On Addressing the Variation in Intellectual Demand of Engineering Undergraduate Research Projects

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***Abstract* - In the civil engineering degree course at La Trobe University, students undertake an investigation or research project. Experience has shown that some projects are significantly less intellectually demanding than others, and yet students still expect that, even though the project is less demanding, they should be eligible to receive a high passing grade. This is inequitable, and the approach proposed in this paper attempts to address this issue by forming the objectives of the project into a hierarchy of three groups of increasing intellectual demand. The first group of objectives must be satisfied to an acceptable standard to obtain a lower passing grade. In addition to these objectives, the student may choose to satisfy the objectives in the other groups and become eligible for a higher passing grade. A substantial proportion of the marks for the unit is allocated solely to the satisfaction of the objectives. Consequently, the student has a much clearer indication of what is expected for both low and high passing grades.**

Key Words- Assessment, Research project, Objectives.

INTRODUCTION

In Australia, full-time undergraduate professional civil engineering degree courses are typically of four years duration and normally consist of thirty-two units (subjects). Four units are studied in each of the eight semesters. Most courses finish with a final-year research or investigation project that is designed to be the capstone experience for the course.

Project work is not a familiar learning form for many engineering students. Our experience has been that, just as students are slow to transfer their academic learning between different units and year levels, so too are they reluctant to transfer skills. We have addressed many of these issues through the development of a Project Learning Stream within the course [1]. This stream consists of the four units *Engineering Practice, Engineering Group Research, Environmental Case Studies* and *Investigation,* with one unit in each year of the course. The aims of the stream are:

- To introduce students to the discipline of Civil Engineering,
- To develop generic work skills related to both individual and group activities,
- To develop skills in report writing and oral presentation,
- To promote a desire for life-long learning, and
- To prepare students for professional practice by working on a specific practical or research topic.

The intensity of activity and expectations of the students gradually increase with each year-level unit in the stream, and the skills acquired in these units complement the skills attained in the discipline-specific units. The *Investigation* unit represents the culmination of the stream where all the skills developed previously are employed.

The use of capstone engineering experiences to assess the success of the course has been investigated [2, 3] as has the ability of such experiences to provide relevant generic skills [4]. However, our experience in the assessment of such units has highlighted inconsistencies related to the comparison of different projects. In this paper, we discuss a new approach to the formulation and assessment of the project to address these problems.

INVESTIGATION UNIT

The *Investigation* unit is undertaken in the final semester of the final year of study. Students undertake a research or investigation project related to the course, and describe their work in a written report and an oral presentation. Whilst the project must be within the capability of an average final year undergraduate student, it should also extend the student beyond the mere application of knowledge already covered in the course. Broad categories of projects include: Design and Development (of a new technique or piece of equipment), Engineering Investigation (of an existing non-routine engineering problem in industry or the community), Academic Research (resulting in new knowledge or an extension of existing knowledge) and Engineering Design (of a non-routine real or fictitious project).

The topic of the project is conceived and developed by both the student and a potential supervisor who may be a member of the academic staff or, for industry-based projects,

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a member of the organization concerned. Students are strongly encouraged to select a topic in which they have a significant interest and are therefore motivated to complete to a high level of achievement.

Previously, the assessment for the whole unit was broadly described in four components as follows:

1. Report	75 marks
2. Individual effort	10 marks
3. Poster	5 marks
4. Seminar presentation	10 marks
Total for the unit	100 marks

Many of the marks allocated for the report (the first component) were directed towards aspects associated with the writing of the report itself, namely overall presentation and format, organization, abstract, introduction, quality of references, literature review, quality of technical work, discussion and critical review, conclusions and recommendations, and citation. Some marks were, however, allocated to the execution of the project, and considered such matters as information search, conceptual understanding, communication with supervisor, adherence to objectives and initiative and discovery.

Marks allocated for individual effort (the second component) reflected the independence of the student, with high marks given to motivated students who required a low degree of supervision, direction and intervention by the supervisor. High marks were also awarded for clear posters and well presented seminars that engaged the audience.

PAST PROJECTS

Experience has shown that there has been a great disparity in the effort, time and intellectual demand of projects undertaken in the past. Two examples of past projects will serve to illustrate this disparity.

The first example is that of an industry-based project centred around the development of a solid waste management plan for a small municipality in rural Victoria. The municipality comprises about 235,000 hectares with a population of about 14,000 people, resulting in a population density of 6.0 persons per square kilometre. It looked at the solid waste management process from collection through to disposal/recycling, and the future development of the existing landfill site including the rehabilitation of already full cells. Based on the current practices of nearby, more progressive municipalities, a plan for the immediate future was developed. Suggestions were made for the longer term (25 years) based on a limited investigation of existing and likely future practices in Europe and the USA. Whilst the project was considered adequate and of interest to the industry concerned (local government), it merely required the student to examine existing practice and, with little or no modifications, simply apply this to the municipality in question as its practices were essentially long outdated. Hence, the nature of the project itself did not extend the student intellectually and effectively limited the highest grade that could be awarded, although this may not have been obvious in the beginning.

