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Addressing issues related to running and assessment of teamwork in engineering education: Improvements observed when using Individual Peer Assessment of Contribution (IPAC)

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ABSTRACT

Teamwork is heavily used and become the norm in Engineering education across all years and disciplines. Academics running such projects/learning activities are well aware of the benefits but also the challenges of such activities, that includes for example the logistics (particularly in large teams), ensuring student engagement,

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equal opportunities, students training and development, and fair assessment. This paper reviews six different case studies in engineering that represent the pathway taken by students in various engineering degrees at UCL. The paper identifies the main challenges faced by practitioners when running and assessing teamwork and mitigations taken to address them. In particular, we emphasise the benefits of using Individual Peer Assessment of Contribution to teamwork (IPAC), and how it helps to successfully mitigate issues that were encountered otherwise. We believe this paper will be useful for any HE lecturer in engineering (even other fields) that runs teamwork such that they improve or reinforce awareness on these challenges, see how others approach them and the impact of those approaches, potentially giving them either ideas for improvement or confirmation of their own practice. We have combined this paper with a workshop and aim to incorporate a reflection on practices at other institutions and broader range of academics.

1 INTRODUCTION

1.1 Use of teamwork in HE

While technical knowledge is still important for graduates, it needs to be paired with other experientially learnt skills such as collaboration or communication (World Economic Forum, 2023), and so skills-based learning within Engineering curricula has increase to prepare graduates for the changing post-university environment (Graham, 2018). The introduction of team projects to programmes has been a key approach to providing students with supported opportunities to learn these more experiential skills but incorporation does not come without challenges that staff will need to address. This is particularly true for large scale teaching which is common within Engineering programmes (Truscott *et a*l, 2023).

1.2 Challenges of Teaching Teamwork in Higher Education

Riebe et al (2016) in their systematic review of various case studies, categorised challenges associated with delivering and assessing teamwork in the Higher Education (HE) context into two themes, i.e., teamwork pedagogy and transaction costs.

Challenges associated with teamwork pedagogy include: (I) *Instruction strategies*, whereby educators and learners lack prior experience, view teamwork as an inefficient use of time and find moving away from tutor-centred teaching challenging (Holt et al, 1997), (II) *Curriculum design* – the degree to which team skills development is incidental or intentional in the curriculum. The intentional inclusion of teamwork training and instructions into the design phase of the curriculum is typically done using the constructive alignment model (Biggs, 1999), and this can be time and cognition intensive. (III) *Team composition*, in terms of team size, diversity, and formation, if incorrectly approached, could result in a negative learner perspective of teamwork productivity with social loafing or free riding being the main concern for learners (Hansen, 2006; Page et al, 2003; Sashittal et al, 2011; Shaw, 2004; McCorkle et al, 1999), and (IV) *Assessment* – which centres on identifying strategies for individual grading and how to address free riding as an assessment concern for learners (Freeman et al, 2002; Ohland et al., 2012).

Willamson's (1979) transaction cost theory assumes that engagement is a function of the benefits or costs derived from developing, coordinating, monitoring,

participating in, interacting with, and evaluating teamwork pedagogy. In terms of teaching teamwork skills, these transaction costs may be incurred by seeking to meet employer and accrediting professional bodies' expectations (Burbach et al, 2010; Kliegl, 2013), as a function of the tutors' readiness to develop resources (Albon et al, 2014), developing strategies and interventions (Kedrowicz, 2007) and teaching teamwork skills (Jackson et al, 2014). The transaction costs also encompass how willing and ready learners are to participate in teamwork learning activities (Bacon, 2005), and available resources in institutions which promote teaching and learning teamwork (Ahern, 2007).

