Towards a competency-based peer assessment for engineering group projects using skill descriptors

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ABSTRACT

Over the past two years, the School of Engineering at Warwick has been considering approaches to group assessment with a particular interest in aligning assessment criteria with the skills evaluated by companies during assessment centre group-work exercises. Whereas assessment centres can benefit from observers to record and monitor individual contribution, in academia it is more common to utilise peer review. Two issues were noted by industrial fellows in contrast with their experience outside of academia: establishing and identifying ideal team behaviour and the individual's role within (in contrast with typical leadership and group behaviour) and, secondly, the method of awarding marks to individuals within a group. We therefore developed a new peer assessment system which focuses on competency descriptors and levels of success instead of numerical scores. The descriptors are carefully chosen to encourage team work rather than reward leadership which risks creating 'pseudo-groups'. A pilot run of the system used mean-weighting of the underlying numerical scores to normalize an individual's assessment of their group members. In further work, we plan to investigate how the peer-review system works for students from different backgrounds including race, gender and disabilities.

This work-in-progress paper describes the background and on-going development of the proposed peer assessment system.

INTRODUCTION

Assessed group work is a prevalent feature of undergraduate Engineering courses and is required to meet learning outcomes as defined by AHEP 3 (Table 1, Engineering Council, 2014). Group work nurtures skills that are valued by employers including oral communication, negotiation and other interpersonal skills (Chin, 2010). Thus, the ability to work in a team is seen to be a strong indicator of employability and so is commonly assessed through competency-based interviews, group exercises, and role-play scenarios. Whilst group work itself is an effective learning activity for developing these skills, it is important to reflect on them by giving and receiving feedback on these behaviours. The ability to reflect and give feedback are further an essential life-long professional skill as defined by UK-SPEC (Table 2, Engineering Council).

Engineering Practice	Understanding of different roles within an engineering team and the ability to exercise initiative and personal responsibility, which may be as a team member or leader.
Additional General Skills	Exercise initiative and personal responsibility, which may be as a team member or leader

Table 1: Extract from AHEP 3

The assessment of individuals within a group can give rise to tensions between group members, who may become more concerned with their mark rather than the outcome of the project. The use of peer assessment here refers to students marking each other's contribution to group work. This can be fraught with difficulty due to game playing and unequal perceptions of a team member's specific contributions, often due to the diversity of the student population.

C3	Lead teams and develop staff to meet changing technical and managerial needs This could include an ability to:	Carry out/contribute to staff appraisals. Plan/contribute to the training and development of staff. Gather evidence from colleagues of the management, assessment and

	• Agree objectives and work plans with teams and individuals • Identify team and individual needs, and plan for their development • Reinforce team commitment to professional standards • Lead and support team and individual development • Assess team and individual performance and provide feedback	feedback that you have provided. Carry out/contribute to disciplinary procedures.

Table 2: Extract from UK-SPEC

In the existing peer assessment system, individual marks for group projects are based upon the relative technical contribution that the other team members believe the student had made to the project. A downside of this approach is that it encourages the students to take a task-based perspective towards team performance. Engineering companies have recognized limitations of such an approach: strong team performance does not consist of just getting the project completed, but also *how* the project was approached. Typically, engineering firms seek to measure the performance of employees against a competency-based framework, measuring more than technical ability (Soderquist et al., 2010).

Figure 1 Task vs Competency

A second issue is how the individual marks are calculated. Previously, a mean-weighted system was used with a fixed number of marks available for distribution within a group. Thus, someone must receive a lower grade in order for another to be rewarded with a higher score. Many students feel under increasing pressure to succeed with some commentators ascribing increase in part due to the increased financial burden of attending university since the change to student fees in 2012 (Bhardwa, 2017). It became evident over a number of years that such a grading system could be gamed by the students and there were particular concerns in cases where some group members had colluded to exclude other students in the group. Anecdotally, academically strong students report pleasure at being grouped with weaker students since there are more marks made available for them. The authors therefore wish to avoid any system which compares individual performance to a single group average.

