Full Paper

Introduction

Team learning is an integral part of engineering education today and teamwork knowledge, teamwork skills and teamwork product have been included as one of the major components of engineering graduate outcomes in an undergraduate engineering curriculum. Team learning is the process of learning and working collaboratively to achieve a common teamwork related and/or associated learning outcomes. Team learning in academic institutions involves students learning and working actively, collaboratively and cohesively on specific team tasks for a collective activity or a common goal whose outcomes are greater than those possible by any one student working independently (Griffith University, 2015). At engineering schools, team learning helps team members generate ideas, share knowledge and complement each other's skills to solve engineering problems and develop solutions.

Obvious benefits accrue in using learning teams, so do numerous problems (Hansen, 2006). Team learning is important for teams to learn how to learn and work together effectively and cohesively (Decuyper *et al.,* 2010). Teamwork skills themselves are one of the 'employability' skills and teamwork also helps to achieve other employability skills. Over the last few decades, social and educational psychologists have elaborated conceptual foundations, dynamics, principles, perspectives, philosophies, stages, models and theories of team learning (refer to Edmondson *et al.* (2007) for perspectives on team learning, Decuyper *et al.* (2010) for dynamic complexity of team learning and Bell *et al.* (2012) for theoretical integration and review of team learning). Tuckman (1965) behavioural stages of team dynamics- forming, storming, norming, performing and adjourning or mourning- are important considerations that help to plan, implement and monitor team learning activities and processes in sequential time domain.

In spite of enormous research advances in theoretical aspects of learning and working in teams, anecdotal evidence suggests that most engineering academic staff are inundated by student complaints of not being able to work in a learning team due to numerous reasons. Moreover, most engineering academic staff are neither expert in team learning nor there are rigorous academic staff development and training programs regarding team learning at engineering schools. They usually depend on educational psychologists' literature which discuss mostly the foundations, principles, philosophies and theories of team learning. Even though these theoretical aspects of team learning are important, they are difficult to comprehend and implement in an engineering unit for most engineering academic staff. Moreover, most engineering academic staff simply do not have sufficient time and adequate resources available to implement team learning thoroughly considering theoretical concepts in their units as they need to cover a huge chunk of unit specific learning materials.

Team learning guidelines, tools and resources developed mostly by educational psychologists at an academic institutional level (for example, Griffith University 2015, Southern Cross University 2015, Deakin University 2015) are less helpful for engineering units as they are usually based on theoretical foundations, such as why teamwork is important, what socio-psychological theories underpin team learning, what dynamic and complexity theories define team learning, what common team learning models are and so on rather than facilitating non-expert academic staff on how the team learning in a particular context is adequately and sufficiently managed. As a result, most engineering academic staff do not prefer to include teamwork in their units. Even if they are asked by engineering schools and course directors to incorporate team learning in their units, they usually take the lowest obstacle path by simply asking students to complete a learning task or assessment in teams. They may also include teamwork if they believe it reduces the marking workload, especially with large student cohorts. However, research evidence has indicated that the team-based assessment items without proper team learning system in place is recognised as a significant problem (Clinebell and Stecher, 2003).

In addition to student complaints, most engineering academic staff are non-expert in team learning theories and methodologies and hence are unsure of specific learning outcomes of a teamwork, approaches to achieve those learning outcomes, suitability of team learning in a particular unit/subject, planning required for implementing teamwork, implementation and monitoring teamwork and teamwork reflection. The goal of this paper is to facilitate engineering academic staff by developing a framework for managing learning teams in engineering units that integrates existing theoretical conceptions and empirical findings from existing literature and anecdotal practices from engineering classrooms.

A Framework for Managing Learning Teams

Through an extensive review of literature, tools and guidelines, and other associated resources regarding teamwork and team learning, a framework for managing learning teams in engineering is developed and presented in Figure 1. Although the framework is presented in a linear fashion, most components interact in complex relationships.