It is critical that engineering graduates develop an ability to work effectively within various team configurations or team types e.g. production, service, management, project, virtual, multidisciplinary, etc (Sundstrom et al., 2000); but also different team styles management e.g. consensus or voting or single leader decision making (Yang 2010). Therefore, understanding the dynamics and requirements of diverse team types is crucial for engineering graduates and educators alike. Tuckman's model (Tuckman and Jensen, 1977) introduced the five team developmental stages i.e. Forming, Storming, Norming, Performing, and Adjourning. These stages provide a dynamic framework for teaching teamwork wholistically to diverse team in varying contexts typically encountered in HE.

Various authors have attempted to address some of the teamwork challenges and developed solutions including introducing learner-team training tools and simulations (Hubbard, 2005;), role play (Crumbley et al, 1998), setting rules and accountability within the team by use of team contracts (Pertegal et al 2019, Ramdeo et al 2022) and introducing learners to the stages of teamwork using the Tuckman's (1965) model. Another popular solution has been the use of self and peer assessment, which we call hereafter IPAC (Individual Peer Assessment of Contribution to teamwork). The IPAC assessment methodology allows the learners to assess the level of contributions of each of their peers, including themselves, from which an IPAC factor or score is generated after moderation by the tutor. The IPAC can then be used in combination with the team mark to generate and individual marks for the team members that reflects the achievements of the team but also the individual contribution (Garcia-Souto, 2019). The assessment methodology is used broadly and has been reported as having significant potential to improve students' experience and engagement and reduce the temporal and efficiency related costs (Hansen, 2006; Page et al, 2003; Delaney et al, 2003; Delaney et al, 2013; Garcia-Souto et al, 2019; Seatwo, 2019).

The IPAC assessment methodology is broadly used at University College London, implemented using the IPAC system developed at our institution that makes it easy to run and insightful for staff and students (Garcia-Souto, 2019). Other universities are also using this IPAC system successfully.

Despite its challenges, teamwork remains a strong training and learning opportunity in the Higher Education (HE) engineering context. It is therefore of interest to find ways in which the challenges are managed, and the opportunities enhanced and enriched. In this paper we bring together the perspectives of 5 members of staff who lead team project units within a common HE environment. Through case studies of each practitioner's teaching activity, we bring together a list of types of challenges faced by those leading team projects and start to build a range of potential solutions

or mitigations that can be used by others. We aim to widen our community of practice through a linked workshop at the 2024 SEFI conference.

2 METHODOLOGY

2.1 Selection of case studies and analysis

Six different case studies from the UCL Intergrated Engineering Programme (IEP) have been identified and analysed in this paper. The IEP is a teaching framework covering the majority of engineering undergraduate programmes within 8 engineering departments (Mitchell *et al.*, 2019). Throughout the IEP there are several team projects, both single discipline and interdisciplinary, that take place with a range of cohort sizes. The case studies included in this paper were selected because they are representative of the pathway of students within a range of engineering degrees, and they cover a range of class sizes, years of study, engineering fields, different team formations and length and weight of the project towards final degree mark. The practitioners brought together in this paper, work within a range of departments and bring different experiences and approaches to teamwork.

A thematic investigation and analysis were performed covering the selected case studies by practitioners. First the activity lead of the different case studies had a chat about their own experiences, from which a list of possible challenges cathegories was drawn by the first author. Then the lead for each case study was individually requested to reflect and elaborate in writing on each challenge, their perception of impact, describe their approach to mitigate it and how successful it was according to own perception. Finally, the first author performed thematic analysis on the written answers, that was then checked and corroborated by the other authors/case study leads. Our results show the main/common approaches that fit all cases, and also specific/local approaches based on case.

2.2 Case studies

The case studies analysed in this paper cover the pathway of engineering students at UCL from year 1 to year 4 in various disciplines and various class sizes as summarized in table 1. The IEP Challenges (case study A) is the first team project experience for all year 1 students and so students are trained and supported on developing teamwork skills (Truscott *et al*, 2021). Then the students take the “scenario projects” within their own disciplines that are a series of six one-week intensive projects spread across the first and second years (case studies B and C given as examples). At the end of the year 2, all students undertake the How to Change the World project (HtCtW) along with management students, and they work in multi-disciplinary teams, with people they have not met before. In the later years of the degree, students take a more significant team project within their own discipline (case studies E and F as examples), carrying out a significant weight towards their final degree classification.

