Teaching, Practicing and Assessing Teamwork:
A Programmatic Mapping of Teamwork Skills and Behaviours

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ABSTRACT

CONTEXT

Teamwork has long been established as a core skill for engineering graduates, with industry advocating for the need for this along with other professional skills such as leadership and communication (Ercan & Khan, 2017). This is also evident in the Engineers Australia Stage 1 competency standards, which outline expectations for engineering graduates related to a range of professional skills. In the university setting, teamwork is often expected and practiced, but it is not reliably taught or assessed in a comprehensive or rigorous way.

PURPOSE OR GOAL

Across the three Infrastructure Engineering degree programs at the University of Melbourne (civil, environmental, geomatic engineering), we sought to improve the way teamwork was taught, practiced, and assessed. We initially intended to use established definitions of what constitutes teamwork, but we found these to be fragmented and not sufficient for our context.

To address this issue, we sought to develop a framework for teaching, practicing and assessing teamwork (TPAT) skills for an engineering program.

APPROACH OR METHODOLOGY/METHODS

The framework was developed over three stages: Stage 1 - Initial Investigation, Stage 2 - Definition, and Stage 3 - Socialisation. Stage 1 consisted of a desktop literature search for existing teamwork frameworks and definitions of teamwork skills. In Stage 2 we synthesised from the literature a prototype skills mapping. In the final stage we consulted with subject coordinators at each level of the degree programs (approximately two per year level) to gather feedback and further refine the skills mapping and improve the implementation plan. We also worked with two subjects to trial the mapping.

ACTUAL OR ANTICIPATED OUTCOMES

We have developed a framework for teaching, practicing and assessing teamwork that consists of a definition of teamwork and a programmatic mapping of attainment of teamwork skills. We also gathered insights from two subjects that have used the mapping to inform their teaching.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

We defined teamwork skills and proposed a mapping for how they can be acquired across a degree program. The next steps of this work will be to create an implementation plan for how this mapping could be embedded into a whole degree program and supported with resources.

KEYWORDS

Teamwork, Infrastructure Engineering, Programmatic Curriculum Development.

Introduction

Teamwork has always been an essential part of a practicing engineer's skill set, and teamwork capabilities are also among the top skills expected from engineering graduates (Ercan & Khan, 2017). This is becoming increasingly important as engineers engage in interdisciplinary work, solving problems related to sustainability, housing, and other societal issues.

Teamwork is typically listed as an explicit program learning outcome for engineering degrees, and it is a recurring component of many accrediting bodies' requirements. At the subject level, teamwork is often approached as something for students to experience rather than learn, with the assumption being that students will gain skills via the collective experiences of working in groups over the course of their degrees, or to lump development of these skills into monolithic project-based learning subjects (Lingard & Barkataki, 2011). This approach is not only suboptimal, it also often fails to document what is *taught*, instead assuming learning will happen via practice.

Assessment of teamwork skills is another area that is lacking (Britton et al., 2017). These skills are sometimes assessed implicitly, based on the product of group work, typically a report or demonstration, and differentiation is often only supported by peer evaluation which tends to measure student perception of effort and does not directly measure teamwork skills. Additionally, these assessment mechanisms are highly susceptible to collusion and peer pressure.

One common approach to address these issues is to teach teamwork and other professional skills in an integrated first-year engineering curriculum that focuses on developing a solid foundation in professional skills across several subjects (Felder et al., 1998). While this approach often does a better job of teaching foundational skills in teamwork, it does not address how these skills are further developed and improved over the whole degree.

A challenge that arises when trying to embed teaching, practising and assessing of teamwork skills is that it is difficult to accurately articulate exactly what good teamwork is and how to develop these skills in students. The Engineers Australia Stage 1 Competency Standards list a broad set of indicators of attainment under element 3.6 "Effective team membership and team leadership", but these do not define specific skills for students to learn. Salas et al. (2005) define a set of five core components that promote team effectiveness, which is useful for defining effective teamwork, but does not directly translate to subject level learning outcomes, nor prescribe how these should be developed over time. A systematic literature review by Chowdhury and Murzi (2019) identified a list of 11 teamwork attributes that are factors for enhancing teamwork effectiveness, however these attributes focus more on defining an effective team and less on what skills, knowledge and behaviours an individual should learn.

