Facilitating Effective Teamwork - Engineering Instructors’ Perspectives on Strategies

Jiachun Huang¹; Tony Vo¹, Scott Wordley¹, Kris Ryan²
¹Faculty of Engineering, Monash University, ²Monash Education Innovation, Monash University
Corresponding Author Email: jiachun.huang@monash.edu

STRUCTURED ABSTRACT

CONTEXT
Team skills such as goal setting, task coordination, and interpersonal communication are among the most sought after competencies in graduate engineers. In an increasingly diverse workforce, engineering programs must ensure students have opportunities to develop the skills and competencies to collaborate with professionals of diverse cultures, skills and technical backgrounds, including those outside of the engineering industry. In the absence of facilitation through appropriate instruction, practice, assessment, and feedback, engineering students may not develop the skills to function as an effective member of diverse and dynamic teams. Existing strategies for facilitating effective teamwork and fostering team skills have been primarily focused on structured learning activities for team development. This research explores engineering instructors’ perspectives on strategies for facilitating effective teamwork in undergraduate engineering education.

PURPOSE
The purpose of this study is to examine the existing ways in which engineering instructors facilitate effective teamwork by applying a team process framework to categorise instructional practice. The findings will be used to inform a framework for facilitating team skills development, monitoring and assessment in engineering education.

APPROACH
This study employed an exploratory case study research approach to examine instructors’ perspectives on facilitating effective teamwork within an undergraduate engineering faculty. Data were collected from three sources: semi-structured interviews, documentation, and observation of instructional practice. Interview transcripts and observation field notes were analysed under a team process framework.

RESULTS
The findings indicate that instructors’ perspectives of effective teamwork aligns well with an established team process theory. Existing strategies to facilitate effective teamwork are influenced by instructors’ industry experience, pedagogical perspectives, and intent to create diverse student teams. Instructors employed a variety of compulsory and voluntary learning activities with the aim of facilitating effective teamwork. Formal activities that facilitate effective teamwork significantly reduced after the common first-year program. There is potential for the university to adopt instructional practices that provide students with formal opportunities for reflective team development, particularly in units beyond the first-year program.

CONCLUSIONS
This study investigated instructional strategies for facilitating effective teamwork. The findings suggest that instructors’ perspectives and practices are consistent with existing theories and practices in the literature. The study identified gaps where certain dimensions of effective teamwork (team processes) could be integrated into team-development strategies and learning activities beyond first year. The findings will be used to inform a framework for reflective team-learning that leverages team processes for the development of teamwork competencies that better equip engineering graduates to succeed in a diverse workforce.

KEYWORDS
Teamwork, effective teamwork, team-learning, feedback, peer evaluation, team skills, team processes
Introduction

In an increasingly multidisciplinary and diverse workforce, effective teamwork is among the most important and desirable graduate competencies (Passow, 2012; Male et al., 2011). The ability to function as an effective team member has long been a required graduate competency in engineering practice standards around the world (e.g. Engineers Australia Stage 1 Competency Standard and ABET Engineering Criteria). Students typically participate in teamwork as part of team-based assessments in undergraduate coursework; it is commonly through this exposure to teamwork that students have opportunities to develop teamwork Knowledge, Skills and Abilities (KSAs) that enable them to become competent in effective teamwork.

Engineering programs should facilitate students’ development of teamwork KSAs by facilitating effective teamwork so that graduates can function effectively as team members in a diverse workforce. In the absence of explicit teamwork-development initiatives, the challenging task of facilitating effective teamwork often falls onto engineering instructors, who are likely to be ill-equipped (Lingard and Barkataki, 2011; Felder et al., 2011). Furthermore, simply placing students in teams without appropriate instruction, assessment, facilitation, and feedback is unlikely to lead to effective teamwork in most student teams. Ultimately, many students may not develop desirable teamwork KSAs such as task coordination, feedback exchange and conflict management.