Table 1. Case studies summary

Case	Name	Eng field	Year study	Class size	Type of teams	Team size	Proj. length	Weight (%) × ECTS

A	IEP Challenges	All	1	>900	Across 7 disciplines	5-8	7 weeks	70% × 7.5
B	Scenario Design Projects (x6)	Chem Eng	1-2	130 - 220	Within discipline	5-7	1-week full time (x6)	~25% × 7.5 (x6)
C	Scenario Design Project in BME	Biomedical Eng	2	70	Within discipline	4-5	1-week full time	25% × 7.5
D	How to Change the World (HtCtW)	All	2	>800	Across 7 disciplines	4-8	2 weeks full time	5% × year 2
E	Design group project	Chem Eng	3	130 - 200	Within discipline	5-6	3 months	45% × 15
F	Design group project	Biomedical Eng	4	20	Within discipline	4-5	6 months	90% × 22.5

3 RESULTS

The analysis was done on the teamwork nature of the activities without reference to the discipline or particulars of the case studies, making results meaningful to the wider engineering community. The challenges identified are given, as well as the proposed mitigations to solve them and how successful they were based on staff perceptions in comparison with their earlier approaches.

List of challenges:

A. Uneven student contribution/engagement and implications towards the assessment.
B. Validity of assessment: This includes concerns of whether each student gets a mark that is representative of their contribution to the teamwork. Concerns are typically felt by students, staff, external examiners, accrediting bodies when all students in a team will receive a unique mark.
C. Diversity in the team: scenarios included here are differences in students' technical knowledge and skills, differences on social skills and ways of interacting/collaborating with people, neurodiversity, differences on working patterns and responsibilities outside of the team project, differences in culture, differences on their communication skills both written and oral in English, etc.
D. Teams with SORA/EC students (SORA indicates reasonable adjustments that should be offered to a student due to long-term conditions, and EC stands for Extenuating Circumstances): Some students might have SORAs or experience some personal issue that might affect their ability to perform in the team. Some might choose to communicate this to the team, but not all.

E. Readiness of students to do teamwork: This includes e.g. (i) ability of students to work in teams successfully, (ii) awareness of the possible diversity in a team and how to work with a diverse range of teammates, (iii) clarity on suitable students' expectations from teammates, particularly when peer assessing individual contributions, (iv) ability of the students on giving and receiving feedback in a way that is professional, critical yet constructive.
F. Team formation (rather than cohesion): Teams originally defined by tutors might be seen not to be appropriated quite early in the project. This includes (i) difficulties at the onset of the project, perhaps due to prior personal interactions between the students of academic/non-academic nature; (ii) some students might not be active in the module e.g. they are going for interruption of studies, changed their diet, etc but the module leads are not aware of it.
G. Team cohesion: Some teams can find it difficult to work together for various reasons once the project is well underway. These include clashes on personality particularly under stress, strong conflicting opinions or ideas on the desired direction of the project, differences on styles of working, or even a break-down of personal relations in or out of the project.
H. Staff workload: This includes time commitment in all aspects of the teamwork, i.e. preparation of the teams, training of students on how to do teamwork, monitoring student engagement and performance and intervening, when necessary, assessment, mitigations/arrangements needed for specific individuals/cases, and dealing with student querying/challenging their individual marks. This strongly relates to the student numbers.
I. Readiness of staff to run teamwork: Are we all ready to lead a teamwork activity? Which knowledge and skills are needed to successfully run teamwork, is there any training to close the gap?