In our engineering programs, teamwork was not addressed in a holistic manner across the degree despite students often being expected to work in teams and practice effective teamworking skills. This was a particular issue at higher level subjects where academics assumed students had a certain set of skills and background in teamwork and were often frustrated when they felt they must spend time developing skills they regarded as fundamental. Because of these reasons, we identified a need to scaffold how teamwork was taught, practiced, and assessed across a whole degree program.

In this paper we outline the preliminary stages of the design and development of a framework for teaching, practicing, and assessing teamwork (TPAT) across an engineering program and discuss early attempts to incorporate it into a first- and second-year subject. This framework was developed for the University of Melbourne's Infrastructure Engineering Program with the intent to expand to the whole of faculty. The goal of this stage of the project was to describe effective skills and behaviours and map their attainment across a degree program.

Methodology

Development of the TPAT framework consisted of three primary stages. Initially we completed a desktop review of literature on teamwork with a goal to establish a clear definition of teamwork in

an engineering context. Second, we extracted the common elements from these sources to create a common set of skills that comprise effective teamwork, and a corresponding set of behaviours for each of these skills, mapped programmatically. Finally, we socialised the mapping with subject coordinators identified as being responsible for subjects that involve significant teamwork elements to gather feedback and improve the mapping. Each of these stages is outlined in more detail below.

Stage 1 – Desktop Literature Review

The goal of the desktop literature review was to find research that provided a clear definition of teamwork for the purpose of assessment and designing learning activities. A snowball approach was also used to find additional sources in articles that studied teamwork.

From this search we identified four key pieces of literature: Salas et al.'s "Big Five in Teamwork" (2005), Boelt et al.'s "A Thematic Analysis of Engineering Student's Experiences of Teamwork in Problem-Based Learning" (2023), Chowdury and Murzi's "Literature Review: Exploring Teamwork in Engineering Education" (2019), and "Engineering Thresholds: an Approach to Curriculum Renewal" from the Integrated Engineering Foundation (Male, 2012). We also included the Engineers Australia's Stage 1 Competency Standards, and Purdue University's Comprehensive Assessment of Team Member Effectiveness (CATME) five teamwork dimensions (Hrivnak, 2013) as additional sources.

Stage 2 – Defining Teamwork

Using the sources identified in Stage 1, we synthesised a list of seven broad skills that comprise teamwork referred to here as dimensions of effective teamwork. For each dimension we described several observable behaviours that we expect a student to be able to demonstrate at the completion of their degree. These behaviours served the basis for defining something tangible that we can evaluate and assess. We then worked backwards across the degree program to identify when a student would be expected to learn that behaviour in their engineering degree. This process was somewhat arbitrary, but the purpose was to spread out attainment of these behaviours to ensure that there was a reasonable progression to the learning and that development of given behaviours was not overloaded in a single year.

The seven dimensions of teamwork identified were: Adaptability, Feedback, Communication, Coordination, Collectivism, Leadership and Empathy. Table 1 shows the teamwork dimensions, their associated behaviours and the expected academic year in which students would be able to demonstrate that behaviour. Where a range was provided for "Year Attained" it means that there was a progression in the level or complexity of that behaviour. For example, if we look at "Provide constructive feedback" the behaviour for 1st year would be "Provide feedback on peer performance using a guide", for 2nd year it would be "provide constructive feedback on technical aspects", and 3rd year, "separate out objective and subjective parts of feedback, reflecting on bias and assumptions".

Stage 3 – Socialising the Mapping

During Stage 3 we held meetings with subject coordinators across the year levels to get feedback on the suitability of the mapping. During these meetings we asked the academics to outline how teamwork was currently taught, practiced and assessed in their subjects, and then to comment on the suitability of the proposed mapping, and in particular: the appropriateness of the behaviours for their level, and what behaviours and skills they expected new students to be able to demonstrate. Based on this feedback we revised the mapping and produced the version shown in Table 1.