In contrast to this, the second example is an investigation into the use of finite element analysis to examine energy transfer between the normal modes of vibrating structures. The student had acquired from the course a basic knowledge of linear finite element analysis and vibration theory. The project required the student to extend his knowledge to the nonlinear formulation of finite elements and more complex vibration phenomena. In addition, the student was required to study techniques for post-processing the time data that arose from the finite element analysis. The student was also required to work with a research team. Hence, this project extended the student significantly beyond the domain encountered in the course and into the arena of postgraduate study. The project was undertaken by a high-achieving student, and the results of the project were presented at an international congress.

These two examples demonstrate the significant disparity between intellectual demand that is a result of either the nature of the project itself or the effort put in by the student, or both. To address this disparity, a complete review of the formulation of the *Investigation* project and its assessment was undertaken. During the review process, it became clear that lower marks were allocated for the report of an intellectually less-demanding project, or a project that required less work, even though the report itself may have been of a reasonable standard. It was decided that the intellectual and work demands of the project, and the associated risks, should be decoupled from the quality of the report and the oral and poster presentations. The review resulted in the method of formulating the project and the assessment of the work described below.

PROJECT FORMULATION

Once the topic of the investigation has been selected, the scope of the work for the particular project (including for industry-based projects, what information and assistance would be provided by the industry) is described in a Project Brief. Based on this scope, the objectives of the project are included in the Project Brief in a hierarchy of three groups. This is a key element of the approach.

Group 1 objectives describe the minimum outcomes that must be achieved to a satisfactory level in the project execution to have the opportunity of obtaining a passing grade at the lower end of the spectrum (a C or a D grade, with D being the minimum passing grade). Successful realization of the Group 1 objectives to a high level is mandatory in order to achieve a passing grade.

Groups 2 and 3 objectives require additional work at a higher intellectual level than that required to achieve the objectives of Group 1. Successful achievement of Group 2 or Group 3 objectives makes the student eligible to achieve a concomitant higher passing grade (a B or a C grade, or an A or a B grade respectively, with A being the maximum passing grade). The hierarchy of groups of objectives is such that the lower order (Group 1) must be successfully completed before the next group can be attempted. It should be made clear, however, that the student is not obliged to attempt these higher objectives in Groups 2 and 3 and may elect to complete only the objectives in Group 1. Note that no additional time is given for the achievement of Group 2 and Group 3 objectives.

Once the Project Brief has been completed, a concise research or work plan, often in the form of a Gant chart, is developed. Both the Brief and the work plan are submitted to the Supervisors' Collective for discussion, modification if needed and final approval. This Collective consists of the Head of Department and Unit Co-ordinator (both ex-officio) and all academic staff who will be supervising an *Investigation* project in the current academic year. Once approved, any subsequent proposed changes to the approved scope and objectives must be submitted to the Unit Co-ordinator who may then either approve the changes or forward them to the Supervisors' Collective for discussion and approval.

EXAMPLE PROJECT BRIEF

A typical Project Brief consists of a title of the investigation, a description of the project and its scope, and a list of the objectives in a hierarchy of three groups. As with any technical publication, the title should give the reader a clear indication of what the project is about. The project description should succinctly outline some background to the need for the work to be undertaken and broadly describe what work is to be done and the scope of that work. The objectives should define unambiguously what is to be achieved as a result of the work done, thus giving the student clear goals to work towards. The following illustrates the form of the Project Brief (project description and grouping of objectives) currently in use at La Trobe University.

Project Title
k_1 Factor for Reinforced Concrete Beams

Project Description and Scope of the Work
Deemed to comply span-to-depth ratios offer a simple alternative to calculating and checking the deflections of reinforced concrete beams. Inherent in determining the allowable span-to-depth ratio is an estimate of the effective second moment of area I_{ef}. In the Australian Standard for concrete structures AS 3600-2007, simple approximations for estimating this parameter are provided for rectangular, T– and L–beam cross-sections using the factor k_1. This project will review the theoretical basis of the deemed to comply span-to-depth ratio approach, the quality/accuracy of the existing provisions and develop new and better equations for k_1, suitable for use in the next edition of AS 3600, to facilitate the routine design of simply supported and continuous reinforced concrete rectangular, T– and L–beams.

Objectives
Group 1:
- Construct a correct, comprehensive computer spreadsheet programme to determine I_{ef} and hence k_1 for both simply supported and continuous beams with either a rectangular, T– or L–section incorporating all relevant parameters.
- Undertake a thorough comparison between the spreadsheet and the existing AS 3600 provisions and critically review the findings.

Group 2:
- Carry out a parametric study using the spreadsheet to identify the significant parameters.
- Undertake a comparison with the provisions of the Eurocode and ACI codes and critically review the findings.

Group 3:
- Based on the foregoing, develop acceptably accurate but relatively simple new equations for the factor k_1 that would be suitable for inclusion in AS 3600, and demonstrate their efficacy.