The final consideration is whether group-work is an effective mechanism for technical learning. Whereas group working is clearly efficient for task completion and enables students to take advantage of each other's knowledge and skills (which is useful in industry), the downside is that some students do not achieve the technical learning outcomes. Although it seems acceptable to reduce an individual mark due to underperformance, to inflate a mark beyond the technical merit does not align with marks received for achievement of technical learning outcomes (unless those outcomes include teamworking skill and other group behaviour). There is therefore a pedagogic aim to prevent students from dividing work between them and simply reporting progress during team meetings. These 'psuedo-groups' were found to be common in the existing group-work in the School. Since members of groups saw each other as competitors for points, they weren't motivated to share knowledge and therefore restricted technical learning to a few members.

LITERATURE REVIEW / RATIONALE

Experience shows that graduates often have under-developed team-working skills. This is supported by recent feedback from graduate recruiters and aligns closely with previous research, which has identified a competence gap between the teamwork skills employers require compared to those developed in undergraduate courses – particularly in Engineering (Willey and Gardner, 2008; Martin et al, 2005). Group projects and collaborative tasks often provide opportunities for individuals to interact with one another, but do not routinely emphasise or facilitate the development of team-working skills (Natishan et al, 2000). It is implicitly assumed that these skills are either already in place or will mature naturally with practice; but this may not always be the case – especially among individuals for whom social interactions can be challenging. Boud and Falchikov (2007) and Keppell et al (2006) advocate that curriculum and assessment design should promote and encourage development of these skills, and we view peer assessment of team performance to serve a key function in this regard. However, it is important that this activity is not relegated to simply scoring peers' performance and instead includes a formative component that informs future development.

The terms “group” and “team” are often used interchangeably, but there are important differences highlighted in (managerial) literature. Fisher and Hunter’s (1997) review outlines that a team is a special designation for a group of individuals that share common goals and an awareness of the nature and complementarity of their respective skills and talents. There is also a notion of shared accountability and “responsibility for outcomes for their organizations” (Sundstrom et al, 1990, p.120). These ideas are developed by Söderhjelm et al (2018) who have investigated how teams evolve, building on Tuckman’s (1965) influential model for team development, and claim that a “work group becomes a team when shared goals are established, and effective methods to accomplish those goals are in place… members feel involved and valued, and their work is of higher quality” (p.203).

In defining how to mark a group project, the first consideration is whether group dynamics, or group performance, are to be rewarded. This is the product vs process question. If group performance is key, then the individual contribution must somehow be evaluated. If the ability to work in a group is a learning outcome, then it has to be measured. Even after establishing the aim, the question remains how to allocate marks and how the marks should affect the overall grade. Winchester-Seeto (Winchester-Seeto, 2002) describes some strategies for mark allocation which are adapted and summarised here.