Team training initiatives aimed at improving teamwork effectiveness by targeting teamwork KSAs development are becoming increasingly prevalent within undergraduate engineering programs. These are typically delivered through instructional strategies and learning activities. Existing instructional strategies for facilitating effective teamwork and developing team skills have largely involved structured learning activities; these are briefly reviewed in the literature review. To understand how best to facilitate the development of teamwork KSAs for engineering students, it is important to identify such initiatives and to evaluate their efficacy relative to leading practices. In light of the current state of team-learning in engineering education, the objective of this research is to investigate the existing ways in which engineering instructors facilitate effective teamwork within an undergraduate engineering faculty at a large Australian university. To achieve this, the following research questions are posed:

1. How do engineering instructors facilitate effective teamwork in undergraduate engineering education?
2. What are the ways in which dimensions of effective teamwork are currently incorporated into team learning?

The findings of this study will be used to inform a framework for facilitating the development of teamwork KSAs in engineering education. The following sections provide a brief review of existing team-learning literature and a description of the research approach; then, the results are presented under an analysis framework followed by a brief discussion on the outlook of team development in the Australian undergraduate engineering education context.

Literature Review

Strategies for facilitating effective teamwork in engineering education appear more commonly in the literature as intervention reporting and evaluation, with few studies that describe an overarching framework used to inform the development and implementation of such strategies. Two studies that do employ theoretical frameworks make reference to team process models as well as opportunities for feedback and reflection (Kirby, 2011) and learning scaffolds (Pazos et al., 2016) as the foundations for team development. Intervention studies which report on instructional practice in facilitating effective teamwork and developing team skills have largely involved structured learning activities and practices that encourage team development (Sashittal et al., 2011; Lingard and Bartaki, 2011; Hurst et al., 2016; Hadley, 2014; Peterson, 2012; Pulkko and Parikh, 2003). These have been reported to correlate with improved team performance (Rapp and Mathieu, 2007) and teamwork KSAs (Pazos et al., 2016).

Studies in engineering education and other disciplines have reported a variety of such activities and practices in the literature; examples include: ice-breakers (Sashittal et al., 2011), peer evaluation (Oakley et al., 2007), using personality types and attributes in team-formation (Shen et al., 2007; Rhee et al., 2013), creation of a team charter (Smith, 2000), project planning and management (Pulkko and Parikh, 2003), web-based communication and collaboration (Lingard and Bartaki, 2011), identifying strengths and weaknesses (Peterson, 2012), and board games (Hadley, 2014). Others have reported on team training programs and interventions that incorporate a series of team-development activities.
over the course of a semester or more (Kirby, 2011; Hurst et al., 2016; Pazos et al., 2016, Rapp and Mathieu, 2007). While we acknowledge that peer evaluation and team formation are relevant and important aspects of team-based assessment, these topics will not be discussed in the present paper.

There are emerging strategies for facilitating effective teamwork that integrate reflective practice into team-learning. One such strategy is the use of industry experts to mentor design teams. Fruchter and Lewis (2003) describe a ‘fishbowl’ experience in which student teams emulate certain behaviours and team processes they observe from an industry expert who participates in their team project as a mentor. Two examples of such behaviours include seeking agreement and collaborative problem solving. Other studies in engineering education have reported on incorporating reflective team activities that prompt students to critically reflect on aspects of teamwork as a team (Socha et al., 2003; Hirsch and McKenna, 2008; Turns et al., 2014). Examples of such activities include: individual reflective pieces, team retrospectives (e.g. what went well, what didn’t?), conversations with industry experts, identifying essential characteristics of successful teams, peer evaluations, team memos, and team process checks.

Hurst et al. (2016) describes a set of workshops that involve guided, teamwork-specific reflection; the study reports that these workshops have potential to improve students teamwork KSAs based on pre- and post-workshop surveys and KSA assessment. Another study (Seidl, 2017) reported on the use of LEGO serious play as an activity to encourage “playful team reflection”; Seidl describes how the LEGO activity can be used to stimulate and moderate student reflections on individual teamwork skills as well as support team reflections on cooperation. However, the study did not elaborate on any potential influence on teamwork and team processes.