Table 1: List of teamwork skills and corresponding behaviours

Skill	Behaviour	Year Attained
Adaptability	• Has current knowledge of team goals and work	1
	• Deal with disruptions to team cohesion	1
	• Fill gaps in team skills	2
	• Adjust problem solving strategies when needed to suit the group dynamics	2
	• Learns new skills as required	3
Feedback	• Provide constructive feedback	1-3
	• Critically reflect on feedback provided to you	1-3
	• Seek out feedback	2
	• Take longer term steps to improve based on feedback	3
Communication	• Practice active listening	1-2
	• Communicate with respect and professionalism	1-2
	• Makes sure teammates stay informed and understand each other	1-3
	• Communicate using appropriate terminology for your discipline and group composition	2-3
	• Use diverse means (sync and async) of communication as appropriate for the team	2-4
Coordination	• Makes effort to attend all meetings on time, and/or promptly communicates when this is not possible	1
	• Take into consideration other's time and availability	1
	• Can identify and schedule team tasks appropriately	1-2
	• Maintains up to date team records (e.g. calendar, project logs, task tracking, etc)	1-3
	• Monitors team progress and communicates delays promptly	2
Collectivism	• Participates fully in team activities	1-2
	• Makes important contributions that improve the team's work	1-3
	• Develops relational knowledge of team roles in context of operating environment	1-4
	• Practices with mutual trust in each team member to fulfill their role and do excellent work	1-4
	• Helps teammates who are having difficulty	2
	• Prioritises team goals	3
Leadership	• Fosters a collaborative and respectful culture within the team	1-2
	• Monitors conditions effecting the team and tracks team progress	1-2
	• Alerts teammates and makes suggestions when problems arise	1-3
	• Motivate teammates	2
	• Direct and coordinate the activities of teammates	3-4
	• Uses information available and sound judgement to make decisions	3-4
	• Promotes the use of and defines processes of work	3-4
Empathy	• Establishes a positive atmosphere	1
	• Recognise the value of and seek out diverse viewpoints	1-2
	• Actively acknowledges the contributions of others work	1-2
	• Is aware of and takes into consideration individual's circumstance/background/position/feelings	2-3

Implementation in subjects

Elements of the mapping were used in two subjects to gather feedback and insights on its use and appropriateness. The coordinators of two subjects (one first year and one second year) took

different approaches to using the mapping with one using the mapping as a teaching aid to provide additional context and motivation for students completing existing activities, while the other coordinator used the mapping as a guide to design teamwork activities that addressed the framework dimensions and behaviours. Ethics was sought to evaluate these approaches (human research ethics approval from The University of Melbourne #29907) and a combination of surveys, written responses and educator reflections were used to evaluate the implementations. Further details of each subject are outlined below.

Table 2 Mapping of the TPAT Framework to activities in ENGR10004 and GEOM20013.

Dimension	Subject Approach	
	ENGR10004	**GEOM20013**
ADAPTABILITY	Team Management Plan	Set up a Group Charter
FEEDBACK	Peer Assessments	Sections of the Group Charter; progress meetings with their "supervisors" (tutors)
COMMUNICATION	Microsoft Teams (as project management platform)	Sections of the Group Charter establishing communication channels and expectations
COORDINATION	Independent work outside of class	Sections of the Group Charter (internal time plan); working under tendering conditions (no late submissions accepted) and contract conditions (contractual penalties for late delivery)
COLLECTIVISM	Workshop and Project assessments	Sections of the Group Charter (agreed mechanisms to deal with possible dropouts of individual group members at any time). Time plan in the tender document.
LEADERSHIP	Workshop tasks/activities	Call to use the Group Charter – on agreed behaviour – throughout the semester
EMPATHY	All activities	Set up and reviews of the Group Charter at defined points in the semester – listening to each other and finding agreements

Engineering Technology and Society

Engineering Technology and Society (ENGR10004) is a first-year undergraduate subject in which students work in teams of four on a semester-long design project (Lam et al., 2024). For many students completing this subject, it provides the first introduction to working as a team on a real-world engineering design project. It is therefore important for the subject to provide a structured and scaffolded curriculum for the development of their teamwork skills. A comprehensive teamwork framework within ENGR10004 (Chan & Lam, 2023)) had previously been established, involving years of iterative improvements since the subject's inception in 2018. The framework describes teaching activities that support the development of relevant teamwork skills through various collaborative activities and assessments, such as weekly workshop and project tasks, peer assessments, a team management plan, a video presentation and a project report. In this study, existing activities in ENGR10004 were mapped to the TPAT framework, aligning them with each of the seven dimensions of the TPAT framework, as shown in Table 2. The main aim of establishing this mapping was to motivate our first-year students to adopt a longer-term and future-focused perspective on the development of their teamwork skills by fostering an appreciation for the learning progression from first year to the Master's level.

The TPAT framework mapping was presented to the ENGR10004 cohort of Semester 1 2024 in their second workshop of the semester, when project teams were first established. The mapping was introduced through a PowerPoint presentation sequentially outlining the seven TPAT dimensions, providing an overview of the activities and assessments in the subject and setting the

learning expectations for students embarking on their semester-long team project. In this paper, reflections from the teaching staff (who are authors on this paper) are presented on the suitability and effectiveness of this approach.