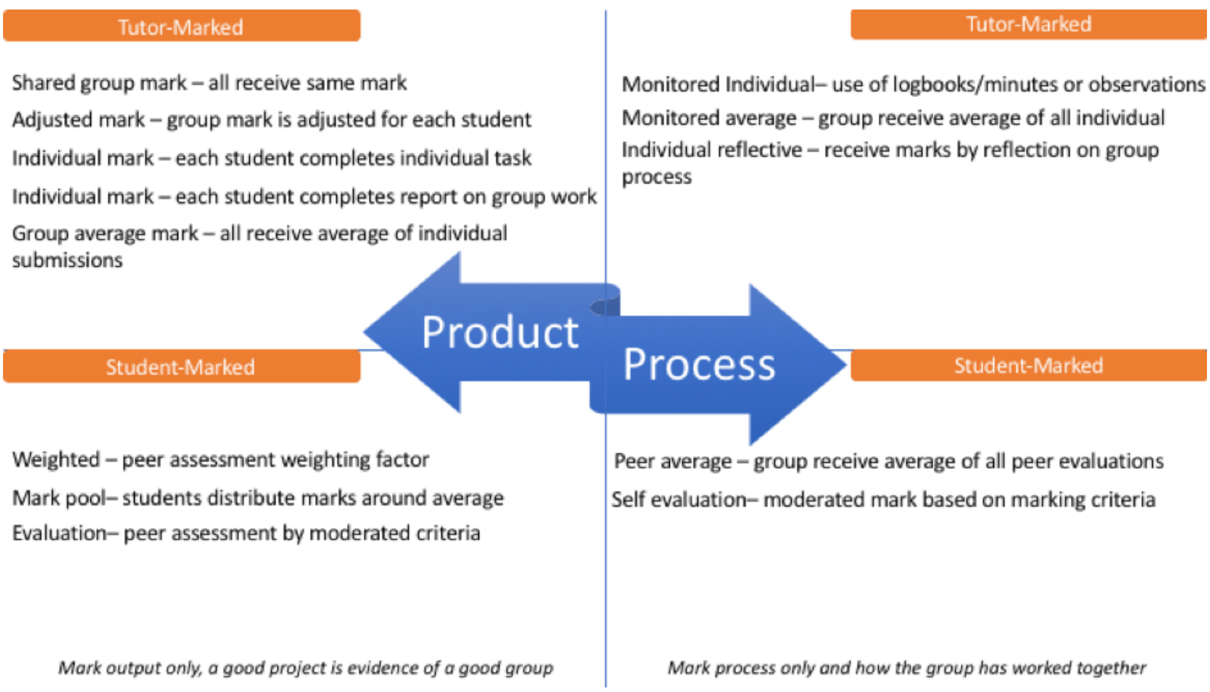

Figure 1 Product vs. Process in Group Marking

There are two main technological solutions relevant here: WebPA and SPARK. In WebPA, students receive a proportion of a group mark adjusted around a mean. SPARK allows for various calculations including a knee formula which does not reward those who do the bulk of the work but incentivises those who would otherwise underperform. Both of these systems invite students to provide a mark against a descriptor.

WebPA is a free, open-source, online peer assessment tool, developed by Loughborough University and appears to have become established as the current state of the art in peer-moderated marking. The development of the system is documented by Loddington et al (2009) and appears to have arisen in response to students' sense of "unfairness" in receiving identical marks to their peers for group assignments. Key benefits are cited as reduced workload and time saving for academic staff, as well as a reduced number of complaints from students. Students also comment that the system facilitates more timely feedback and provides an opportunity to reward those who worked hard, while the most significant benefits for institutions are its flexibility and the centralisation of data (Murray and Boyd 2015, Honeycurch et al 2013). While these are undoubtedly key considerations, its creators recognise that collusion is a significant threat to the validity of assessment data in WebPA. This occurs when group members discuss and manipulate peer evaluation marks, rather than submitting independently and anonymously. The phenomenon was investigated by Pond et al (2007), who identified ways in which it might be detected, but providing such in order for institutions to take action might be very difficult.

AIM AND OBJECTIVES / RESEARCH QUESTION(S)

Ultimately, the School aims to create Engineers who will excel in team projects once employed in industry, especially with reference to the AHEP learning outcomes. By defining what characteristics these successful team players should exhibit, descriptors can be derived for the students to match to exhibited behaviour. Within this assessment context, the School also aims to identify and penalise students who make inadequate contributions whilst rewarding exceptional students whose contributions clearly exceed the overall performance of the team. In particular, we wish to nurture co-creation of output by teams rather than groups, to reward the sort of leadership which supports others in the team to achieve the technical learning outcomes as well as facilitating reflection and growth.

METHODOLOGICAL APPROACH

The study began with a literature search on approaches to marking of group projects (see also Lucas, 2017). By reviewing other methods, we decided to create a student-marked peer evaluation of moderated criteria that reflects desirable characteristics of successful engineers.

Discussions with employers were conducted in order to establish desirable characteristics when considering employability, and to identify more subtle roles that aren't necessarily rewarded by students (Kao, 2013). These discussions were supplemented by researching competency-based recruitment and performance management of two companies: Jaguar Land Rover Ltd and BAE Systems.