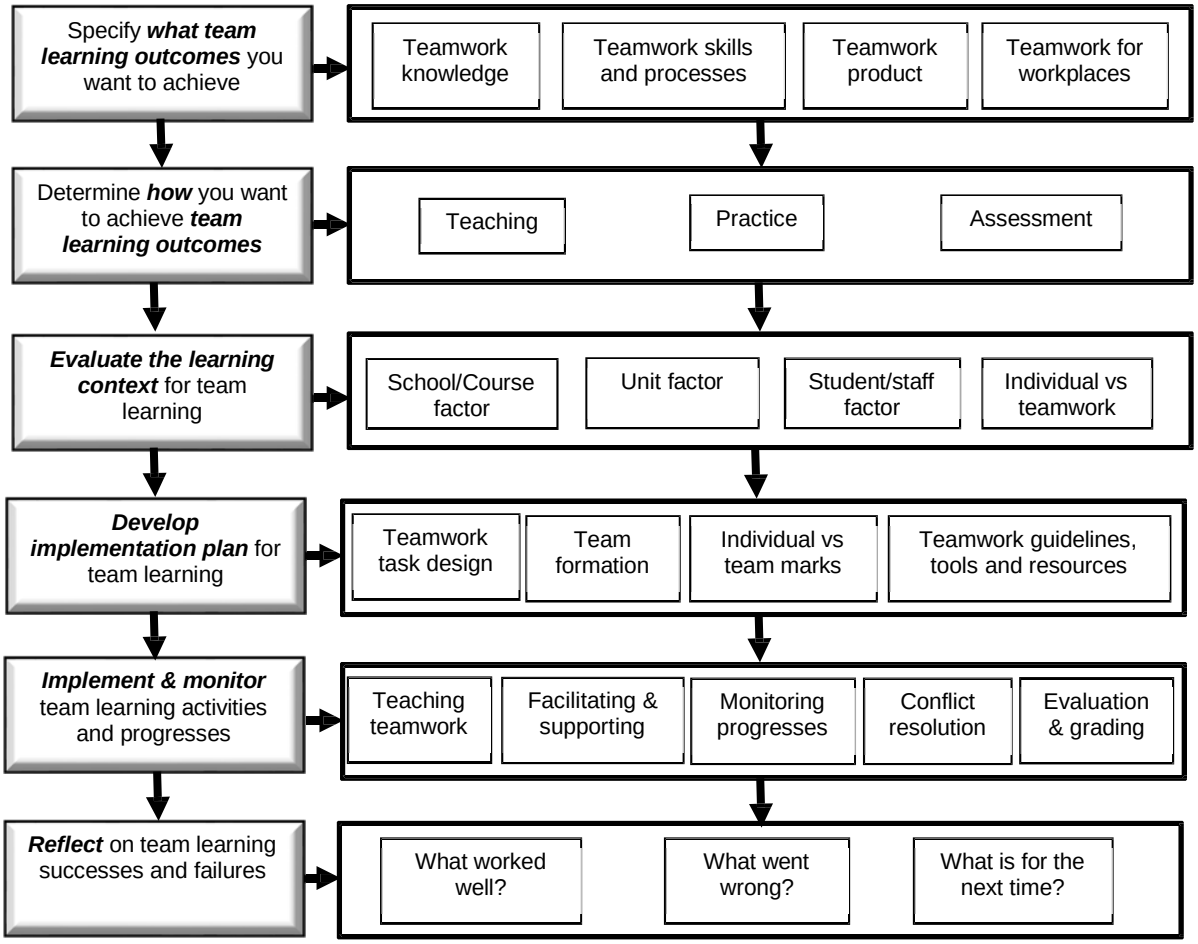

Figure 1 Framework for managing learning teams in engineering units

Learning outcomes of a teamwork

Even though teamwork has been commonly listed as an important graduate outcome of all engineering course curriculum, it is often unclear what it specifically includes. It is important to breakdown what team learning outcomes a particular unit is intended to achieve. Team learning outcomes can be broken down into four major categories- to understand and comprehend the knowledge of teamwork, to develop and apply teamwork skills, to improve the quality of teamwork product and to replicate teamwork for workplace situations. A particular engineering unit can accommodate some or all of these team learning outcomes. It may not be necessary to cover all these team learning outcomes in one engineering unit but

