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Undergraduate Teaching of Ideal and Real Fluid Flows: the Value of Real-World Experimental Projects

by
Tom E. BALDOCK ([1]) and Hubert CHANSON ([2])
([1]) Senior Lecturer, Division of Civil Engineering, The University of Queensland, Brisbane QLD 4072, Australia, Email: t.baldock@uq.edu.au
([2]) Professor, Division of Civil Engineering, The University of Queensland, Brisbane QLD 4072, Australia, Url: http://www.uq.edu.au/~e2hchans/, Email: h.chanson@uq.edu.au

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STRUCTURED SUMMARY

This study describes the pedagogical impact of real-world experimental projects undertaken as part of an advanced undergraduate Fluid Mechanics subject at an Australian university. The projects have been organised to complement traditional lectures and introduce students to the challenges of professional design, physical modelling, data collection and analysis. The physical model studies combine experimental, analytical and numerical work in order to develop students' abilities to tackle real-world problems. A first study illustrates the differences between ideal and real fluid flow force predictions based upon model tests of buildings in a large size wind tunnel used for research and professional testing. A second study introduces the complexity arising from unsteady non-uniform wave loading on a sheltered pile. The teaching initiative is supported by feedback from undergraduate students. The pedagogy of the course and projects is discussed with reference to experiential, project-based and collaborative learning. The practical work complements traditional lectures and tutorials, and provides opportunities which cannot be learnt in the classroom, real or virtual. Student feedback demonstrates a strong interest for the project phases of the course. This was associated with greater motivation for the course, leading in turn to lower failure rates. In terms of learning outcomes, the primary aim is to enable students to deliver a professional report as the final product, where physical model data are compared to ideal-fluid flow calculations and real-fluid flow analyses. Thus the students are exposed to a professional design approach involving a high level of expertise in fluid mechanics, with sufficient academic guidance to achieve carefully defined learning goals, while retaining sufficient flexibility for students to construct there own learning goals. The overall pedagogy is a blend of problem-based and project-based learning, which reflects academic research and professional practice. The assessment is a mix of peer-assessed oral presentations and written reports that aims to maximise student reflection and development. Student feedback indicated a strong motivation for courses that include a well-designed project component.

REFLECTIVE ESSAY DETAILS

Group structure and assessment

Several options are possible in determining the student group structure. Either students are placed in a group according to set criteria or at random, or students determine their own groups. While the pedagogic outcomes for individual students and the group dynamics probably depend on the choice made, the course structure at the University of Queensland leads often to timetable clashes that restrict choice. Therefore academic staff form the groups based upon students' preferences and timetable availability. Each student then has the option of swapping with another student if both wish to change. Few difficulties have occurred with group dynamics during experimental works with all members usually contributing fully. However, contingency has to be made for illness since the projects run on a tight time-frame and cannot be rescheduled. The group size is dictated by logistics to some extent, but the projects are modified annually to suit. Each project requires extensive commitment; one week of experimental time using the facility and 1-2 days of technical time to setup, and technical staff are on call throughout. As academics, the lecturers commit 2-3 days over and above normal class hours. Research students are involved if pedagogically appropriate. It is difficult to quantify the overall costs. As an indication, typical rates on a consulting basis are $300/hour for both the facility and technical time. One aim of the projects is to introduce students to the complexity of physical model testing, so that they maximise their use of increasingly expensive facilities if they need to do so as professionals.

Each group is required to summarise their experimental results and analysis in an oral presentation in front of the class, other students, and academic and technical staff. This is assessed by their peers (50%) and the academic staff (50%), subject to moderation if required. In addition, students submit a group report which is assessed by the lecturers. Individual tasks within the report are determined by the students themselves. This has led to a small number of problems with group dynamics, when some members believed that others did not contribute fully. To address this, team members might be requested to complete an anonymous peer rating of the contribution from their colleagues and themselves. This is assessed by academic staff and marks may be adjusted in consequence. In future, it is conceivable that groups may be asked to formalise their group work, including meeting times, member tasks/responsibilities, expectations, and how to deal with conflicts.

Student experience

A key outcome of the projects is the personal hands-on experience gained by students. While this aspect is difficult to quantify and often ignored by university management, there is no doubt that practical experimental work enhances student's individual experience and personal development. Both authors have experienced this first-hand, and they receive laudatory individual feedback. Group work contributes to new friendships and openings, e.g., between Civil and Mechanical engineering students, between Australian and international students, and between students and technicians involved in the study. Such personal experiences are at least as important as the academic experience.

Handwritten and verbal student comments added some personal feedback highlighting a strong student motivation for the fluid mechanics course associated with the experimental projects. The projects helped the students to face real professional situations. These motivated them much more than conventional lectures and audio-visual aids (e.g. slides, video). The students understood that they were facing a professional challenge. For example, "this is awesome", "fascinating", "I did not think of the problem that way" (CIVL4160 students' comments on the wind tunnel project). The students demonstrated a greater motivation for hands-on experiences under academic supervision.

This increased interest for the course translated always in higher marks in semester work and examination papers, and, more importantly, a smaller failure rate in the subject. Prior to the introduction of experimental projects, the failure rate in the advanced fluid mechanics subject ranged from 20 to 30%. Since the introduction of professional projects, the failure rate, in the same subject, has been reduced down very significantly. (This trend was clearly noted because the subject curriculum remained unchanged.) In the first two years following the introduction of the project, the failure rate was zero, and 10% in the third year. The impact of the projects on students' performances was noticed among all students. Anonymous student feedback on the projects was collected in 2003. The anonymous results demonstrated that students considered the projects as an essential component of the fluid mechanics courses and an important aspect of their civil/environmental engineering curriculum. For example, 100% of the students agreed strongly and very strongly that "the project work was an important component of the subject" and that "all things considered, project works in industrial facilities are an important component of the curriculum". Project works encouraged strong group bonding allowing students to gain better in-depth understanding of professional teamwork and designs. Although the students believed that the projects did not replace traditional lectures, a large majority felt that the project experience helped them to think more critically.

While introductory laboratory classes are simple, advanced projects, such as those described above, may be sometimes feared by students. The writers can mention cases of students who were apprehensive about the practical activities prior to the activities. Yet all the students had the courage to take on the challenges and the writers have not experienced a single failure. Discussions with students after the projects indicated that all had a positive learning experience. In particular, students learned the difficulties associated with the complexities of making real measurements, working with advanced, and sometimes "temperamental", instrumentation and equipment, and the extent to which careful planning can help resolve many issues in the testing process, but invariably never all. There is therefore always the challenge of fixing a problem or finding a way around it. Such experience cannot be gained in the classroom.

Finally it is important to note that the experiment arrangement may require immediate expert technical assistance to change or fix broken apparatus. The availability of Technical Staff is an essential aspect of this form of teaching, and must not be overlooked during planning. At present the writers are fortunate to have this level of technical assistance available and they believe that it should be properly accounted for in the teaching budget. Indeed the students always learn a great deal from Technical Staff who are experts in the field of model testing and equipment calibration. At the same time, the projects expose the students to the issues of measurements errors and reliability. This is another pedagogical outcome.

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