Some explanation of this example Project Brief may be beneficial. During the course lectures, students learn how to calculate the deflection of a reinforced concrete beam using the method described in the Australian Standard AS 3600. This method uses the concept of an effective second moment of area I_{ef} to allow for the progressive development of cracks. A brief introduction is also given to the alternative of selecting a beam depth that complies with an allowable span-to-depth ratio. The work needed to meet the Group 1 objectives requires the exploration of both approaches in somewhat more detail than is able to be covered in class lectures. Also, consideration needs to be given to the ranges of parameters likely to be encountered in engineering practice, e.g. beam spans, beam spacings, concrete strengths and the like. Once the spreadsheet has been constructed and its correctness confirmed, the provisions of the current version of the Australian Standard can then be reviewed and possible inadequacies identified. The Group 2 objective of a comprehensive parametric study can, of course, only be successfully conducted once the spreadsheet has been developed, i.e. the Group 1 objectives have been satisfied. In this case, the student would have to discover the influence of all parameters that affect the value of I_{ef} and justify the selection of significant (and insignificant) parameters. The requirement to compare the provisions of the other codes extends the student into understanding and correctly interpreting unfamiliar rules that are not covered in the course. The Group 3 objective requires the student to develop new (and better) equations for approximating I_{ef} whose accuracy over the ranges of all the parameters is better than the existing provisions but are still not unduly complex. Whilst the existing Australian Standard provisions can be used as an initial frame of reference, the form of the new equations could well be very different. This extends the student into the realm of creating something 'new'.

Ideally, all projects should have similar construction to the foregoing example where a hierarchy of all three groups of objectives can be developed, and the student therefore has the opportunity to receive the highest passing grade. However, there may be projects that appeal to students which, by their very nature, are limited in scope and depth, thereby placing lesser intellectual demands on the student. Such projects may have objectives only in Group 1, or perhaps in Groups 1 and 2, but none in Group 3. Some industry or community based projects may fall into this category. Whilst this is not considered desirable, at least the student knows in the beginning that, as the project has been described, passing grades will be at the lower end of the spectrum. Of course, as with any project, a change of direction may occur, or the tasks may be much more difficult (or somewhat easier) than originally thought. Potentially, Group 3 objectives could be developed and subsequently included if this possibility is recognized sufficiently early during the course of the investigation. A re-evaluation of the project and its objectives may then be appropriate.

ASSESSMENT OF THE WORK

As a result of the review of the unit mentioned previously, the first component of the assessment has been subtly, but significantly, changed as follows:

1. Contents of the report, report writing technique and satisfaction of the objectives 75 marks

The other components of the assessment remain unchanged in their weightings. Moreover, the marks for these other components are largely unrelated to the satisfaction of the objectives of the project. Hence, a student may do a mediocre job at satisfying the objectives of the project, and thus receive correspondingly low marks for that component, but still may score highly on the other components (individual effort, poster and seminar).

Of the seventy-five (75) marks allotted to the first component of the assessment, only about one-third (35%) of these marks is allocated to the contents of the report and the report writing technique, considering matters that have been described previously (overall presentation and format, organization, abstract, introduction, quality of references, literature review, quality of technical work, discussion and critical review, conclusions and recommendations, and citation). The remaining 65% of the (75) marks is allocated to reflect which objectives have been attempted and the extent to which these objectives have been satisfied, with a sub-division as follows: 40% to Group 1, 15% to Group 2, and 10% to Group 3.

Thus, a student who elected to complete the objectives from Group 1 only and did a perfect job of this, and who scored perfectly in the other components would receive a final total of $(0.35 + 0.4)\times 75 + 10 + 5 + 10 = 81$ marks (out of the possible 100 for the unit). It is somewhat unlikely, however, that perfect scores would be obtained in the other components. Hence, if the report and other components receive, say, three-quarters of the maximum allotted marks, the total would become $(0.75\times 0.35 + 0.4)\times 75 + 0.75\times(10 + 5 + 10) = 68$ marks (out of the possible 100). This could be even lower if the Group 1 objectives are not fully met, or are not met to a satisfactory standard, and therefore receive only part of the 40%. A passing grade that corresponds to the total mark for the unit would then be awarded.

CONCLUDING REMARKS

In this paper, we have discussed the development of a different approach for the capstone *Investigation* unit in the Civil Engineering course at La Trobe University. The proposed approach addresses inconsistencies in the intellectual demand and work requirements arising from the inevitably diverse nature of projects that are usually investigated under the umbrella of civil engineering. After describing the project and justifying the need for the work together with its scope, a key element of the approach requires the clear specification of the objectives of the project before any substantial work on the project itself commences. These objectives are structured into a hierarchy of three groups of increasing intellectual demand. The student must satisfactorily complete the objectives of the first group in order to obtain a passing grade. Completion of the other groups of objectives is at the discretion of the student who may elect to undertake these objectives with a view to securing a higher passing grade. However, no extension of any deadlines is granted if the student elects to attempt these objectives. A substantial proportion of the marks for the unit is allocated solely to the extent to which the objectives are satisfied. This more transparent approach results in a fairer assessment of the outcomes of the investigation or research work, since the student has a much clearer indication of what is expected in order to achieve a particular passing grade.

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