scaffolding and mapping of units within a course help to identify what aspects of team learning need to be covered in a particular unit. This distinction on the specific learning outcomes of a teamwork is a starting point of managing learning teams in engineering. Teamwork skills include, among others, coordination skills, communication skills, interaction skills, negotiation skills, discussion skills, creative thinking skills, decision-making skills, leadership skills, role-defining skills, conflict management skills, coaching-mentoring-feedback skills and diversity awareness. Teamwork is not the only way to achieve some of these skills, but it can be used to support the development of key professional skills such as coordination, negotiation, decision-making and leadership qualities that students cannot develop in isolation (Tucker & Abbasi, 2015).

Approaches to achieve team learning outcomes

Clear distinction in learning outcomes of a teamwork helps to utilise appropriate teaching, practice and assessment approaches and associated strategies. Knowledge of the teamwork is a low level learning outcome and may be achieved only through teaching and/or some sort of quick individual assessment system. However, in order to develop teamwork skills, it may be necessary to teach, practise and assess these skills. When a learning outcome of a teamwork of a unit is to improve the quality of teamwork product, it may not be necessary to assess the teamwork skills or knowledge as the assessment of teamwork product may be sufficient to make judgements on the achievement of unit learning outcomes. One of the major problems with only the assessment of the teamwork product is that it is difficult to assign different individual marks from the team mark. On the other hand, if the learning outcome of a teamwork is to assess the teamwork skills, it may not be necessary to assess the quality of teamwork product. One of the problems with the assessment of only teamwork skills is that the teamwork does not necessarily lead to a meaningful product. However, if the unit learning outcomes are focused on improving a teamwork product using teamwork skills and knowledge, a typical unit curriculum for the majority of engineering units at universities, it is important to adopt an approach to assess all teamwork knowledge, teamwork skills and teamwork product (Nepal, 2012a). Moreover, as motivation and rewards of teamwork in learning (i.e., academic performance) can be perceived quite differently to the motivation and rewards of teamwork in workplaces (*i.e.*, job performance), it is often difficult to resemble input-process-output model of learning teams and workplace teams.

Evaluation of learning context for teamwork

Before incorporating teamwork as a part of learning outcomes in an engineering unit, it is important to evaluate whether the learning context is suitable for efficient and effective team learning. A number of factors are to be taken into account including, requirement from school and from the course perspective; suitability of unit's learning materials for teamwork; both quantity, *e.g.*, class-size and quality, *e.g.*, previous teamwork experience, socioeconomic compositions etc. of student cohort; expertise, experience and motivation of academic staff; and, proportions of team learning and individual learning components in the unit.

From ***school, course and unit curriculum*** perspective, it is important to choose suitable (not necessarily all of them) engineering units to implement team learning which can help achieve learning outcomes of a teamwork more efficiently and effectively. Anecdotal evidence suggests that in theoretical and fundamental units such as mathematics, physics, mechanics, geology etc. which require students to grasp the established theories and principles rather than idea generation, discussion, negotiation etc., team learning may not add additional value sufficiently. It does not mean that we cannot have team learning in these units but learning outcomes in these units may be better achieved while learning individually. However, for professional practice and engineering design units such as engineering practice, project management, infrastructure design, engineering projects etc. where teamwork skills play an important role, team learning can be instrumental and effective for students' deeper learning.

Both ***students and academic staff*** have mutually reinforcing roles to play not only of implementing teamwork and monitoring progresses, but also towards the achievement of intended learning outcomes of a teamwork (Graduate Skills, 2015). Both the quality and quantity of academic staff (number, expertise, experience and motivation) and students (cohort size, teamwork experience and attitude) play a vital role in team learning. Although teamwork can be adjusted to suit for any student variation (both quantity and quality), it may not be that effective for a very large or a very small cohorts. For large cohorts (say >100), it may be too difficult to effectively and efficiently manage a large number of teams whereas for small cohorts (say <20), the teamwork may not provide sufficient flexibility and diversity. The manageable class size for team learning is around 20-100 students or 5 to 20 teams. It, however, also depends on the time and resources available for the unit. Vast majority of students have mixed feelings about and diverse attitudes towards teamwork and hence teamwork skills and capabilities are not acquired nor developed without scaffolding and facilitation (Kazlauskas and Applebee, 2007).

