Laboratory Teaching in Undergraduate Hydraulic Engineering – Addressing the Negative Sentiment

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Index Terms: Laboratory, student evaluation, questionnaire survey

ABSTRACT

This paper summarises the findings of a study to investigate reasons for negative sentiment towards laboratory instruction in the 3rd Year Hydraulic Engineering module in the Civil Engineering programme at University College Dublin. The study involved analysing the results of an independently and anonymously conducted survey of 3rd Year students in the 2007 - '08 academic year. A total of 55 questionnaires were circulated and of these, 44 were returned, representing a response rate of 80%. Results indicate that laboratory instruction that is activity based and involves hands-on input from students is preferable to a format where laboratories consist of formal demonstrations given by trained technicians. Within such an activity based learning programme, the need for effective communication between demonstrators and the laboratory group is essential if the required learning objectives are to be met. The timing of laboratories in a teaching semester is also important and for optimum benefit should be scheduled to ensure that material relevant to the laboratory should first be covered in both lectures and tutorials. Good organisation should not be limited to timetabling issues alone but should include the finer detail that relates to the duration of laboratory classes and the size of groupings within these classes.

INTRODUCTION

Laboratory instruction has long been considered an integral part of undergraduate engineering education and in many instances is reflected in the established learning requirements that need to be demonstrated for an undergraduate engineering programme to be professionally accredited (e.g. by Engineers Ireland and by the Canadian Engineering Accreditation Board as reported in [1]). The benefits of laboratory teaching are well documented and include illustrating principles taught in lectures in addition to familiarising students with both apparatus and measuring techniques in an experimental environment [2][3]. Laboratory instruction is a fundamental component in the 3rd Year Hydraulic Engineering module at University College Dublin (UCD). Within this module, each student is required to complete three laboratories. Although it is recognised that there has not been universal agreement on the objectives of engineering laboratories [4], practical laboratory classes in this module have as their main objectives: (a) strengthening the relationship between theoretical concepts and practical applications; and (b) allowing students to visualise important principles in a controlled environment. However, negative sentiment towards these laboratories has prevailed over the last number of years. In an attempt to further investigate the reasons for this negative sentiment, an independently and anonymously conducted survey of 3rd Year students in the 2007 - '08 academic year was undertaken. The results of this survey are presented in this paper.

BACKGROUND

Fuelled by the "Celtic Tiger", Ireland has recently witnessed a phenomenal upsurge in the development of residential, commercial and industrial properties and in the civil engineering infrastructure required to facilitate development at this scale. The high profile of the construction industry has attracted considerable numbers to Civil Engineering programmes throughout the country. Civil Engineering at UCD is no exception to this and over the last decade has experienced significant growth in undergraduate numbers. Increasing numbers increase the pressures on available resources, particularly with regard to laboratory teaching. One module to suffer these pressures in the UCD programme is Hydraulic Engineering. Hydraulic Engineering is a compulsory module for

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undergraduate Civil Engineering Students at UCD. The module is delivered in Year Three of a four-year programme and consists of three components. The main component comprises 36 hours of lectures where theoretical concepts are presented and explained. These are augmented by tutorials where students are given the opportunity to apply theory to practical design problems and by laboratories where data is extracted from hydraulic apparatus to produce a known result. Laboratory capacity can be increased to accommodate increasing numbers by large-scale capital investment in laboratory infrastructure. However, due to financial constraints combined with the fact that undergraduate Civil Engineering numbers have historically fluctuated in line with the prevailing health of the construction industry, a permanent increase in laboratory capacity for the UCD Hydraulic Engineering module was neither a practical nor a financially viable solution.

