USE OF TEAM ASSIGNMENTS IN ENGINEERING MECHANICS TO EDUCATE LARGE COHORTS OF UNDERGRADUATE STUDENTS

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Summary Engineering mechanics has traditionally been taught using formal lectures and tutorials, without recourse to laboratory sessions or student assignments, both of which are resource intensive. Five years ago, following a programme review in 2006, this was entirely changed at University College Dublin, Ireland. Each freshman engineering class involves a cohort of 260 students. Three integrated laboratory sessions were developed so that students would complete a variety of analytical and enquiry-led exercises in numerical, graphical and written form. In addition, team-based assignments to the same cohort of 260 students, involving up to five students per team, are set a design challenge directly related to one specific topic from the course syllabus. These changes have proven popular with students and have led to improved learning outcomes and student performance without compromising on academic standards. This paper describes these innovative developments in which Irish engineering students have opportunities for active learning in this manner.

INTRODUCTION

The understanding and application of Newton's three laws of motion is fundamentally important in all university level engineering programmes. A solid foundation in these concepts is needed to understand more complex engineering subjects such as mechanics of materials, fluid mechanics, dynamic systems, machine design and control theory. In a university environment, it is common practice to teach Newtonian mechanics through theoretical analyses, ignoring the tangible everyday connections that students may actually have with the subject. By introducing practical sessions where fundamental mechanics principles are demonstrated and experienced personally by each student, a stronger mental connection can be made with the theory and students can actually see the studied principles being applied in action.

The active involvement of students in laboratory sessions significantly stimulates understanding in the context of engineering education. Over the course of the past decade, however, scarce infrastructural resources (space, technicians, equipment and hardware) have compounded the effects of financial constraints to force engineering schools in Ireland and in other countries to rely increasingly on demonstrations to large groups of students or on computer simulations. In many engineering programmes, the capital equipment required for laboratory sessions is prohibitively expensive and laboratory group sizes for students tend to be too large to provide genuine "hands-on" experience. When teaching engineering mechanics at University College Dublin, however, students in most laboratory sessions work in small group sizes (3-5 per group) and in teams where each student is personally required to use single items of laboratory apparatus. Where multiple sets of apparatus are not available, different students are expected to take lead responsibility for different aspects of team assignments and then to transfer their learning to each other. In such laboratory based learning sessions, students are required to use a broad range of tools (experimentation, simulation, validation, statistical analysis, etc.) to fully explore the relevant subject matter.

The present paper describes the new team-based approach that has been developed to educate large cohorts of Irish engineering students [1]. Three separate laboratory classes and one assignment all contribute to provide concrete experiences to students to complement formal lectures and tutorials. In particular, the team assignment activity is described along with the benefits of this balanced mode of learning. Assessment of this module is now divided between a traditional written examination (70%), individual laboratory reports (15%) and a team assignment (15%). Previously, this module was assessed solely upon a written examination of material taught via a set of formal lectures.

TEAM ASSIGNMENTS

An open design problem with some given constraints is assigned to the class, and they are allowed to solve the problem by any means necessary as long as it complies with given guidelines. The class is randomly divided into groups of up to 5 students which compete against each other to achieve the best solution according to given criteria. Group projects such as these design challenges can be used to further enhance the involvement of the students with the theory learned in lectures, and to encourage their creativity, teamwork, and communication skills, which are very important for any working environment. A friendly competitive environment between the groups is created to further motivate the quality of the results and to encourage each student's interest in the results from other groups. A mechanics problem can be analysed on many levels, depending on the knowledge of the person. A theoretical explanation as detailed as the student's current knowledge allowed was required from the students, to establish the mental connection between theoretical analyses and everyday life. Students are also encouraged to research more advanced concepts personally, in order to enhance their understanding and analysis of the mechanical phenomena involved in the project.

As an illustrative example, we describe a typical assignment brief. Students were asked to design and build a structure made using only pasta and glue. The structure was required to support containers of given dimensions, to

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which weight was added incrementally (Fig. 1). The main topic in the course dealing with this assignment was trusses and distributed forces. The structure was required to rest freely on two tables at a span of 1 m. The maximum weight of the structure was not allowed to exceed 4 kg. The structures were ranked according to the performance criterion of maximising the ratio of weight carried to structure weight. Students were allowed to use any available combination types of pasta, and any commercially available adhesive. They were asked to deliver a short report where they listed the technical specifications of their structure and justified their design choices. The brief was given during the first month of the semester, and the delivery deadline was set for three weeks later. This allowed students to think about the project while they were learning the concepts from the course that were needed to justify their solutions. The projects from all groups were evaluated on the competition/assessment day. The criteria used to evaluate the projects were designed to facilitate evaluation of a large quantity of group projects during a single session (52 groups each of approximately 5 students). The highest marks were given to the team that built the structure with the best performance criterion. Marks were also given for the consolidated team report. This group assignment accounted for 15% of the total course mark.

