EFFECTIVE STRATEGIES FOR GROUP WORK IN ENGINEERING CURRICULA

K. Kelly

School of Engineering, Trinity College Dublin.

ABSTRACT

Modern engineers are expected to be able to work effectively in teams and accreditation criteria (e.g. Engineers Ireland [1], ABET - Accreditation Bureau for Engineering and Technology [2]) typically make explicit reference to these competencies at both an individual and programme level. However, assessment at university has traditionally been performed at the individual level, and many difficulties are regularly noted by engineering educators when trying to manage group projects. These difficulties include equity of marking, balance between individually and collectively assessed components, provision of appropriate levels of guidance and intervention in managing group dynamics, and over-discretization of marking leading to selective targeting by students at the expense of higher order module level learning outcomes.

This work reports on two group-design, project-based modules taught in the author's institution, and a number of specific strategies that have been put in place to address the difficulties noted above. One of the modules is a 5 ECTS [3] second year module and the other is a larger 20 ECTS module taught in fourth year. The rationale behind the implementation of the strategies is noted and results from an end-of year student survey are discussed, to examine the efficacy of these strategies in addressing the commonly encountered difficulties so typical of these types of projects.

KEYWORDS: Education, Assessment, Groupwork

1. INTRODUCTION

The ability of engineers to work effectively as part of a project team is recognised as a key skill in industry and is usually a formal learning/programme outcome in accredited engineering programmes around the world – see, for example, Hirsch & McKenna [4] for an overview. 2014 US professor of the year, Sheri Sheppard, notes "Today's modern engineering work, more so than ever, is about being on teams, and so educators more and more are thinking about how to bring those team experiences into the classroom" [5]. An analysis of the year 1 and year 2 curriculum in the authors institution indicates that ~13% of the assessment/module content is via group based exercises, reflecting this increased emphasis on teamwork in programme accreditation. A key requirement of such teamwork exercises is to ensure that the grading/assessment is fair and appropriate and is capable of adequately rewarding and/or penalising students relative to their individual achievement of the desired learning outcomes.

2. GROUP AND INDIVIDUAL ASSESSMENT

This section will cover traditional/common methods of group and individual assessment, and note typical problems

The use of 'non-traditional' assessment strategies such as self, peer and co-assessment has received some considerable attention in the education literature – see for example Dochy et al [6] for a review of different strategies. Kaufman and Felder [7] describe a co-assessment process where students rate the effort of their teammates, from which a weighting factor (individual rating divided by the average over the entire group) is used to scale the mark assigned to the group submission. Common concerns and issues arising are noted by both sets of authors above, and include:

- 'Social loafing'/'hitch-hiking', where individuals fail to undertake their fair share of the total team effort required
- Friendship marking, where personal relationships (or lack of) unduly influence the marks awarded
- Collusive marking, where there is explicit or implicit pressure to award similar rating to each team member
- 'Decibel marking' where some individuals seek to, and succeed in dominating the group with the explicit or implicit objective of gaining a higher proportion of the marks

To the above may be added other observations and reflections from the authors own experience and from discussions with colleagues, namely:

- Much of the work reported in the literature is from the US and Australian context, where students will typically have a broader range of choices in terms of the modules they take than would be the case in an Irish institution, where the 'menu' is more prescribed. A consequence, particularly in the smaller class sizes characteristic of this study, is that individuals will have more frequent and longer lasting interactions with their team-mates and may therefore be more reluctant to risk confrontation through 'penalising' or 'ratting out' each other for lack of effort.
- Much of the work reported in the literature seems to refer to smaller scale projects, presumably of relatively short duration, where the assessment is largely taking place at the conclusion of the project. With larger scale projects where the assessment is spread over multiple submissions, students may be prepared (usually over-optimistically in the authors experience!) to tolerate poor teammate behaviour in the hope/expectation that matters will subsequently improve
- While bright students will typically engage conscientiously with any and every assessment or task, irrespective of how many marks are available for it, weaker students will tend to be more selective in choosing where to invest their efforts. Typically effort will be expended up to a level required to achieve a given objective (usually passing the module), before re-assigning efforts to other assessments/modules. This rationing of effort can be dealt with relatively easily in individual work, but there can be significant frustration for team-mates (leading to significantly poorer team outcomes) when individuals 'write off' what they perceive to be

non-critical (in terms of marks available) items. As educators therefore we often face a difficult choice in terms of assigning disproportionate (in relation to student effort) marks to certain task based on their importance to a higher order objective of learning or team project execution.