In the inputs-processes-outputs model of teamwork (McGrath, 1984; Hackman, 1987), effective teamwork has been closely linked to team processes (Ingram, 1997). Research in team-effectiveness theory suggest that effective teamwork emerges from the presence and development of team processes (Marks et al., 2001; Ingram et al., 1997). In the current state of research in team-learning in engineering education, there are few studies which explicitly relate team processes to the facilitation of effective teamwork. Examining the ways in which instructional practice address teamwork processes will shed light on how best to facilitate effective teamwork in the engineering classroom. In this study, instructional strategies for facilitating effective teamwork are identified and analysed according to a framework for team processes developed by Marks et al. (2001).

Theoretical Perspective

The structured approach to facilitating effective teamwork can be framed through scaffolding theory. Scaffolding of learning was first coined by Jerome Bruner to describe learning that involves active support and structured guidance (scaffolding) from an expert. Scaffolds can be gradually removed as students become more independent in their learning or as they acquire the necessary skills (Wood et al., 1976). In this study, Bruner’s scaffolding theory is extended to team-learning in undergraduate engineering. The existing literature has shown that it is possible to facilitate effective teamwork by providing structured opportunities for team development and development of teamwork KSAs. As students progress through their undergraduate course, these structures (scaffolds) can be gradually removed as students gain confidence and competency in navigating teamwork, and as students develop the skills to carry out team processes in new and dynamic team settings.

Team processes are prominent in management research and form the basis of the analytical framework in this paper. They are defined as “processes that enable team members to combine their resources to solve task demands and, in doing so, be effective” (Kozlowski and Ilgen, 2006). Kozlowski and Ilgen also ascribed team processes as “the critical enablers of team effectiveness”. Marks et al. (2001) present and describe a taxonomy of ten team process dimensions in their temporally-based framework, which they categorise under three overarching categories: transition, action, and interpersonal (Table 1). Within this taxonomy, some processes are more prevalent during the transition period of a team (early stages of teamwork), while other processes are more prevalent during the action period (the doing period). Marks et al. (2001) specify that interpersonal processes are expected to occur throughout both the transition and action phases of a team. This taxonomy serves as as part of the analytical framework for examining instructional strategies for facilitating effective teamwork at a large Australian engineering faculty.
Table 1 - Taxonomy of team processes taken from Marks et al. (2001).

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<thead>
<tr>
<th>Transition</th>
<th>Action</th>
<th>Interpersonal</th>
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<tr>
<td>Team mission and planning</td>
<td>Monitoring progress towards goals</td>
<td>Motivation and confidence building</td>
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<td>Goal specification</td>
<td>Systems monitoring</td>
<td>Conflict management</td>
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<td>Strategy</td>
<td>Team support and feedback</td>
<td>Regulating emotions</td>
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**Method**

The research phenomenon under study is instructors’ facilitation of effective teamwork in undergraduate engineering team-learning; it is a contemporary event to be studied in its real-life context and over which the investigator has little to no control, therefore, an exploratory case study was considered an appropriate research methodology (Yin, 2009). Data were collected from three sources: documentation (unit descriptions and learning resources), semi-structured interviews, and observations of instructor practice. Potential participants were selected by purposive sampling based on the following selection criteria:

1. The participant is an instructor in undergraduate engineering units in which the team-based continuous assessments made up at least 30% of the unit’s overall grade.
2. The unit involves one or more team projects that overall last at least 6 weeks (half the teaching period).
3. Students remain in the same team for the duration of each team project.
4. The project(s) to some extent involves collaborative and interdependent engineering teamwork, in which there are unique team roles (i.e. a group of students collecting experimental data and collectively writing a report is ineligible).