Since 2006, when the UCD undergraduate programme was semesterised, the Hydraulic Engineering module has been scheduled into a twelve week teaching semester. Prior to this, the module comprised 24 teaching weeks that included 48 lecture hours in conjunction with associated laboratories and tutorials. The semesterised structure has therefore placed additional strains on laboratory resources already under pressure from large student numbers. In preparation for the semesterised structure and for the purpose of easing these pressures, consideration was given to increasing the size of laboratory groupings and/ or reducing the duration of laboratory sessions within the existing laboratory teaching framework. In addition, the option of 'stretching' resources by removing the hands-on component that is typical of many laboratories was also considered. This would have involved changing the laboratory format to formal demonstrations given by trained technicians with significantly reduced input from students. However, it was felt that any of these options would result in devaluing the student laboratory experience. As a result, changes to laboratory teaching in the Hydraulic Engineering module were resisted in the first year of semesterisation and continued to follow a structure where students receive written and oral instruction, complete specified tasks, record data and report in a prescribed format.

Each year, the module (as with all other modules in the undergraduate programme) concludes with an independently conducted student evaluation in which the teaching quality of all components are assessed. The results of these evaluations for the three years up to and including the 2006 – '07 academic year indicated that while the lecture and tutorial content of modules is generally very favourable, a disproportionate number of students fail to realise any benefit from laboratories. Although not reflected in closed questions in the end-of-year evaluation, answers to an open ended question showed that an overriding concern of students was that the semesterised structure compressed all teaching and required that some groups completed laboratories prior to the relevant material being covered in lectures. An attempt was made to rectify this for 2007-'08 by reducing by half the duration of laboratory sessions and thereby enabling all laboratories to be undertaken in the latter half of the semester. However, results of the evaluation for laboratory teaching that year were significantly worse than in previous years and suggested that other issues may be impacting on the quality of the laboratory learning experience. The results of these evaluations, shown in Fig. 1, highlight the ongoing negative sentiment towards laboratory teaching. The data in Fig. 1 is based on 45 responses from the 2004 – '05 evaluation, 51 from 2005 – '06, 27 from 2007 – '08 and 48 from the most recent survey of 2007 – '08.

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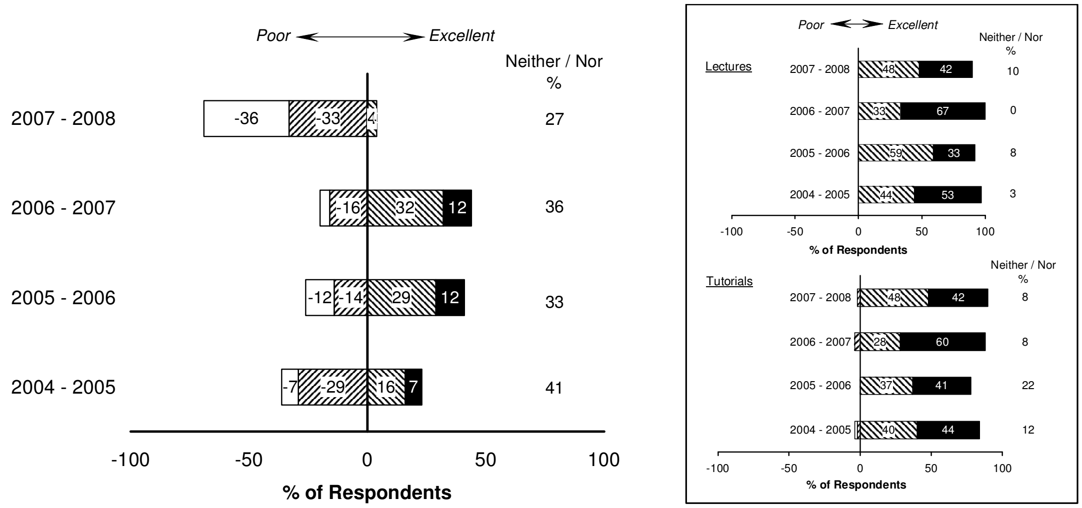

Fig. 1. End of year evaluations of components of Hydraulic Engineering module

As shown in Fig. 1, the evaluations of the laboratory teaching are in stark contrast to that of the lectures and tutorials which are also shown and which are generally very favourable. In an attempt to further assess why this is the case and to assist in developing a new approach to laboratory teaching, a detailed quantitative investigation of Hydraulic Engineering laboratories was undertaken. This involved conducting a detailed survey of the 2007 – '08 3rd Year students to gauge their opinion on the current laboratory structure. The objective of the survey was to identify existing difficulties so that future decision making could be informed by student input.