Jaguar Land Rover: Business Behaviours	BAE Systems
• My Business • Effective Relationships • Strong Teams • Efficient Delivery • Agility and Flexibility • Positive Impact • Clear Direction • High performance	*Continuously Improving* • Seeks and accepts feedback from others • Can take a step back • Considers how solutions / processes can be improved *Working Together* • Is willing to co-operate to achieve objectives • Encourages others to become involved • Actively seeks to understand others' point of view

Figure 2 Business Behaviour in Industry

The authors also worked together to identify characteristics of 'teams' separate to 'groups' to understand how team work might improve technical learning by all team members. By speaking with students who traditionally succeeded in the existing peer-review system, we were able to see that strong leaders were highly rewarded by their peers compared to those delivering work. This was particularly evident in multi-disciplinary projects where work was distributed according to skill (programming, manufacturing) rather than the amount of time the work might take. In order to enable team work, 'sprint' projects were introduced whereby students were co-located for a week-long project working on a task which required consideration of multiple approaches, negotiation, idea generation and evaluation. By removing the luxury of time to 'go away and think about it' we were able to force groups through the stages of 'norming, forming, storming and performing' relatively quickly.

Group	**Team**
Separate goals, common interest	Common goal, separate skills
Strong leader bringing everyone's contributions together	Share ownership
Individual accountability with one leader	Mutual accountability
Individual work-products	Collective work-product
Leader runs efficient meetings where work done is described	**Open ended discussion and active problem solving during meetings**
Proud of output	Proud of each other

Figure 3 Group vs Team Characteristics

We therefore identified four key skills that we believe to define successful team performance within Engineering:

1. Commitment: The team member attended meetings, provided ideas and was generally available as needed.
2. Performance: The team member contributed to their agreed role and to the success of the project as a whole.
3. Attitude: The team member was positive, honest and played a constructive role to identify and address challenges.
4. Team dynamics: The team member encouraged other members of the team, helped the group to reach consensus and did not engage in bullying or discrimination.

To facilitate peer assessment, a bespoke system was developed in house. In our proposed peer assessment system, students rate their team members according to each of these skills using qualitative descriptors rather than a numeric score (see example in Table 3). We remove numeric scores to encourage students to focus on the evaluation criteria rather than the final numeric score. Success against the normal marking scale (1st, 2.i, 2.ii, 3, fail) is linked to a numeric scale 'behind the scenes'. The highest scores were retained for students who not only showed high individual performance, but also facilitated achievement by other students. The four skills are weighted evenly, except for "Performance" with a double weighting. Students can write brief statements about each team member to support their chosen descriptors. Students have multiple opportunities to complete the review and receive feedback, encouraging improvement during the project.

The final peer score is calculated as follows. The scores assigned by a given student are normalised by the *median* of those scores. Using the median enables a student to recognise and reward exceptionally high performance, or call out absent members, without being forced to redistribute marks. After the scores assigned by each student are normalised, an individual's final peer score is the mean of the normalised scores assigned to them by their teammates. The final peer score is then used to scale the group project mark to determine the individual project mark.

Key skill	Fail	2:2	2:1	1st
Commitment	Did not attend meetings and had no valid excuse	Attended meetings but was ill prepared and/or late	Well prepared for meetings, arrived on time and fully participated	Well prepared for meetings, arrived on time and encouraged others to participate
Performance	Does not contribute or perform well in the project	Is a good performer with effort varying throughout the project	Makes a sustained effort performing highly throughout the project	Holds others accountable and makes a huge effort with high performance throughout
Attitude	Did not contribute positively to challenges perhaps giving up	Morale affected by challenge but willing to persevere	Responded positively to challenge, accepting new direction	Aided discussion on overcoming challenges
Team Dynamics:	Is not transparent or willing about issues affecting the team and/or avoids or actively seeks conflict	Is not always forthcoming when discussing issues affecting the team and/or finds it difficult to negotiate	Is willing, fair and transparent when engaging with and negotiating team issues	Is skilled at identifying and bringing issues to discussion, negotiating and incorporating others' viewpoints

Table 3 Rubric for individual key skills

KEY FINDINGS

We ran a pilot using a one-week project which is part of a module taken by all first-year engineering students (Systems Modelling and Computation). The results from the pilot system were compared with the existing system using a student survey. The students were positive about the new system and liked the preliminary assessment which gave them a chance to improve before the final peer assessment. The use of feed-forward assessment in this way contributed to improvement in students' group-work skills.

We also compared individual student scores on group projects to their overall performance on other modules. We observed that the existing peer assessment system tends to result in higher comparative scores for lower-performing students and vice-versa. The piloted peer assessment system produces scores that are more reflective of the other assessments. This suggests that the proposed system more accurately and fairly reflects students' contributions.