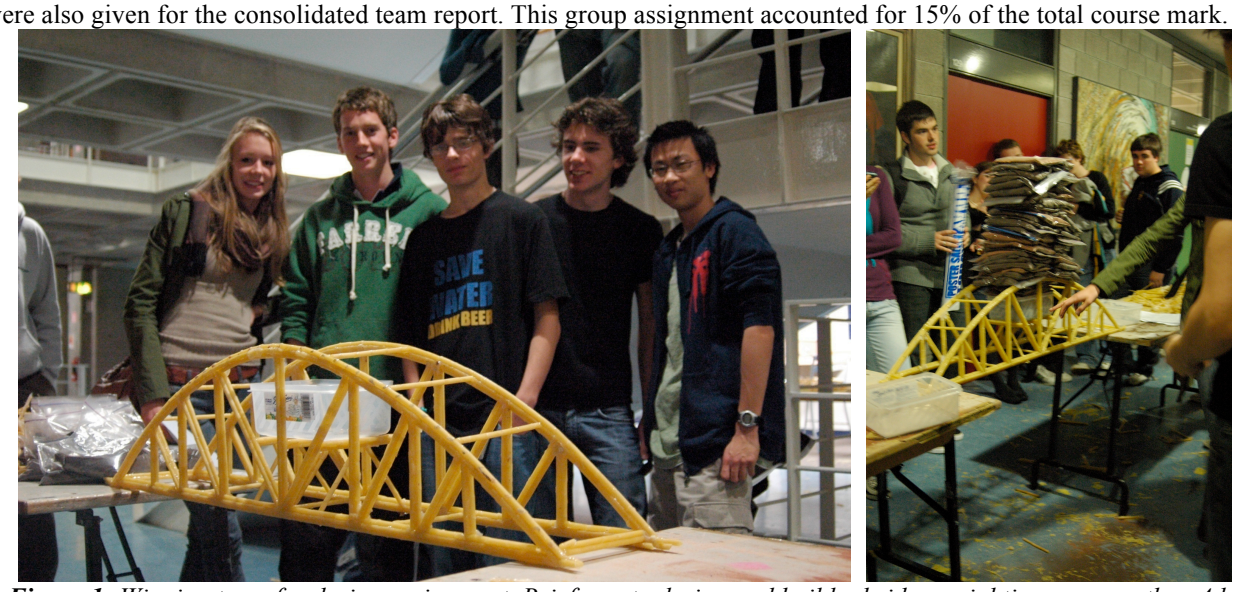

Figure 1: *Winning team for design assignment. Brief was to design and build a bridge weighting no more than 4 kg using only pasta and glue which would maximise the ratio of weight carried to bridge weight. The winning team's truss (shown above) carried 21 times its own weight.*

DISCUSSION AND CONCLUSIONS

Anonymous survey questionnaires, including those administered centrally by the university, confirm that these changes are regarded as an improvement and are uniformly well received by the students. It is evident that students have become more confident and enthusiastic about active participation in their education. It has also been noted that students are willing to share their knowledge with each other during laboratory classes. The laboratory sessions are deemed to be an additional opportunity to reinforce concepts learned during lectures and tutorials; they also provide a way to gauge the level of understanding of students, as they are less inhibited about asking questions when they are part of small size laboratory groups. This was seen, irrespective of whether or not students had taken applied mathematics or physics in their pre-university education.

There is a significant increase in active student participation in the engineering mechanics module due to the inclusion of laboratory and tutorial sessions and group assignments. While attendance records are not taken during lectures, participation rates are typically in the order of 80-90%, compared to 50-60% previously. The First Year Mechanics for Engineers course taught at UCD has been enriched by this increased participation. Students are consulted periodically to confirm their level of understanding and overall satisfaction with the course. The use of practical sessions with the combination of conventional teaching techniques has been popular with undergraduate students. Failure rates appear to have remained relatively static at approximately 20%. This is consistent with the calibre of students entering university remaining high and the academic standards being set within this engineering module also remaining high. The highest grades that have been awarded dropped from almost 30% to no more than 10%. This is not due to a weakening of the calibre of students or a lowering of threshold standards. Instead, it is a consequence of using lecturing and assessment methods that extend beyond solving conventional mathematical problems to rely also on team-based laboratory classes and research-led assignments. This has required more resource-intensive modes of delivery with support from a small number of Teaching Assistants.

References

[1] Forero Rueda, M.A. & Gilchrist, M.D., Innovations in undergraduate engineering mechanics education: Use of team-based research-led project methods for large student cohorts. *Int. J. Engineering Education*, **27**:821-830, 2011.