METHODOLOGY

Quantitative research methods that involved the circulation of an in-class self-completion questionnaire were used in this study. The questionnaire was anonymous and was conducted independently to ensure that results reflected accurately the opinions of students. The questionnaire adhered to the key principles of questionnaire design and, as such, the majority of questions were short and simple and of a pre-coded and prompted nature. Precise and unambiguous questions were formulated to minimise misunderstanding. Both open-ended and closed questions were included in the questionnaire. Closed questions were designed with a meaningful scale that was selected to provide a good spread of answers. Where appropriate, scales comprised equal intervals between equivalent end points (e.g. very dissatisfied, quite dissatisfied, neither satisfied nor dissatisfied, quite satisfied and very satisfied). The main themes of the questionnaire assessed (1) The benefit of laboratory learning in comparison to other teaching components of the Hydraulic Design module; (2) Understanding the objectives of laboratory teaching; and (3) The problems/ limitations with current arrangements for laboratory teaching.

A total of 55 questionnaires were circulated and of these, 44 were returned, representing a response rate of 80%.

RESULTS AND DISCUSSION

Until recently, there has not been general agreement on the objectives of engineering laboratories [4]. However, practical laboratory classes in the UCD Civil Engineering programme should serve to (1) Strengthen the relationship between theoretical concepts and practical applications; and (2) Allow students to visualise important principles in a controlled environment. To realise the benefits of laboratory instruction, understanding their objectives is necessary. The initial part of the survey required that students express the degree to which they agreed or disagreed that these two objectives were met. The results, based on the 40 students who responded to this question are summarised in Fig. 2.

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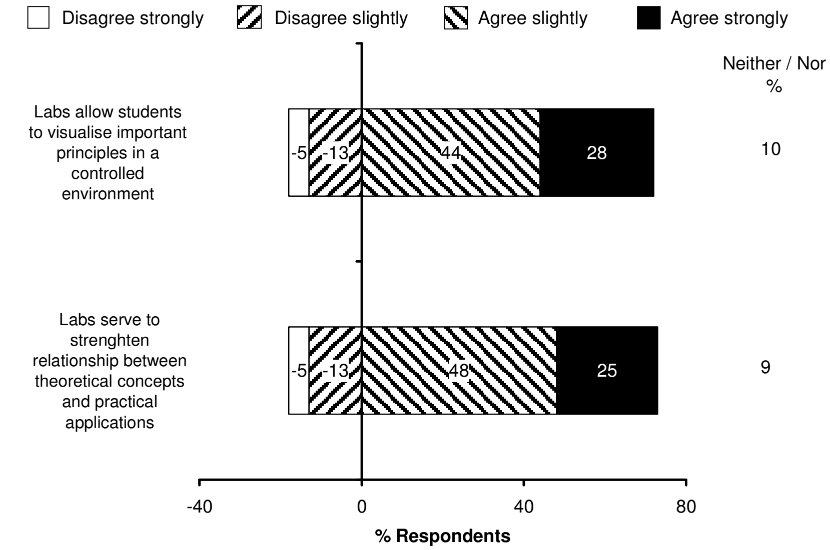

Fig. 2. Levels of agreement that objectives of laboratory instruction are being met

The results in Fig. 2 are encouraging in that a significant majority of students understand the objectives of laboratory instruction but more importantly are satisfied that these objectives were met in the most recent laboratory exercises in Hydraulic Engineering.

Following this, the survey focussed on assessing how laboratory teaching contributed to understanding the principles of hydraulics in comparison to both lectures and tutorials. For this, students were asked to express their satisfaction levels in this regard for the three components of the module. There were 44 responses to this question and these are summarised in Fig. 3.