- In extreme cases, when using the co-assessment rubric reported by Kaufman & Felder [7], a high performing student who ensures a high quality group submission may actually receive more than the 'maximum' marks notionally available! Similarly an average student who does likewise may receive a very high individual mark for what is overall a weak group submission. There is a risk therefore that group submissions get artificially divided into individually completed components, so that an 'I did my bit' mentality prevails at the expense of the teamwork-based learning outcomes.
- When designing curricula and associated assessment rubrics, most acadamics will be aware of the potential for 'hitchhiking', and will usually include individually assessed components to provide some discrimination between individual students in a group. Indeed the author is unaware of any entire engineering module being taught in his instution where the mark returned is derived entirely from groupwork. There are of course sound pedagogical reasons for having individually assessed components (e.g. reflections) within a group-based endeavour, but it is perhaps an open question as to whether significant amounts of individual assessment components in such courses are more motivated by discouraging (or compensating for) social loafing than by fundamental learning outcomes.

3. CONTEXT AND OBJECTIVES

The two modules discussed here are both modules that involve substantial group project effort, in a (broadly) mechanical/manufacturing engineering context. Course A is a 10 ECTS project, delivered in year 2, with student teams of size 4/5, working over a 24 week academic calendar. 19 students in 4 groups were presented with the challenge of designing and building a metal bodied resonator guitar. A 'back-story' concerning the business context (e.g. finance and equipment available) was also presented to situate their conceptual and engineering design work, with an objective of encouraging broader based thinking and an integrated technical/business focus. There are similarities with the Scenario Based Learning approach proposed by Schar et al. [8].

Course B is a 20 ECTS project, delivered during the first year of the Masters cycle, with teams of 3/4, working over an extended academic year (typically 36 weeks). Project 'prompts' are provided by industrial sponsors. The course structure and pedagogy are strongly based on the ME310 course delivered in Stanford University [9] and approximately half of the projects are conducted with a joint project team formed with an academic partner university in another country. 18 students in 5 teams represent the cohort referred to in this study.

Noting some of the typical difficulties encountered in group design work, as reported in the preceding sections, the specific 'additional' (to norms of fairness, transparency, relativity etc.) objectives of the assessment methodology described here were:

- Reward consistency of individual and team effort
- Penalise 'hitch-hiking'/'social loafing' behaviour by non-performing team members
- Appropriately balance the individual and group components
- Discourage 'selective marks harvesting' where students identify a grade level they are satisfied with and identify discrete elements to minimize their efforts required
- Appropriately incentivize satisfactory completion of pedagogically (or organisationally) important elements of the module, for which the effort required may only justify a very small amount of marks in a traditional assessment framework

4. METHODOLOGY

An assessment rubric was devised which combines geometric and arithmetic averaging, with a weighting factor somewhat similar to that used by Kaufman and Felder [7]. Every assessed component (group-based or individual) is assigned three 'dimensions' for assessment:

a) A mark, similar to what would apply in a conventional summative system.
b) A 'sufficiency grade' – a minimum value representing no submission (1% chosen in this case) and 100% (submission received on time and constitutes a genuine attempt, however poor, at meeting the criteria).
c) An 'item weight' – allowing for importance to overall module outcome to be adjusted, independently of any marks (a) awarded

From (b) and (c) above, two weighting factors are developed – an individual factor (only including the dimensions for those assessments that are individual) and a total factor (all assessments). The process for this is to use a weighted (using the item weights) average of the logarithm of the sufficiency grades. The total grade for any student is then calculated as:

(Individual Factor)*(sum of individual marks) + (Total Factor)*(sum of group marks)

An example is developed below for a notional student project. In this project we have a team of 2 students – Jack and Jill. As a group they have to submit a project plan, followed by a first prototype at the midterm stage, before submitting a final product and report at the end of the project. Additionally they are asked to provide a 1 page 'top tips' report for future students undertaking the module. Individually they are asked to submit a short personal profile at the start of the project, to participate in one session each of assessing other groups' project plans, and to keep a reflective journal. Attendance is also tracked.

Jack is a smart but lazy student, who rarely attends early morning lectures and has a tendency to leave his work to the last minute, often resulting in late submission and occasionally forgetting to submit at all. For this project he missed a large number of the morning classes, and forgot to submit his personal profile. He did a competent job when required in assessing one of the other teams project plan presentation and wrote some good entries on his reflective journal when he remembered to complete it.

Jill is a very hard-working and organised student. She trusted Jack to add some photos to their project plan presentation before submission and was very annoyed when he forgot and she had to remind him the next morning. Jill diligently completed all of her individual assignments, although she struggled to grasp what was required in the reflective journal. After her early frustrations with Jack, she took charge of submission for each assignment to ensure it was submitted on time.
Their marks are summarised in table 1 below.

Student	Assignment	Mark	Sufficiency Grade	Item Weight	Group?
Jack	Attendance	-	50%	2	N
	Reflective Journal	18/20	70%	4	N
	Personal Profile	-	1%	1	N
	Peer assessment	-	100%	3	N
Jill	Attendance	-	100%	2	N
	Reflective Journal	12/20	100%	4	N
	Personal Profile	-	100%	1	N
	Peer assessment	-	100%	3	N
Jack & Jill	Project plan presentation	4/5	90%	5	Y
	First Prototype	5/10	100%	3	Y
	Final product	34/45	100%	5	Y
	Final report	15/20	100%	2	Y
	Top tips	-	100%	3	Y

Table 1. Sample Marking Process

Note that under a conventional marking scheme, 80% of the marks would be awarded for the group component, so that the maximum difference in marks between Jack and Jill would be 20%. In this example, each would receive 58/80 for the group component with Jack and Jill receiving 18/20 (maybe modified by a late penalty!) and 12/20 respectively for the individual component. No account would be taken of Jack's poor attendance or his failure to submit the personal profile. Jack would get a final grade of 76% and Jill would obtain 70%.

In the assessment scheme proposed here, the first step is to calculate the individual and total weighting factors. The total item weights for individually assessed components is 10 (2+4+1+3) and for group components is 18 (5+3+5+2+3). For Jack, the individual factor is 10^x where x = (1/10)*(2Log0.5 + 4Log0.7 + Log0.01 + 3Log1) = (0.1)*(-0.3 – 0.15 – 2 + 0) = -0.32. The individual factor for Jack works out at 0.48. By similar processes the total factor can be calculated as 0.75. Jack's final grade will therefore be (0.48)(18)+(0.75)(58)=52.2%. Jill's final grade works out at 68.9%

Surveys were issued to all students partaking in both modules. These were based on standard surveys issued to all students in all modules. Comparative (to other modules) Likert scales were used where possible, and topics covered were:

- Personal experience covering amount learnt, enjoyment, satisfaction with module choice, including willingness to recommend to future students (not asked for year 2 module, as it is mandatory)
- Quality of teaching support and organisation
- Workload (self, and teammates)

- Assessment fairness and usefulness and timeliness of feedback
- Skills required

5. RESULTS

A summary of the student responses to key questions is provided in table 2 below. There were 18/19 responses from the year 2 class and 16/18 from the year 4 group. All questions were posed as comparative with respect to other modules.