In the interest of participant confidentiality, this paper does not disclose any information about participants’ demographic information nor any information that directly links them to the units that they teach. Eight participants, each representing a different engineering specialisation, were recruited to this study, of which, two taught into first-year engineering units and the remaining instructors were evenly split across final and penultimate year units. Participants were invited to the research via email; these were obtained from the university staff directory. Participants took part in a one-on-one semi-structured interview prior to the start of the teaching period. The investigator maintained correspondence with participants throughout the teaching period, during which time, documentation and observational data were collected. It was important to first shed light on what instructors considered to be effective teamwork. This was elicited from semi-structured interviews, in which instructors were asked to share a teamwork experience of their own and what they considered to be effective teamwork. Participants were also asked to describe activities or opportunities for team development and for students to collaborate on team projects or reflect on teamwork; their responses were triangulated with classroom observations throughout the teaching period at scheduled intervals. Interview transcriptions, documentation relevant to the units, and observational field notes were subject to thematic analysis with coding categories relevant to scaffolded learning, team processes, instructor’s pedagogical perspective and instructor’s industry experience.

Ethics approval was sought and granted for this study through the university's human research ethics committee (#12137).

**Results and Discussion**

What is considered effective teamwork?

Participants’ perspectives on what they considered to be effective teamwork illuminated team processes consistent with those identified by Marks et al. (2001). Analysis of interview transcriptions revealed the following dimensions considered by instructors to be related to effective teamwork:
Learning activities that facilitate effective teamwork

Instructors described a range of compulsory and voluntary learning activities that aim to facilitate effective teamwork and team development. The compulsory activities were most prevalent in the common first-year program, beyond which, team-development activities were not completed in class; they were prescribed on a voluntary basis and were not assessed. The use of a team charter, a team-development strategy for establishing team process dimensions such as team mission and goal specification (Smith, 2000), was neither reported by, nor observed in any participants in this study. However, two participants reported on the use of structured activities that guide teams in establishing communication and collaboration agreements such as communication medium and meeting times, amongst other teamwork aspects. These, and other strategies, are described in the following section.

One instructor described four team-development activities that ran at intervals throughout the twelve-week teaching period for a unit in the common first-year program. These activities were part of a larger suite of professional skills development activities in the unit and included: 1) icebreaker and establishing communication and meetings; 2) understanding team dynamics, management and expectations; 3) reflection and performance review; 4) project breakdown and task planning. The instructor of another common first-year unit described similar team development activities at intervals throughout the teaching period that included: 1) understanding team roles; 2) icebreaker and using meeting agendas; 3) project management tools; 4) team performance reflection; 5) professional communication. These activities most closely align with transition processes such as planning and strategy as well as action processes such as coordination and feedback.

Interview responses from participants consistently indicated a lack of explicit team development in individual units beyond the common first-year program. There were isolated cases of initiatives to facilitate effective teamwork; these included: assessment of project management, a LEGO activity, and expert mentoring. In the first case, the instructor of a third-year unit emphasized the importance of project management by requiring teams to produce a project management plan as part of continuous assessment. This unit had a strong focus on professional practice, with quality assurance playing a significant role in the artefacts being produced. Retrospectives, a common reflective practice in software engineering, were encouraged but not required. It is therefore difficult to gauge the extent to which teams demonstrated competency in conducting retrospectives.

In the second case, the instructor of a final-year unit required students to complete a creative team-development activity with LEGO pieces in week 1; it has two primary objectives: as an icebreaker and to teach teams about effective communication and teamwork. While it is consistent with the emerging instructional strategies for facilitating effective teamwork (Seidl, 2017), the LEGO activity employed by this instructor was novel among the strategies employed by the participants of this study. The activity was designed to be self-directed by student teams and has potential to facilitate rapid team development for effective teamwork in senior student teams.