There is a planned full trial of the proposed system in July 2019 to confirm whether:

1. Teamwork skills improve – by testing the same cohort again in a second year project we can evaluate the benefit of feedforward for group-work skills
2. Technical skills improve – by comparing the scores of high-performing teams with their individual score on the written examination we can see if teamwork improves technical learning for all team members. Conversely, we are interested in whether low performing teams have individuals with higher technical competence as measured by the written examination
3. Fairness – by observing group work in sprint sessions do academic assessors notice anything which is not captured by the proposed descriptors.

DISCUSSION

Group-work can undoubtedly be efficient for both academics and for students; large projects can be divided into smaller tasks yet a single output can be marked reducing workload for all. The authors wonder however whether there is an impact on individual learning, whereas in industry one would not expect the team to understand all components there is a requirement for students to demonstrate technical learning outcomes. We propose that there is a way to get the benefits of economy in group work whilst still ensuring learning across the group by promoting team-work. This also encourages a flexible workforce who are able to adapt to different job roles and learn from each other.

The literature reviewed identified concerns about student gaming which were evident in our own system. The well-accepted peer review system used in the sector had not addressed these concerns and, despite increasing diversity, the experience of individuals with diverse needs of group work and assessment is not well-understood. It was clear that confident leaders were encouraged and rewarded by the existing system.

This project was motivated by the industrial experience of the authors which was at tension with the widely accepted system of peer-assessment within and outside of engineering. In particular, the business behaviours so encouraged and rewarded in industry were not rewarded or trained in undergraduate Engineers and, conversely, those encouraged and rewarded by the peer review system were not those desired by companies. The development of descriptors for both successful teams and for successful individuals did not therefore stem from the literature but from discussion with employers as well as brain-storming by authors experienced in both sides. This proposal sits at an unusual boundary between the two and is a perspective with further potential. By more closely aligning assessed behaviour in group-projects with those in industry we aim to improve students' success at assessment centres. This also gives students an opportunity to understand how they might be judged against set competencies (for example when attempting to gain chartership) rather than specific achievement.

CONCLUSIONS & RECOMMENDATIONS

It is clear that there is merit to further explore the descriptors for desirable behaviour and to validate our initial findings that the sector needs more 'players' rather than 'leaders'. Discussion with a wider range of employers and academics would add valuable dimensions and help us to refine the criteria, especially when incorporating the descriptors for chartered engineers. Together with further refinement of the mechanism for weighting individual scores, the authors will continue to iterate and improve this peer review system whilst also monitoring longitudinally the benefit to students and their group work skills, perhaps measured by their success at graduate assessment centres or by improvements in their peer review scores. Iterations will also be monitored for the protection they offer against collusion and gaming to continue to improve fairness and accuracy in measurement of individuals working together in projects.

There are two follow-on projects which emerge from this work. The first is to look at how we can encourage and teach team-work as separate from group-work. Agile, co-located, multi-functional project teams are becoming more prevalent in Engineering industry with the advance of Scrum and Kanban methodologies not covered here. The authors will be teaching these methods to a subset of the Engineering cohort at the end of year 2 and wish to compare the experience of students once they have been taught how to work as a team.

Finally, the authors hope to gain deeper understanding of how individuals with varying needs and background experience group projects. We want to determine which factors affect the peer-scores as it is possible that students from certain backgrounds are unfairly penalised. We want to uncover the impact of bias and build a peer review system which prepares Engineers for working in ever more diverse teams and ensures all strengths are recognised by our own academic systems.

REFERENCES

Bhardwa, S., 2017. Finance one of the main causes of student stress, *Times Higher Education*, [online] Available at https://www.timeshighereducation.com/student/news/finance-one-main-causes-student-stress [Accessed 6 January 2018].

Boud, D. and Falchikov, N. eds., 2007. ***Rethinking assessment in higher education: Learning for the longer term***. Routledge.

Chin, P. & Overton, T. "Assessing group work: advice and examples ". *HEAcademy* 2010 [online] Available at https://www.heacademy.ac.uk/system/files/assessing_group_work.pdf [Accessed December 2016].