Although ***teamwork-based tasks or assessment items*** can be of any proportions ranging from 0% (all individual-based tasks) to 100% (all team-based tasks) in a unit as widely seen in practice, it may be a good idea to have less than 50% team-based assessment items in a unit. This would prohibit free-riders to pass the unit by riding freely on other team members' works and may also decrease student complaints about teamwork particularly from those who do not prefer learning in teams. Teamwork-based assessment items of about 20-40% would not significantly impact the overall academic performance of an individual student in a unit and hence would be suitable. Teamwork-based assessment items of less than 20% may not effectively help to achieve intended learning outcomes of a teamwork as students may not fully commit towards teamwork.

Development of implementation plan for teamwork

Once the decision is made to include teamwork in a unit in order to achieve intended learning outcomes (knowledge, skills, product and workplace) of a teamwork using appropriate approaches (teaching, practice and assessment), the next step is to develop a plan for teamwork implementation. The plan includes, but not limited to, designing teamwork task or assessment item, forming learning teams- size and composition, developing a process of identifying individual contributions that help to allocate individual marks from a team mark and, preparing context-specific teamwork guidelines, tools and resources. Once developed, the information needs to be conveyed to the students at the start of the teaching sessions (semester or trimester) to reduce student complaints about teamwork, to reduce or eliminate teamwork hindrances, to manage team learning processes, and to optimise team learning outcomes.

Teamwork tasks need to be designed based on collaborative (constructivist approach to learning) and cooperative (sharing of ideas) learning theories and pedagogies. They are to be designed considering students' workload, have clearly defined team learning outcomes, contain clear criteria against which learning outcomes are assessed- either by an assessor or in conjunction with the students, provide clear understanding of a variety of roles and responsibilities, allow scope for creativity, require a team 'product' that can be assessed collectively, and require for high level cooperation (Griffith University, 2015).

The optimal learning ***team size and composition*** is highly debated and contested topic in existing literature and will vary depending on the learning tasks at hand. Small teams of 3 or less lack enough diversity. Teams that are too large (>10) create freeriding environment. Most studies have suggested the team size between 3-10 members. Moderate team size of 4-6 members is suggested as optimal team size. There are a number of methods of allocating students into teams (i) self-selection- students decide team members (ii) random allocation- the academic staff randomly assigns students to teams (iii) deliberate allocation- academic assigns students to teams, based on pre-existing attributes, *e.g.,* academic performance, skills, knowledge, and topic interests, (iv) pairing- both students and academic

staffs are involved in selection. There are advantages and disadvantages associated with each method of allocating students to teams but social and cultural diversity in teams have been identified as beneficial for team learning.

Existing literature suggest that a number of methods can be used to award ***team and/or individual marks*** (Lejk *et al.*, 1996, Race, 2001). Nepal (2012a) have extensively reviewed the methods to award individual marks from a teamwork. The best method suggested include a balanced approach that rewards above-average contributions, penalises below-average contributions (free riders), controls individualistic behaviours (selfish, do-it-all approaches) and aligns individual contributions with the quality of teamwork product.

A simplified versions of available institutional level ***teamwork guidelines, tools and resources*** can be used. However it may be beneficial to simplify and contextualise them. They should clearly include students' roles and responsibilities within their learning team, setting ground rules, creating positive team learning culture, incorporating ideas from all team members, managing conflicts within the team, creating and distributing roles, organising, conducting and minuting meetings, communicating, documenting contributions etc.

Implementation and monitoring of team learning aactivities and progresses

Implementation and monitoring of team learning activities and processes is the most time consuming and complicated step. As team learning activities and tasks usually form a small component of an engineering unit, the time and efforts required for them is often neglected and taken for granted. Teamwork teaching, facilitating and supporting, monitoring, conflict resolution and evaluation or grading are the important components of this step.