Framing these dimensions according to the taxonomy of Marks et al. (2001), goal setting and project planning are dimensions of transition processes; contribution, task coordination/monitoring, and utilizing individual strengths are dimensions of action processes; and team rapport and giving/receiving feedback are related to interpersonal processes. When asked what makes teamwork a positive or satisfying experience, instructors identified three prevailing ideas: there is team rapport, teammates become friends at the end of the project, and team members feel that they have made meaningful contributions. These ideas align with the motivation and confidence building dimension under interpersonal processes (Table 1). These findings suggest that participants’ conceptions of what is considered effective teamwork align with team process dimensions in the literature. The findings also indicate that participants recognise that effective teamwork, teamwork experience and team performance are related to having effective team processes. For example, one instructor described a positive teamwork experience as: “when they get the software working and they can see that working in a team has helped them, that they feel that they can rely on their teammates”. This is a positive finding as it supports a framework for facilitating effective teamwork based on developing team processes in student teams.

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<td>Transition processes</td>
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<tr>
<td>Contribution</td>
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<tr>
<td>Task coordination/monitoring</td>
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<tr>
<td>Utilising individual strengths</td>
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<tr>
<td>Giving/receiving feedback</td>
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<td>Team rapport</td>
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<td>Project outputs</td>
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Proceedings, AAEE2018, Hamilton, New Zealand
In the third case, two instructors made use of industry and academic experts to mentor student teams throughout team projects on a weekly basis. The team projects in these units are heavily design-based and relevant to industry practice; thus, the instructors felt that student teams would benefit from having weekly access to an industry or academic expert with whom to discuss project matters. Both instructors reported that consultation with mentors was also a way for teams to raise and resolve teamwork issues with minimum input from the instructor. One instructor mentioned:

“The role of the mentor is to meet with each team each week and they’ve got two responsibilities: to make sure that the team knows where they are on their project plan, so they realise if they’re behind, and they talk it through what they’re going to do to get back on track. And the second thing is to try and resolve any conflicts that are happening in the team… so that’s where the mentors really have to try and sort out issues...”

The instructional strategies and activities for facilitating effective teamwork described by the participants of this study are consistent with those described in the literature (Pazos et al., 2016; Hurst et al., 2014). Two participants reported the use of formal activities for facilitating effective teamwork which focus on transition and action processes (e.g. planning and feedback), with activities that centred on reflection (e.g. team performance review), which have not been prominent but are emergent in the literature (Turns et al., 2014). These practices were not reported by, nor observed in participants that taught in units beyond the common first-year program, with the exception of isolated cases in which team-development activities were informal and not assessed (e.g. retrospectives).

There is a significant decline in scaffolded team-learning and explicit team-development opportunities after the common first-year program. At the same time, participants who are instructors of third and final year units consistently reported instances of having to intervene in teams that could not resolve/manage their teamwork problems, often quite late in the teaching period. In these cases, team issues ultimately manifest in peer evaluation results which can affect students’ individual marks for a team project based on peer ratings. From this, an area of focus for facilitating effective teamwork is for students and teams to be able to recognise and manage teamwork issues, rather than allow those issues to remain undetected and worsen until the end of the team project, by which time, there is little that students can do to rectify team problems. This area of focus can be addressed by employing a team process framework such as that of Marks et al. (2001) in strategies that allow teams to develop and monitor team processes throughout teamwork.

Factors that influence instructional strategies in facilitating effective teamwork

Participants made reference to several aspects of teamwork which relate to their personal pedagogical perspectives; these align with the interpersonal processes according to the taxonomy described by Marks et al. (2001). The instructor of a third-year unit spoke about the importance of ‘gel’ in teamwork, a concept that aligns with the dimension of coordination under action processes. It was described as:

“Gel is that thing that happens after you’ve sorted out all of the arguments and you’ve gotten to know each other’s strengths and weaknesses and you just immediately know when a task comes into your team, you’ve got some idea of who should do it, who’s going to be best at it, and you just work together seamlessly without stressing out over fine details. Not all teams do gel, especially not all shotgun wedding teams that have been put together by force by the lecturer.”