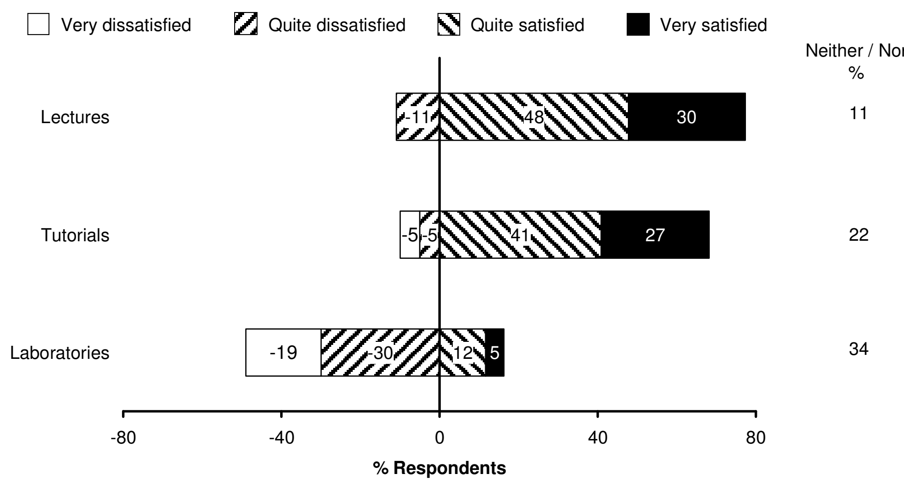

Fig. 3. Satisfaction levels of how module components contribute to understanding principles of hydraulics

Fig. 3 shows that levels of satisfaction for laboratories are significantly lower than for both lectures and tutorials and suggest that the benefits of this component in conveying hydraulic principles are relatively poor. This would appear to be somewhat inconsistent with the findings shown in Fig. 2 where students indicated that the learning objectives of the laboratories are being met. Laboratory classes should, by their hands-on nature, provide students with greater scope for creating and developing ideas than would be possible from lectures and tutorials. This resource therefore, should potentially provide an ideal environment for contextualising and

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understanding these hydraulic principles. Students who expressed dissatisfaction were given the opportunity to provide reasons for this being the case. This was an open ended question to which 18 of the 44 (approximately 41%) students provided replies. These responses were collated and grouped into common themes as shown in Fig. 4.