Applying Digital Infrastructure

Applying Digital Infrastructure (GEOM20013) is a second-year undergraduate subject in which students work in teams of four on an eight-week GIS project: four weeks on a "tender" (the design phase), and four weeks on the "delivery" (the contract phase). Despite their first-year teamwork experience they are still anxious and relative inexperienced in active group management, which is the focus of the use of TPAT in this subject. In the first week tutorial groups are formed, and students engage in a range of activities on group formation and reflection. These activities include discussion of case studies of potential teamwork issues and how they would feel about them and respond to them. They are then guided to complete a group charter using a scaffolded workshop that prompts students to reflect on strengths, weaknesses and skills in the group and asks the students the following; "What are your group's goals for the collaboration?", "Who is responsible for each activity and what roles will each member have?", "What are your group's expectations regarding meetings, attendance, and other forms of interactions?", "What constitutes an acceptable/unacceptable excuse for missing a meeting or a deadline?", "What process will group members follow if they have an emergency before a meeting or deadline?", "What are your group's expectations regarding the quality of deliverables that members bring to the group?", and "What methods will be used to keep the group on track?"

This group charter is reviewed twice in the semester, after milestones of their group work have been completed (i.e., based on their experiences), and the students are encouraged to refer to their charter in their teamwork management document. The subject culminates in a reflection worth 25 points, set up as a performance review discussion with their supervisor. The structured discussion asks students to reflect on their experience of teamwork management and what they took away from the process.

Table 3 List of survey questions for GEOM20013

1. Reflecting on your groupwork experiences in this subject, what groupwork skill(s) do you feel did you develop most?
2. Similarly, where did you feel you could have had more support or development in relation to groupwork?
3. Describe a positive groupwork experience that you had in this subject. This may be something you learnt, or an interaction you had with a peer.
4. Describe a time when you felt the group was not working well together. This may be something you learnt that did not work, or something that was not learned and came as a surprise. What would have helped in this situation?
5. The group charter:
    a. Has prepared me well for the challenges ahead (*n=6*)
    b. Has created a group spirit early on (*n=5*)
    c. Has been referred to in our conflicts (*n=2*)
    d. Was purely a matter of duty for us (*n=5*)
    e. Was an awkward experience for me (*n=1*)
    f. Other: (*n=2*)
6. Which of the following are true for you:
    a. I learned valuable lessons about teamwork that I'll take away (*n=6*)
    b. The active focus on groupwork made the teamwork more productive (*n=7*)
    c. The active focus on groupwork encouraged new behaviour (*n=4*)
    d. The active focus on groupwork helped addressing conflicts (*n=3*)
    e. In my next teamwork I'll push for a group charter again (*n=3*)
    f. Other: (*n=0*)

These activities were designed to develop skills and behaviours aligned with team management such as leadership, collectivism, coordination and communication. Students were invited to complete a voluntary, anonymous survey (shown in Table 3) towards the end of the semester, which sought to understand how students perceived their teamwork skills improved and in particular, how the group charter was used. The group charter activity was scaffolded in such a way that each of the seven dimensions were addressed in some way.

Results and Discussion

The framework was designed to be used both as a tool to design and to review subjects. Initially our aim is to provide the framework to academics to use as they see fit in their subjects and to structure how teamwork is addressed programmatically. Long term the intention is for the framework to be expanded with resources and guides to support academics to teach, practice and assess these behaviours in their subjects.

The following section presents the results from the two subjects that utilised the framework and discusses the implications of these results.

Engineering Technology and Society

In ENGR10004, the teaching staff felt that the activities and assessments within the subject were particularly helpful in developing their skills around communication, task delegation, and leadership within the TPAT Framework. Students seemed to indicate an appreciation for the integration of Microsoft Teams as a project management platform and was evidenced by consistent use of the platform for communication channels and distribution of tasks. In addition to this, the weekly hands-on tasks in the workshops provided students with an avenue to develop their leadership and collaboration skills.

Apart from their teamwork experience, students also pointed out that the power point slides presented during class on the full mapping of the seven TPAT dimensions across the four levels in an engineering course, which is a sizable matrix, was rather overwhelming at first year level. Refining the medium and content of delivery will continue to be a work in progress in the subject following this initial implementation. Despite the challenges, the overall feedback provided a sense that majority students felt inspired by the understanding of the TPAT framework, and they enjoyed and appreciated the importance of their teamwork experience in the subject.