In this case, the participant suggests that the presence of gel may be influenced by team formation strategies. In another case, the instructor of a first-year unit spoke about the importance of diplomacy as a teamwork skill in managing power differences and team dynamics; this resonates with the dimension of conflict management and regulating emotions (Table 1) under interpersonal processes. The participant described an example of diplomacy in giving feedback as:

“You can do it in a team meeting and you could, to my face, say “well look at the crap that X produced”... That’s embarrassing to me and I could probably feel quite upset if it was said in front of the other team members… A more diplomatic way to do this would be, if you had this opinion, would be to talk to me in person and say “hey, I was unhappy with this for this reason”… that has better outcomes in the sense that one person doesn’t get as upset [and] has an opportunity to correct things...”

During the interview, the participant acknowledged that there are no provisions in the engineering course (to their knowledge) to develop diplomacy as a teamwork skill. This indicates that there may be a learning gap in engineering education that concerns the development of teamwork KSAs relating to interpersonal processes; though it is possible that provisions exist not to the participants knowledge.
When asked to describe opportunities available to students to reflect on teamwork experiences, all but two participants reported that there are no formal activities for reflection in their units. Some participants reported that they encourage teams to reflect on teamwork and exchange feedback but do not make provisions for it beyond peer evaluation. The lack of opportunities for monitoring and feedback means that action processes may be particularly underdeveloped. Examples of participants’ responses when asked about formal activities for reflection and feedback include:

“We encourage them to talk about the feedback, but that’s entirely up to them and I expect most of them don’t.”

“Well I don’t know if they do that. There’s no provision. We just have chat sessions if they… well no, it’s all on [online peer evaluation tool].”

“Formal feedback on aspects of teamwork, unless things went badly pear-shaped, no.”

“There’s no formal processes I wouldn’t say. It’s just the allocation of time and I hope that they all meet together and discuss that…”

Two participants with industry backgrounds both strongly emphasised the importance of professional team conduct and practice in their instruction. Their perspectives align with the dimensions of monitoring progress towards goals and goal specification under action processes (Table 1), as exemplified by these interview responses:

“Minutes are really important. I mean people think they’re a bit time consuming and wasteful… if things go badly wrong, you will be looking at the minutes all the time… so minutes are actually really important, and I do tell the students that, but they don’t believe it until they have problems later on. And in a professional situation, you might end up in court! You might end up in a legal situation. You need to have that evidence.”

“A successful team-based project are the teams who take on feedback, take on information, so they will take on any information that they’re given, and evaluate whether it’s useful to them or not, and not pass up an opportunity to find out more.”

The instructional practices presented in this study align with team process dimensions in the literature. The practices examined in this study are generally more focused on transition and action processes. Formal team-development opportunities beyond first-year units exist only in isolated cases; this is an indication of gaps and opportunities for development in team-learning instructional practice. There are few provisions beyond first-year for student teams to develop action processes, particularly those relating to feedback, and interpersonal processes. In light of this, the present research agenda has been extended to evaluate the instructional strategies identified in this study from students’ perspectives. We would like to find out whether senior-year students develop strong team processes in practice, when there are fewer opportunities for structured team development. This provides an avenue for future work to examine student teamwork practice under the same team process framework based on data collected from interviews, observations and surveys.

**Conclusion**

This study examined instructors’ perspectives on strategies for facilitating effective teamwork within the Engineering faculty of a large Australian university. The findings indicate that instructors’ conceptions of effective teamwork align closely with team process dimensions from teamwork literature. Instructors employed a variety of compulsory and voluntary learning activities which aim to facilitating effective teamwork. It was found that the extent of scaffolding in facilitating effective teamwork was limited to isolated cases after the common first-year. There is potential for more reflective practice to be integrated into team-learning through learning activities that explicitly address all dimensions of transition, action and interpersonal team processes, particularly in units beyond first year. In closing, this study validates the applicability of a team process framework for team development in the Australian undergraduate engineering education context.

**References**


