on text structures (Cope and Kalantzis 1993, Martin 1999). This approach is widely used to teach writing at university, in both face-to-face and online situations (Jones 2004, Drury 2004).

Following genre based pedagogy, the online design makes explicit both the product and process of report writing through structured and scaffolded learning tasks embedded within the context of the course. This is captured in the Help with Report Writing section of the module which guides the user through the sections of a typical soil mechanics laboratory report. These include: the overall structure and purpose of a typical laboratory report; what kind of information belongs in different sections of a report; how to structure the information in each section in a logical way; and how to use scientific language in an appropriate way. This is achieved by providing students with interactive and animated explanations and exercises, with feedback, to make explicit the structure and language of each section of a typical laboratory report. Authentic student examples for each report section are highlighted and annotated as the basis for providing an explanation of the structural stages and language features. These examples have all been taken from the Flow Net laboratory exercise. This exercise was selected as it contains all the elements of a laboratory report, and the interpretation which requires comparison between theory and experiment has always been poorly attempted. As only one fifth of the students have to write up this report this might be expected to advantage these students, but this has not been evident in the marks.

Students can also undertake self-testing quizzes on entry to each section to find out what they already know about writing that particular section. At the same time, students can access a learning module to help them understand the content of the experiment they are writing about. This takes the form of a multiple choice quiz that is intended to assist students with their understanding of how to construct a flow net. In this way, both language and content are brought together.

7 DISCUSSION

The introduction of both the pre-laboratory work, and the support for the writing task, have both produced significant gains. Attempts to obtain student feedback have not been very effective, so it is difficult to quantitatively assess the impact on student learning and attitudes. Nevertheless, the outcomes measured in performance and attitude in the laboratories have changed dramatically for the better. The majority of the students turn up well-prepared for the laboratory classes, have a reasonable idea of what they are meant to be doing and why. The biggest difference is that all students are actively engaged and it is now rare to have a student wandering around the laboratory, talking to friends, and other unacceptable tendencies. Different students take to the pre-lab tasks with differing levels of commitment, but we have found that the pre-lab program has pushed up the level of well-prepared students from less than 1 in 5 to about 3 in 5. This creates a dominating group-dynamic which sweeps-up the less-committed students and leads to far greater individual completion rates for the laboratory worksheets, as opposed to just copying another students numbers. As noted above, all students have to complete the recording of data and the worksheet to be marked off as meeting the laboratory requirements.

The laboratory supervisors who had looked after the same laboratory exercises before the pre-lab program were strongly of the opinion that the laboratories were now much easier to run, and that students were more motivated and understood the laboratory much better. The greater student preparedness has meant that conversations between supervisors and students have been more sophisticated and this has enhanced the teaching and learning. Also, it has resulted in the exercises being properly completed within the scheduled 2 hours.

Completion of the pre-lab quiz was no guarantee that students had read all the pre-lab material, because the quiz was based mainly on the theory section. Nevertheless, it is considered that the benefit of at least getting the students to give some thought to the upcoming laboratory was of value.
A further benefit of the pre-lab work is that it enables students to tackle the laboratory well prepared even if the laboratory is scheduled either before or after the relevant course lectures. The laboratory exercises are generally scheduled to commence one week before the lectures on that topic, and finish four weeks after.

To assess the WRiSE site module, students were asked to complete questionnaires on their past writing experiences, the user friendliness of the module, their pathways and the sections they had accessed and their perceptions of how the module had improved their understanding and confidence. Unfortunately numbers completing and returning the questionnaire were small ($n = 17$ users, $n = 6$ non-users), but informal evaluations carried out during laboratory sessions indicated that the majority of students had in fact used the module and were overwhelmingly positive about it. Tracking data also support extensive use of the soil mechanics module. The majority of civil engineering student users agreed or strongly agreed about their improved understanding and confidence in both report writing and understanding of discipline content related to report writing.

Performance data also indicated that students who used the site gained higher average report marks ($mean = 58.64$) than those who did not ($mean = 51.33$). This trend was repeated across other science and engineering discipline areas and, on average, report marks of those who used the site were significantly higher than those who did not ($t (306) = -3.02$, $p = .01$). Since the user and non user groups displayed similar demographic and language characteristics and reported comparable past writing experiences, it can be concluded that the website helped students to improve their performance in report writing.