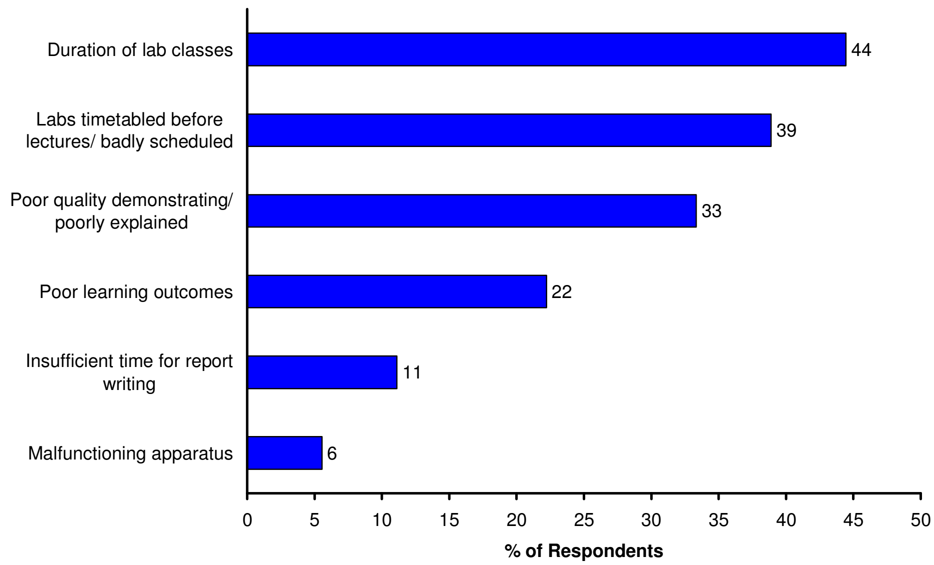

Fig. 4. Reasons for dissatisfaction with laboratory teaching

Fig. 4 highlights a variety of reasons for laboratories failing to realise their full benefit in assisting students with the understanding of hydraulic principles. The most common reason cited (44%) related to the duration of laboratory classes. Results here were inconsistent however, with no agreement that laboratories were either too long or too short. This issue was dealt with in greater detail elsewhere in the questionnaire from where more detailed responses were given. These results are presented in Fig. 5. Another issue shown in Fig. 4, identified by 11% of students, was that insufficient time was available for preparing laboratory reports. It was a requirement that student reports for each experiment were electronically produced and submitted within 2 days of taking measurements. A further problem identified by 39% of students was that although laboratories were scheduled in the latter half of the semester, some students were still required to complete laboratories prior to the relevant material being covered in lectures and tutorials. Poor learning outcomes also feature in Fig. 4. Issues with demonstrating (cited by 33% of students) were raised in this open ended question but this too was dealt with elsewhere in the questionnaire and its results are presented in subsequent paragraphs in this paper.

Laboratory classes in Hydraulic Engineering typically comprise groups of no more than 8 students being assigned to a single demonstrator for each experiment. Each group is required to complete three experiments. Demonstrating of laboratories is a compulsory part of postgraduate study in Civil Engineering at UCD and is exclusively carried out by research students with assistance from staff technicians. A period of one hour is allocated for the demonstrator to explain the principle of the experiment, the workings of the apparatus and for the students to record the physical measurements for the experiment. Completing the experiment requires a hands-on input from the student in which the demonstrator assumes a supervisory role. All students are required to be involved in this process. A potential alternative to this involves changing the laboratory format to formal demonstrations given by trained technicians with significantly reduced input from students. The questionnaire asked for student opinions on (a) size of laboratory groupings; (b) length of laboratory classes; and (c) whether technician demonstrations would be preferred to laboratories where students had hands-on input. A total of 40 responses were returned to these questions and are presented in Fig. 5.

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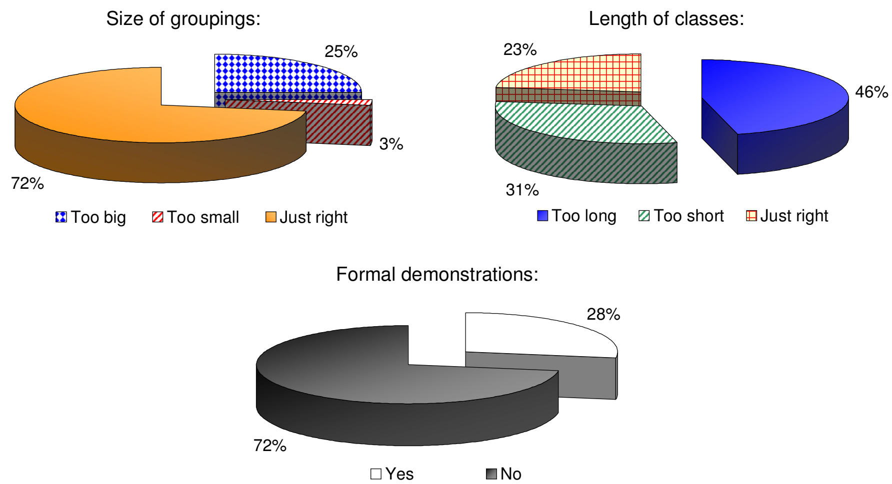

Fig. 5. Student opinions on (a) size of laboratory groupings; (b) length of laboratory classes; and (c) whether technician demonstrations would be preferred to hands-on student input

Fig. 5 indicates general satisfaction with the size of laboratory groupings with only 25% of students suggesting they be made smaller and 3% preferring larger groups. Results relating to the length of laboratory classes are less decisive with no real consensus of a preferred length emerging. Fig. 5 suggests that the existing hands-on component of laboratory instruction appeals to the majority of students with only 28% expressing a preference for the laboratory format to change to formal demonstrations given by trained technicians.

An issue with laboratory instruction as shown in Fig. 4 relates to the quality of demonstrating and explanation of laboratory issues being provided to students. The questionnaire investigated this issue by asking students to express their levels of satisfaction/ dissatisfaction with the demonstrating they received and if they were dissatisfied, to give reasons why. Results are shown in Fig. 6.