Delaney, M., Bowe, L., Fitzgerald, B., MacCann, P. and Ryan, C., 2016. Methods for Deriving Individual Marks from Group Work.

Engineering Council, 2014. "The Accreditation of Higher Education Programmes UK Standard for Professional Engineering Competence Third edition", *The Engineering Council,* UK [online] Available at **http://www.engc.org.uk/engcdocuments/internet/Website/Accreditation%20of%20 Higher%20 Education%20Programmes%20third%20edition%20(1).pdf** [Accessed January 2017].

Fisher, S.G. and Hunter, T.A., 1997. Team or group? Managers' perceptions of the differences. ***Journal of Managerial Psychology***, 12(4), pp. 232-242.

Freeman, M. and McKenzie, J., 2002. SPARK, a confidential web–based template for self and peer assessment of student teamwork: benefits of evaluating across different subjects. *British Journal of Educational Technology*, *33*(5), pp. 551-569.

Honeychurch, S., Barr, N., Brown, C. and Hamer, J., 2013. Peer assessment assisted by technology. *International Journal of e-Assessment*, *3*(1).

Kao, G.Y.M., 2013. Enhancing the quality of peer review by reducing student "free riding": Peer assessment with positive interdependence. *British Journal of Educational Technology*, *44*(1), pp. 112-124.

Keppell, M., Au, E., Ma, A. and Chan, C., 2006. Peer learning and learning-oriented assessment in technology-enhanced environments. ***Assessment & Evaluation in Higher Education***, 31(4), pp. 453-464.

Loddington, S., Pond, K., Wilkinson, N. and Willmot, P., 2009. A case study of the development of WebPA: An online peer-moderated marking tool. *British Journal of Educational Technology*, *40*(2), pp. 329-341.

Lucas, C., 2017. Group Marking [Online] Available at https://warwick.ac.uk/fac/sci/eng/research/grouplist/eerg/group_marking/. [Accessed 13 September 2018].

Martin, R., Maytham, B., Case, J. and Fraser, D., 2005. Engineering graduates' perceptions of how well they were prepared for work in industry. ***European journal of engineering education***, 30(2), pp. 167-180.

Murray, J.A. and Boyd, S., 2015. A preliminary evaluation of using WebPA for online peer assessment of collaborative performance by groups of online distance learners. *International Journal of E-learning and Distance Education*, *30*(2).

Natishan, M.E., Schmidt, L.C. and Mead, P., 2000. Student focus group results on student team performance issues. ***Journal of Engineering Education***, 89(3), pp. 269-272.

Pond, K., Coates, D. and Palermo, O.A., 2007. Student perceptions of peer review marking of team projects. http://dspace. lboro. ac. uk/dspace/bitstream/2134/3040/1/IJMEPaper, 20190, pp. 20-23.

Söderhjelm, T., Björklund, C., Sandahl, C. and Bolander-Laksov, K., 2018. Academic leadership: management of groups or leadership of teams? A multiple-case study on designing and implementing a team-based development programme for academic leadership. ***Studies in Higher Education***, 43(2), pp. 201-216.

Soderquist. E.K., Papalexandris, A., Ioannou, G. and Prastacos, G., 2010. From task-based to competency-based: A typology and process supporting a critical HRM transition. *Personnel Review,* **39(3)** pp. 325-246.

Sundstrom, E., De Meuse, K.P. and Futrell, D., 1990. Work teams: applications and effectiveness. ***American Psychologist,*** 45(2), pp. 120-33.

Tuckman, B.W., 1965. Developmental Sequences in Small Groups. ***Psychological Bulletin,*** 63, pp. 384-99.

Winchester-Seeto, T. 2002. "Assessment of collaborative work – collaboration versus assessment". Invited paper presented at the Annual Uniserve Science Symposium, The University of Sydney. April, 2002.

Willey, K. and Gardner, A., 2008. Improvements in the self and peer assessment tool SPARK: Do they improve learning outcomes?. ***ATN Assessment***, 1(1).

Willey, K. and Gardner, A., 2009. Developing team skills with self-and peer assessment: Are benefits inversely related to team function?. *Campus-Wide Information Systems*, 26(5), pp. 365-378.