Depending upon the existing teamwork experience of the student cohort, it may sometimes necessary to ***teach teamwork***. While most engineering design takes place in teams and most engineering educators agree that teamwork is important, less is known about how to provide effective instruction about teamwork (Hirsch and McKenna, 2008). It is not sufficient just to put students in teams and ask them to work together—students need to be taught the teamwork knowledge, skills and processes to function successfully in a teamwork environment. In addition to theoretical concepts and literature evidences about teamwork, teaching teamwork involves team building activities and role plays. However, anecdotal practices suggest that most engineering academic staff rarely teach teamwork.

In addition to teaching teamwork, academic staff can ***facilitate and support*** teamwork from start to finish. It includes directing, coaching, supporting, delegating, mentoring and counselling. Facilitation and support can be done by providing guidelines, tools and resources, initiating discussions, helping to establish ground rules, summarising important points, clarifying confusions, challenging ideas and assumptions, providing research evidences, providing feedback, helping to reach consensus and resolving conflicts.

A proper system of ***monitoring progresses*** should be used by establishing alert mechanisms, operating random checks and requesting progress reports. Sheard and Kakabadse (2002) suggest monitoring teamwork in four dimensions- task, individual, team and environment. A common practice in engineering schools regarding teamwork monitoring is to stay way unless there is a seriously reported issues in teamwork.

While some people may argue the best method of ***resolving conflict*** is to prevent it from occurring, others believe conflict is inevitable irrespective of how hard individuals try to prevent this from occurring within their team. Conflicts are part of individual relationships, and no relationship can hope to mature to be successful without being able to resolve conflicts effectively (Cottringer, 1997). Learning teams are to be encouraged to seek help from academic staff when conflict reaches a stage that is significantly affecting the team's outputs and processes. But it is better to discuss and manage conflict early within the team so that issues do not get out of hand.

Student's contributions and behaviours to a teamwork is largely dictated by how they are **assessed, *evaluated and graded***. Limited high achievers usually think of maximising their individual academic performances whereas a vast majority of students do what they perceive is just enough to fulfil the requirements for the teamwork task (Tucker and Abbasi, 2015). Depending upon the type of teamwork-based learning outcomes, teamwork knowledge, skills and products can be assessed and graded. Knowledge of a teamwork can be assessed by using traditional types of assessment system whereas teamwork skills and processes are usually assessed through observations, co-assessments, peer-assessments, self-assessments and reflections. Teamwork product can be assessed purely based on evaluation criteria of the teamwork product.

Reflection on Teamwork

Reflection provides opportunities for students to abstract key principles about teamwork from their activities and that students understand and value most of the same characteristics of successful teams identified by studies of successful teams (Hirsch and McKenna, 2008). Reflection can focus on overall team performance and processes in relation to achieving outcomes, not on individual team members' particular strengths or weaknesses; to identify the team's strengths and weaknesses and things to improve, not the person's; and to identify any particular problems the team encountered and how they could be resolved (Griffith University, 2015). Reflection can be during and after the teamwork implementation. Academic staff can help to develop the reflective practice by asking teams to report on what is going well, what is not going well and what needs to be improved.

Conclusion

This study develops a framework for managing learning teams in engineering units through extensive reviews of existing literature and anecdotal practices. The focus is to provide academic staff the step-by-step procedure so that team learning in engineering unit can be effectively managed. Depending upon the time and resources available to academic staff, managing engineering learning teams can be both simple as well as complex. The proposed framework is expected to help find an optimal path. For better management of learning teams, academic staff need to focus their attentions to specifying learning outcomes of a teamwork, identifying approaches that help achieve these learning outcomes, evaluating the suitability of teamwork in a particular educational context, developing implementation plan for teamwork, implementing teamwork and reflecting teamwork. It is important to test these components of the framework in a particular context so that optimal team learning can be achieved. Based on the additional research evidence, the framework can be continuously implemented, monitored and updated.

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