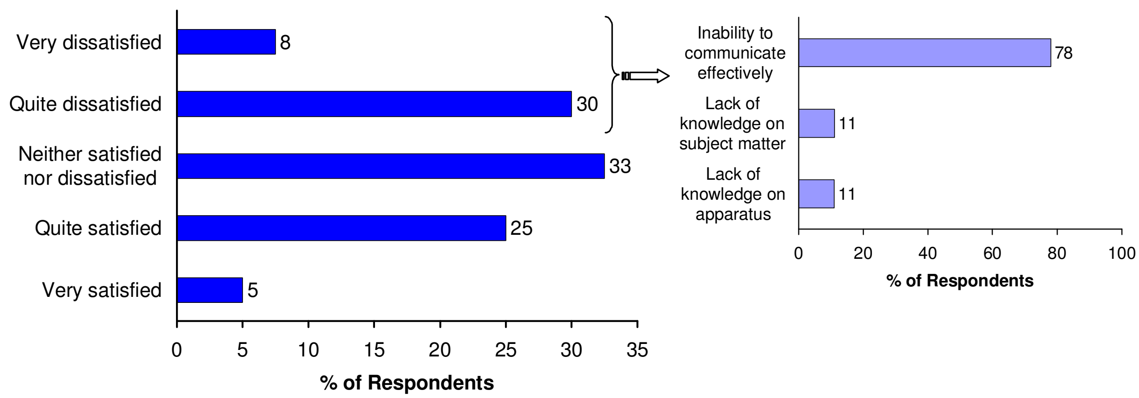

Fig. 6. Levels of satisfaction/ dissatisfaction with laboratory demonstrating with reasons for dissatisfaction

A total of 40 responses were returned to the first part of this question with 15 of these (38%) expressing opinions of either being 'very' or 'quite' dissatisfied with the demonstrating that was given. However, 27 of the respondents provided reasons for being dissatisfied, indicating that some students who were not dissatisfied highlighted some negative aspects with the laboratory demonstrating. These were collated and grouped into common themes and are also included in Fig. 6.

The overriding issue with laboratory demonstrating, cited by 78% of students who gave reasons for dissatisfaction relates to the inability of demonstrators to communicate effectively. The "Celtic Tiger" in Ireland and the buoyant conditions that have prevailed in the construction industry have resulted in an abundance of

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highly paid employment opportunities being available for graduate civil engineers. This has made it increasingly difficult to attract graduate students with English as their first language to research opportunities and in recent years, a significant proportion of postgraduate students have come from overseas. These students, particularly in their early years in Ireland, must become proficient with the English language and this sometimes presents barriers to effective communication and explanation in the laboratory environment. Insufficient knowledge on both the subject matter of the laboratory and of the apparatus was also perceived as a problem in Fig. 6. These issues are more readily addressed and can be done so through improved briefings and training with the laboratory apparatus.

As part of the survey, students were also asked whether the detail of the hand-out material that supports laboratory instruction was sufficient and if not, suggestions of how it could be improved were requested. A total of 38 students answered the initial part of this question and as shown in Fig. 7, an overwhelming majority of these were satisfied with the content of this literature.

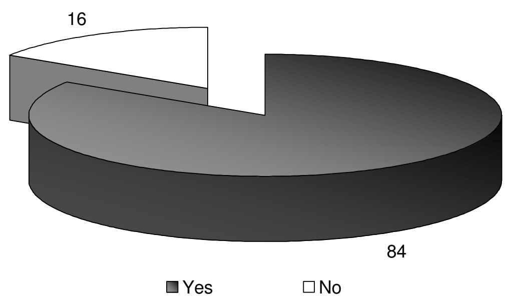

Fig. 7. Whether students are satisfied with the detail of hand-outs provided to support laboratory instruction

Only 5 responses were returned outlining how supporting literature may be improved and these highlighted the need for an improved explanation of the experiment and increasing the level of information/ detail that is provided.