Experience with previous subjects (Lam et al., 2021) has indicated that a more programmatic approach to curriculum design can help improve student engagement and learning by allowing them to recognise and harness connections between their subjects. This integrative approach to curriculum design has previously been applied to more technical content, but the TPAT framework is the first time we have applied it to highlight a professional skills-focused throughline in our engineering program. From a teaching staff perspective, the TPAT framework has provided the ENGR10004 teaching team with a formal structure upon which to anchor our existing team-based activities. This has allowed us to more confidently articulate to our first-year students the rationale behind including such activities in the subject. Based on our discussions with students and looking at their work, we believe the TPAT framework has enabled our students to better understand and appreciate the various activities in the subject. Here, we have observed a change in mindset in our students: from one restricted to the immediate relevance (or indeed perceived irrelevance) of specific activities, to one that considers a longer-term and whole-of-program view of the development of their teamwork skills.

In summary, the initial incorporation of the TPAT framework in ENGR10004 has been promising, with student feedback validating elements of the framework expected of first-year students. Future work will focus on further embedding the TPAT framework in the subject. We found that students should be continually reminded of how each of the team-based assessments map back to the TPAT framework, instead of just being exposed to it once early in the semester. More constant exposure to the framework in first year will better highlight teamwork as a professional attribute that is valued in the engineering profession, foreshadow future development of teamwork skills in higher-level

subjects, and cement a consistent throughline for the development of teamwork skills through their chosen program, particularly once the framework is more widely adopted across the faculty.

Applying Digital Infrastructure

In GEOM20013 we conducted an anonymous and voluntary survey on the students' experience of the active teaching of teamwork. The survey ran during the end of the teaching period and included four open-ended and two multiple-answer questions. The questions are shown in Table 3. We received 13 responses from 120 enrolled students.

The results of the survey were largely supportive of the experience of active teaching of groupwork. In response to Question 1, students reported that, on reflection, they developed patience, collaboration skills, and trust, for example: "I am able to learn how to coordinate with my peers who have different time commitments and responsibilities, and delegate tasks with weightage that everyone agrees upon."

In response to Question 2, they reported that they would like more development on group spirit, on creating a cohesive group work environment, on time management, and to experience more encouragement. In particular, one student shared "I need to learn more about creating a more inclusive and cohesive team environment."

When asked to identify specific positive experiences (Question 3), the most common responses were opportunity to bond, good division of work practices and a willingness to try and work together. Conversely, when responding to Question 4, participants mentioned overloads of individuals with communication and organization, members going missing or being absent, and the slow progress due to the challenge by the project.

From the teaching staff perspective, a few observations stand out. In comparison to 2023's delivery (with no active teaching of teamwork, but the same expectation on working in teams), a remarkable difference is that all tender submissions and all contracted submissions were made in time, indicating that the groups actively managed their responsibility for timely delivery, and succeeded. Another remarkable difference is that, of the about 30 groups formed, only one group reported a case of grossly unequal contributions – while this case was taken care of, the lack of more reporting can be interpreted as groups being more engaged on group management and members taking more responsibility. These observations relate to the TPAT dimensions collectively rather than any individual one. Also, the largely positive response in the survey is not only showing that students have worked actively on their teamworking skills, but also recognize what they have learned – and this is again in stark contrast to 2023's delivery that saw in the subject experience survey several harsh critiques of teamwork expectations.

Regarding the responses to Questions 5 and 6, students were split between seeing the activity as perfunctory or duty (n=5) vs seeing it as a worthwhile activity (n=6). Few respondents (n=3) felt the group charter was something that they would use again, however the majority identified that the focus on teamwork activities resulted in a more productive teamwork (n=7). The number of choices for each sub part of questions 5 and 6 can be seen in Table 3.

Conclusion

The framework presented in this paper is intended as the first step towards improving how teamwork is taught, practiced and assessed across a whole engineering degree program. Early adopters of the mapping have identified its usefulness in communicating the importance and scope of teamwork skills to first year students, and it has been successful in guiding the design of how teamwork is taught in a second-year subject.

With this initial phase complete, our next goal is to develop resources to describe how the specific behaviours in the mapping can be taught and embedded into curriculum. Simultaneously we will develop new strategies to assess students' ability to demonstrate these behaviours. With the framework complete, our focus will shift to evaluating and refining how the framework is

implemented programmatically and then disseminating the results more broadly across institutions.

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