List of mitigations per challenge:

Challenge A: Uneven student contribution/engagement -successfully mitigated

- Use the IPAC assessment methodology, so students are aware of the individual accountability to the team members, and acts as a deterrent of unjustified lack of engagement. Feedback to students from peers is valuable.
- Provide training to students in earlier years, while in 3rd/4th years need less training as they are already aware of the IPAC methodology and work expectations.
- Check points with staff are helpful, i.e. regular meetings with a member of staff, either as a team or with individual students. This is particularly common in large teamwork components in senior years, e.g. cases E/F.

Exceptional cases of very significant lack of engagement are dealt by staff, with the possibility of removing the student from the team. If the lack of engagement is justified, the staff offers deferral or alternative assessment.

Challenge B: Validity of assessment – successfully mitigated

The IPAC methodology (which includes standard tutor revision and endorsement of the marks) almost solves this challenge entirely. It is particularly useful when team dynamics are not obvious to staff. It handles students' concerns in a formal/standard way, and students are mainly comfortable with the peer assessment and happy with

the methodology. It is uncommon for individual students to raise concerns with their IPAC marks, but such cases are reviewed by staff.

In long projects we recommend the use of IPAC for formative purposes at the start/middle of the project. It is an insightful “check point” for staff and it allows students to improve /continue with good practice in their project. It avoids surprising IPAC mark at the end, almost eliminating individual students that complain about their own mark.

Challenge C: Diversity in the team – successfully mitigated

Teams are encouraged to use the diversity and individual skills to their advantage. Particularly in year 1 (or first few times doing teamwork in HE), staff discuss with the students the value of diversity, but also train them in soft skills like communication or teamwork styles. The staff might try to balance the diversity when making the teams – this is further discussed under challenge F.

Teams write a contract at the start of the project. This engages students onto an upfront discussion on how to accommodate/take advantage of the diversity in the team. The typical student team contract reflects that students expect team members to put equal “effort” on the project as opposed to equal “output”.

The IPAC assessment is used for students’ self-reflection, which supports students to understand and enhance their role in the team. The feedback that each student receives from their peers often also help them to see how their teammates value them, and encouragement in the areas that could need further development.

Challenge D: Teams with Summary of Reasonable Adjustments (SoRA)/ Extenuating Circumstances (EC) students- successfully mitigated

- When SORA students are known to staff in advance, they are distributed across the teams. SORA/EC students are supported by staff when needed and encouraged to participate in the team project if possible.
- Team contract provides an opportunity for students to disclose personal circumstances that might be relevant in the teamwork and for the team to be aware/adjust to the needs of all individuals.
- Make clear to students, which adjustments can be applied in the teamwork for students with SORAs or ECs, and equally those that cannot be applied. Adjustments are subjected to reason, e.g. a SORA student might be given a 2-weeks extension in most of their individual assignments, but it does not apply to team submissions. SORA/EC students that cannot participate in the team project are “effectively withdrawn” from the team and a suitable alternative assessment offered.
- Projects should be feasible to completed even if missing a team member.

Challenge E: Readiness of students to do teamwork - mitigated

This challenge applies more significantly to year 1, when the students are new to teamwork. A significant improvement is observed from year 2 onwards. We found useful to give students training in year 1 on key aspects of teamwork, communication, conflict, etc as part of a taught year-1 module and have a team project focused on the development of teamwork skills (case study A). This sets up a strong foundation of students’ skills to do teamwork. Students are also further

supported/guided in following years. Marking criteria for the IPAC assessment is presented/discussed with students to clarify and standardize student expectations.

The IPAC assessment also gives students an opportunity for self-reflection and insights on their own performance by anonymous peer regarding their performance and ability to work in a team, which help them with their self-development.

There is always room for improvement by adding more training and mentorship.

Challenge F: Team formation – successfully mitigated

Team formation can be addressed in three different ways.

- Random or semirandom teams' membership. This is the common practice in large classes run across engineering degrees (case studies A and D).
- Semirandom but staff-planned such that students work with as many different students as possible within their degree. This seems to solve quite a few issues and it provides a good training to students. It is typically used in small/medium classes that run within a single degree programme (case studies B and C).
- Diversify membership: In small/medium classes undertaking a very large project within an engineering degree, teams are formed by tutors with consideration to balance gender, academic performance, cultural diversity and typically no more than 1-2 SoRA students (case studies E and F).