Question	Least	Lower	Average	Higher	Highest	***Mean***
Fairness of Assessment	0	1	13	12	8	**0.79**
Enjoyment	0	1	3	16	14	**1.26**
Level of Teamwork Required	0	1	2	11	20	**1.47**
Balance Between Group and Individual Work	1	2	14	14	3	**0.47**
Workload	0	1	4	17	12	**1.18**
Student Learning	0	1	2	21	10	**1.26**

Table 2. Summary of Student Responses

Students attitude to the assessment scheme was strongly positive, see Figure 1 below, with an all but one student (3%) reporting they felt the scheme was as fair (38%) or fairer (59%) than that employed in other modules.

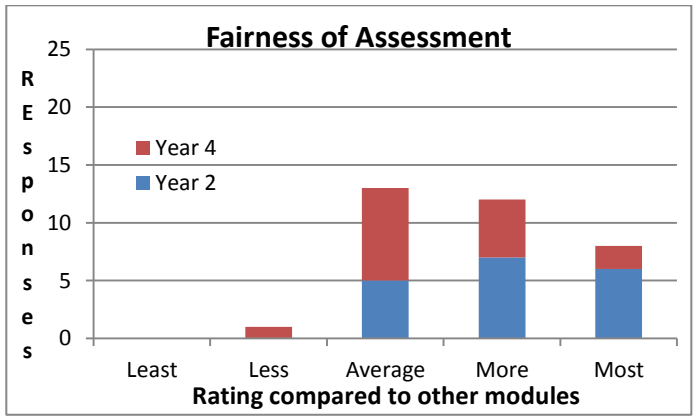

Figure 1. Students perception of fairness of assessment scheme

The respondents reported high levels of teamwork required and perceived that they had learnt significantly more than in other modules, see figures 2 and 3.

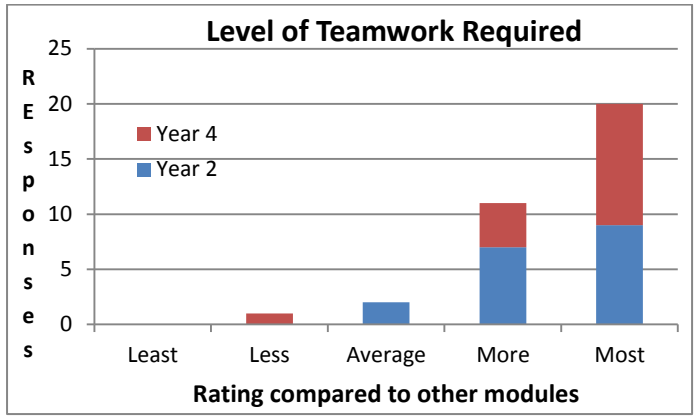

Figure 2. Students perception of degree of teamwork required

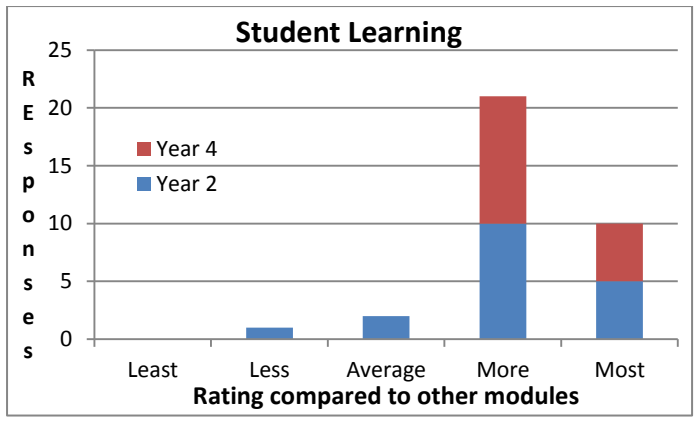

Figure 3. Students perception of amount learnt

Students were mildly positive on the question of whether the balance between group and individual components was suitable (mean Likert score of 0.47), but reported enjoying the module substantially more than other modules (1.26) despite the workload being seen as substantially heavier (1.18) than average.