It was evident when marking the reports, from presentation and language, that some students had engaged with the report writing module and for these there were significant improvements in the reports compared with previous years when students received only general advice on report writing. However, there has not been a significant increase in the average mark, and this is because the marker expectations are now higher.

Despite these benefits and the evident success of the online learning environment in improving students’ report writing, a number of issues remain. The majority of students who reported not using the website said they did not know about it and this was despite the fact that it was strongly promoted during lectures, and through links in the course website. It may be the case that students are overwhelmed by the variety and number of online resources available to them. We have noticed that when provided with simpler paper based instructions, even though these are excellent and contain all the necessary information, the students did not spend time engaging with the WRiSE site and the quality of the reports suffered. We have learnt from this the importance of providing a single and unambiguous set of instructions about the need to access the WRiSE material.

Also some students were either neutral or disagreed about the benefits of the module. Some of the open ended comments indicated areas of dissatisfaction or confusion ‘quizzes were a waste of time’; ‘the content should be much simpler’; ‘the module helped me improve my report writing but there were ambiguities with knowing what was expected’ and ‘the site was particularly helpful for me as my report was on flow tanks, might not be so helpful for other areas’. Students also wanted more practice, more examples and more feedback on their report writing and may not have engaged with the site due to the low weighting given to the report (8%).

In addition, implementation practices need to be proactive so that students are introduced to the learning materials in laboratory sessions or lectures and they do not merely remain as a link within a learning management system. At the start of the semester students claimed they were using the website when handing in their reports, but in fact, the early reports submitted did not show any improvement and it was only when this was pointed out and the importance and relevance of the learning module reiterated in a lecture that students used the website properly.

8 CONCLUSIONS

We present these conclusions largely as a matter of judgment based upon our direct observations and anecdotal evidence from students and laboratory staff.

The pre-lab program has re-energised the laboratory component of civil engineering. Students now see the lab program as an essential and interesting element of civil engineering. Laboratories are clearer for the students and easier to run for the supervisors.

The driving force of the entire program is personal contact with the students – the online pre-lab work is not a “set-and-forget” solution for laboratory preparation.

The glue in the whole program is the consistency or dove-tailing of the various components: online, hard-copy and personal contact present a coherent, well-planned laboratory session for the student. This is also referred to as blended learning.

The main motivation for students is that each pre-lab quiz is worth 0.4% of their final assessment. This small amount is enough that nearly all students (>92%) do the pre-lab quizzes without any further prompting and more than half make a second attempt to improve their mark. This represents quite a lot of self-driven learning. Anecdotally we have noted that 0.4% is not enough motivation for students to cheat. Based on the students’ responses, we believe that we have struck the right balance between marks earned and the time and difficulty required to complete the quizzes.

A secondary motivation is that the pre-lab modules are interesting, well-presented and colourful, with a good selection of supporting images and links to
other sites for further exploration. They are also highly relevant to the laboratory exercises, a fact which students soon become aware of.

A third motivation is that students know they will be questioned face-to-face if they do not do the pre-lab work or if they perform badly on it. This is a simple but very successful technique and is particularly effective with students who have a predilection to “disappear in the crowd”, which is particularly common among international students with cultural adjustment or language difficulties. It only needs to be done a few times before all students get the idea.

For the average student the pre-lab program provides the resources they need and want to get through the laboratory program. They know they have to do it, but they also know it will make the laboratory more interesting and relevant.

The online resource WRiSE has made a significant difference to the writing and presentation of student reports. The challenge is to get the students to use it. One possibility suggested by the success of the pre-lab work is to include a quiz within the WRiSE module that can count towards the course assessment. Alternatively we could include some of the activities from WRiSE in a tutorial session so that students could work through the language activities and apply them to a draft report.

The success of WRiSE has led to further support to develop an online writing centre to support engineering students with writing throughout their undergraduate years, and in particular with their writing of a major project report in their final year of study. The lack of development of writing skills in the early undergraduate years means that writing a large report is challenging both for the students and their lecturers who need to provide them with feedback and guidance. The use of online resources such as WRiSE assist in integrating writing skills into the curriculum so that students learn how to write as engineers and enables them to use writing to consolidate their engineering knowledge.

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