Observations on what works:

- Students respond more positively to team membership when the IPAC methodology is in place, even with random and diverse memberships.
- Staff might avoid putting together students with unsolvable standing conflicts due to prior/outside academia personal issues. This is particularly useful in long projects like year 3/4 design team project modules.
- Often the number of students in a team varies within a given activity. This does not seem to present a challenge provided the project can offer flexibility and is suitable to be completed by the smallest team.
- Staff monitors engagement in the early stages of the project e.g. running a formative IPAC or checking attendance to in-class events. If issues within the team are detected, staff decides in a one-to-one basis if teams/particular students just need some initial support or as last resort if some teams need to be re-adjusted. This also identifies non-active students, even if registered.

Challenge G: Team cohesion

Training and general support is provided to students, particularly in year 1. As consequence, it is rare that a team will become truly dysfunctional. However, if a team does break down as a result of external and/or internal factors, tutors provide support meeting with the team or individual students as need. Often team difficulties become significant learning experiences for team members. If the issues are significant, then this is addressed on a case-by-case basis. Dysfunctional groups are either identified by self-referral or reviewing the IPAC scores, hence it is useful and insightful to run the IPAC methodology at some point at the beginning or middle of the project even if only for formative purposes.

Challenge H: Staff workload

Team projects can require significant planning, preparation, and coordination hence staff workload is high and needs to be shared across various staff, especially in large classes. Typically, we have (1) one or two staff activity organizers that lead the planning and running of the activity, monitors and liaise with the class and deploy resources and personnel as needed; and (2) a range of PGTAs/academic staff/technical staff that support different areas of the teamwork activity and also act as supervisor for various teams. The activity organizers typically stay the same, while support personnel is more variable, specially PGTAs, and need training each year. We recommend having at least two staff members that can act as activity organizers for resilience, since it would be very challenging to replace a single activity organizer at short notice e.g. in case of illness/accident.

Challenge I: Readiness of staff to run teamwork

Teamwork seems to be typically led by self-driven staff that generally appreciate the value of teamwork for students' development and have a natural inclination to seek training and peer dialog about best practice. However, there is however no official or mandatory training. Activity leads acknowledge that staff training is needed, and often both offer training/guidance themselves to the support staff/PGTAs and refer them to relevant seminars when available. We believe that a more standard and comprehensive training for staff would be useful.

4 SUMMARY AND ACKNOWLEDGEMENTS

Based on the case studies presented, the authors believe that the IPAC is helpful in addressing some of the challenges related to the running and assessment of teamwork (challenges A, B, C D & F). It facilitates a quick and neat way of providing formative peer feedback, which students can then reflect upon to improve on future teamwork activities and submissions. In that sense, the IPAC assessment method takes a similar approach to the Tuckman's model (Tuckman and Jensen, 1977) and its stages of team development, using peer-feedback to foster the development of teamwork skills across diverse contexts. The IPAC facilitates students' assessment literacy, as they participate in aspects of the grading and helps build emotional intelligence in providing constructive feedback. The IPAC also provides students a sense of fairness in assessment and team allocation, it directly encourages constructive student engagement, and it is seen as a fair intervention for addressing free riding or uneven contributions.

Although the IPAC methodology has mitigated many of the challenges faced, it has its limitations. The IPAC marks need to be reviewed, in few cases moderated by staff, first of all because marks must be endorsed by staff but also as a student's safeguarding process especially for cases involving SoRAs and EC students. Typically, only a few cases might need moderations, and these academic judgments are based on the peer comments and available staff observations. Other important aspects to good teamwork are (i) student training and mentorship by staff; and (ii) team management tools such as the use of a student-developed team contract at the start of the project, which will encourage good communication and understanding of needs between the team members.

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