6. DISCUSSION & CONCLUSIONS

It must be acknowledged that whatever assessment rubric is in place, it will be possible for individual students to 'optimise' their contribution to ensure they achieve a desired minimum score with the least effort invested. We return therefore to the objectives set out in section 3, and note that the methodology proposed here rests on an implicit assumption that individual effort for individually assessed and completed components is a reasonable proxy for effort over the entire module. Anecdotal feedback from informal interviews with students suggests that this is at least partly true, and results from Kaufman & Felder [7] indicate strong correlation between peer ratings for 'team citizenship' and individual marks in class tests. It is also noted here that as the total weighting factor can never be greater than 1, the best performing students can never receive more marks for the group-assessed component than the raw mark awarded - in contrast to the peer-weighted method [7] (although this method has its own limitations as previously noted). As the weighting factor always acts therefore to

reduce the final grade awarded, it is important to compensate somewhat in the marks awarded to individual elements. It was the author's experience, as an experienced assessor, that this proved relatively straightforward – simply considering the likely end result based on the current weighting factor.

At a more theoretical level it is possible to a priori set the assessment parameters to penalise, to whatever degree decided, miscreant behaviour (e.g. late submission) by individual students with regard to any individual submission. For any specific assessment, n, we will have the three quantities referred to in section 4, namely the mark, m_n, the sufficiency grade, g_n, and the weight, w_n.

For the submission of interest, we are interested in how the overall student grade is impacted. The impact of the m_n is readily apparent, so we will focus instead on the impact of g_n and w_n. Figure 4 below shows a graph of g_n and the relative weight of an individual assignment (i.e. $w_n/\Sigma w$) and their influence on the 'total factor'(which will be applied to the group generated assessments). This allows us to see the relative impact of individual assignment performance on the final grade obtained from group work.

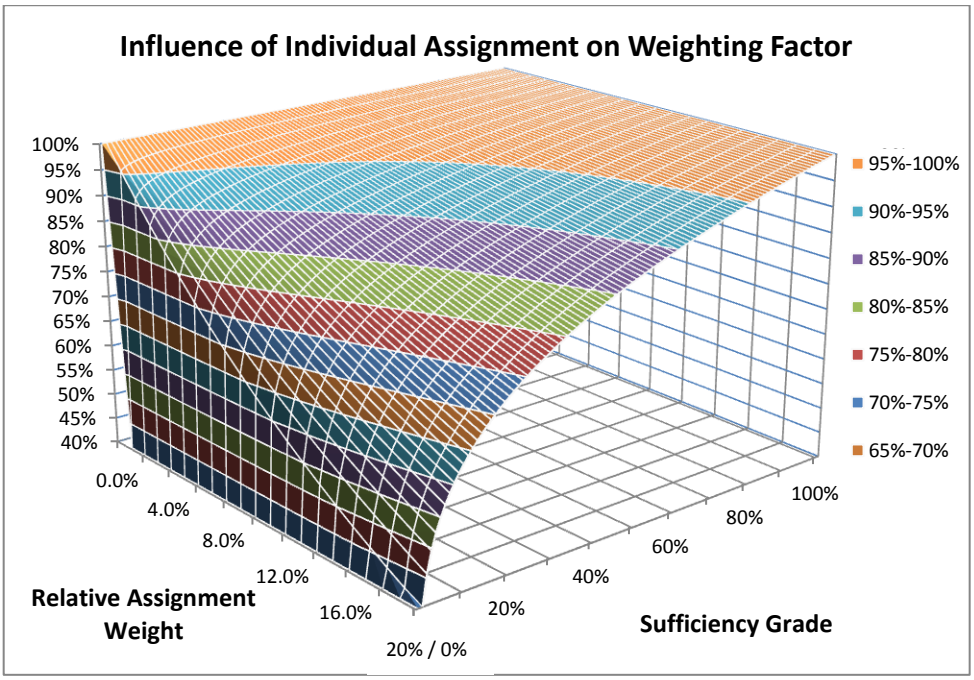

Figure 4. How Sufficiency Grade and Relative Assignment Weight influence the 'total factor' used to moderate group effort mark.