Finally, survey participants were given the opportunity to offer suggestions and recommendations on how laboratory teaching may be improved. Only 14 responses were returned for this question and as before, these were collated and grouped into the common themes shown in Fig. 8.

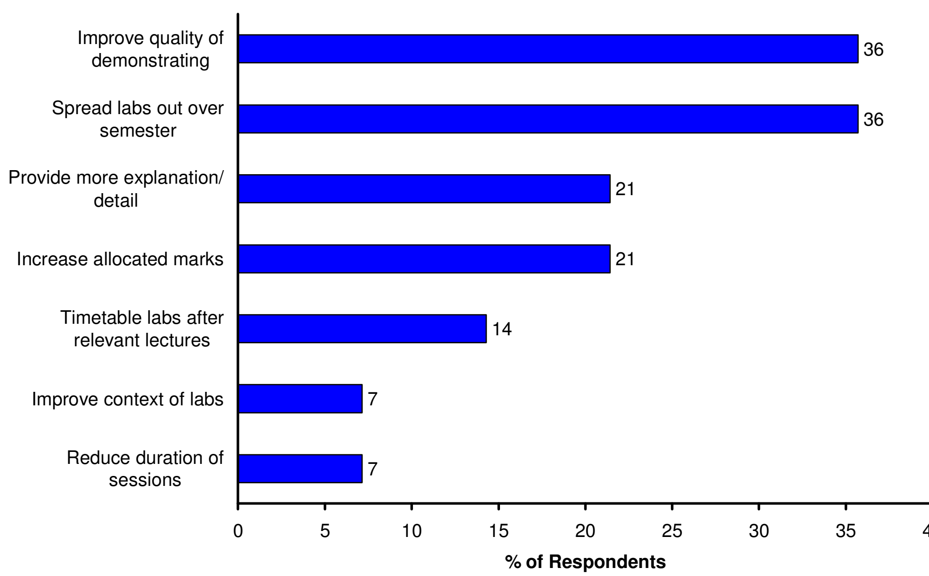

Fig. 8. Summary of suggestions and recommendations to improve laboratory teaching

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Many of the issues raised in this question had been highlighted from responses in other sections of the questionnaire and need no further explanation. However, a suggestion not represented elsewhere in the survey is to increase the proportion of the overall module marks currently being awarded for laboratory assessment. This currently stands at 7.5% (2.5% for each of the three laboratories) and is not consistent with the well-known educational principle that *the assessment drives the learning* reported by Felder and Brent [5]. However, the apportioned marks are deliberately maintained at this low level to discourage plagiarism from fellow students. Furthermore, if undetected plagiarism does occur, it is important that the potential rewards should be kept to a minimum.

CONCLUSIONS

The results of an anonymous and independently conducted student survey were presented in this paper. Negative sentiment towards laboratory instruction in Hydraulic Engineering, a 3rd Year Civil Engineering module at UCD has prevailed for a number of years. The aims of the survey were to investigate the reasons for this negative sentiment so that future decision making on laboratory instruction could be informed by student input. A total of 55 questionnaires were circulated and of these, 44 were returned, representing a response rate of 80%. The main findings were as follows:

- The perceived benefits of laboratory instruction in contribution to understanding the principles of hydraulics lag some way behind both lectures and tutorials.
- Although opinion on the benefits of laboratory teaching remains low, results suggest that students recognise that laboratories have a role to play in engineering education and agreed that the prescribed objectives of laboratory instruction were being met.
- Details of organisation cannot be overlooked when developing a laboratory programme that will optimise student learning. Correct organisation in this regard should ensure that laboratory classes are scheduled within the teaching semester at a time after the relevant material has been covered in both lectures and tutorials. Effective organisation should not be limited to timetabling issues alone but should include the finer detail that relates to the duration of laboratory classes and the size of groupings within these classes.
- Engineering students, as may be expected, prefer laboratories with hands-on input as opposed to a format where laboratories are reduced to formal demonstrations given by trained technicians.
- The availability of high quality demonstrators with the ability to explain technical issues clearly and communicate effectively with undergraduate laboratory groups is of paramount importance if learning objectives are to be met.

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