It may be seen from the graph that it is possible for any weight or sufficiency grade, to choose the other parameter to levy an appropriate penalty. For practical purposes individual assignments are unlikely to have a relative (to total assignments, both group and individual) weight of more than 10% or less than 1%. A minimum sufficiency grade of 1% (used in both modules described) would result in a 'total factor' of 63% and 95% respectively. In terms of practical impact, failure to complete an individual assignment would have had between 2% and 40% impact on final grade for an individual student on either of the two modules described above.

As the method described above was implemented for the first time, extra care was taken by the author to clearly communicate to the class the consquences of non-compliance with submission requirements. While most students found the detail of the system somewhat confusing at first, the general principle (don't write off assignments, even the the maximum conventional marks available are small or zero!) was well understood. As a further measure, individual students who were late with initial assignments were promptly warned of the overall consequences to their module mark. Student satisfaction with both modules, as reported in the survey was high – with an average Likert rating of 0.79 for fairness of assessment (0 being average fairness compared to other modules, and 2 being fairest). There was a mildly positive score for the balance between team and individual work (0.47) and a very high score for the amount of teamwork required (1.47) Both modules were seen as very demanding in terms of comparative workload (a score of 1.18), but were also enjoyed by the students (a score of 1.26).

In conclusion, the new method deployed can be considered to be a success both in terms of meeting the objectives stated in section 3 and in terms of the positive student feedback as reported in section 5. A key focus for future use will be on the early and frequent communication to the students of the potential consequences/benefits of compliance/non-compliance with assignment submission and completion requirements.

7. ACKNOWLEDGEMENTS

The help of my colleagues, summer interns and teaching assistants, in particular Mark Culleton and Tassiana Padeiro, in the preparation and implementation of the strategies described in this paper is greatly appreciated.

8. REFERENCES

[1] Engineers Ireland, Accreditation Criteria for Professional Titles, available at *http://www.engineersireland.ie/EngineersIreland/media/SiteMedia/email/jobs/EngineersIrelandAccreditationCriteria2014.pdf*, accessed 6th May 2015

[2] CRITERIA FOR ACCREDITING ENGINEERING PROGRAMS, 2015 – 2016 – ABET, available at *http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2015-2016/*, accessed 6th May 2015

[3] European Credit Transfer and Accumulation System (ECTS), available at http://ec.europa.eu/education/ects/ects_en.htm, accessed 31st May 2015

[4] P. Hirsch and A. McKenna, Using Reflection to Promote Teamwork Understanding in Engineering Design Education, *Int. J. Engng Ed*., 24(1), pp. 377-385, 2008

[5] S. Sheppard, "Sheri Sheppard of Stanford is U.S. Professor of the Year", available at https://youtu.be/sKIc0aZKMKQ, accessed 31st May 2015

[6] F. Dochy et al., The use of self-, peer and co-assessment in higher education: A review, *Studies in Higher Ed.*, 24(3), pp. 331-350, 1999, DOI: 10.1080/03075079912331379935

[7] Kaufman, D.B. and Felder, R.M., Accounting for individual effort in cooperative teams. *J. Eng. Ed*., 89(2): pp. 133–140, 2000

[8] M. Schar et al., Predicting Entrepreneurial Intent among Entry-Level Engineering Students, paper presented at 2014 ASEE Annual Conference, Indianapolis, Indiana. Available at https://peer.asee.org/22929, accessed 31st May 2015

[9] T. Carleton and L. Leifer, "Stanford's ME310 Course as an Evolution of Engineering Design", Proceedings of the 19th CIRP Design Conference – Competitive Design, Cranfield University, 30-31 March 2009, pp547. Available at http://dspace.lib.cranfield.ac.uk/handle/1826/3648, accessed 31st May 2015