Simplified Framework for Managing Team Learning in Engineering Subjects*

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Teamwork has been included as a major component of graduate attributes in all engineering programs at universities. 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 learn and work in teams due to numerous reasons. In order to facilitate engineering academic staff and engineering schools, this study develops a simplified framework for managing learning teams in engineering subjects that integrates theoretical conceptions, empirical evidences and anecdotal practices by reviewing a substantial body of existing literature. The framework identifies that in addition to managing student complaints about learning and working in teams more effectively and efficiently, engineering academic staff and engineering schools need to focus on specifying learning outcomes of teamwork, identifying appropriate approaches to achieve these learning outcomes, judging the suitability of teamwork-based learning in a particular educational context, developing a clear plan for implementing teamwork, implementing and monitoring teamwork, and reflecting and re-evaluating teamwork. The developed framework can be a useful tool to help understand these essential components and complexities of team learning.

Keywords: engineering students; learning teams; managing learning teams; simplified framework

1. Introduction

Team learning is an integral part of engineering education today as most engineering employers value teamwork-based graduate attributes in their new engineering employees as highly, if not more highly than their ability to work independently. Teamwork-based learning outcomes such as teamwork knowledge, teamwork skills and processes, teamwork products or outputs and teamwork experience have been included as a major component of engineering graduate attributes at all levels (professional level, university level, program or course level and subject, unit or module level). Team learning in academic institutions is the process of students learning and working collaboratively, cohesively and cooperatively on a specific team task, activity or assessment item to achieve teamwork-related and/or associated learning outcomes. Team learning is a shared commitment both to a team's processes and to its products [1]. An achievement on learning outcomes of teamwork demonstrates that the students are able to learn and work with other people from diverse disciplines and backgrounds and in a range of situations. At engineering schools, team learning helps students to comprehend and develop teamwork knowledge, learn and apply teamwork skills through a series of teamwork processes in a team task or assessment item, solve engineering problems and develop engineering products or solutions, and practise and experience teamwork for professional engineering workplaces.

Obvious benefits accrue in learning in teams, so do numerous problems [2]. Team learning is important for teams to learn how to work together effectively and cohesively [3]. Teamwork skills themselves are one of the graduate outcomes for 'employability' as professional engineering employees are often allocated to project teams. Teamwork also helps to achieve other graduate attributes such as communication, critical thinking, problem solving and global citizenship (diversity and cultural awareness) etc. Over the last few decades, social and educational psychologists have elaborated conceptual foundations, dynamics, principles, perspectives, philosophies, stages, models and theories of team learning. For detailed discussion, refer to Hrynchak and Batty [4] for theoretical basis of team-based learning (TBL), Edmondson, Dillon [5] for the perspectives on team learning, Decuyper, Dochy [3] for dynamic complexity of team learning and Bell, Kozlowski [6] for theoretical integration and review of team learning. Motivational (needs, behaviour and satisfaction) theories, social cohesion (shared values, identities and norms) theories, cognitive (mental states and processes) theories, developmental (learning stages and behaviour) theories, and complex and dynamic systems (generalised system, complex system) theories have been frequently used to theorise team learning.

Hrynchak and Batty [4] provide an excellent analysis of the theoretical basis of team-based learning (TBL). They review the constructivist theory of education as it applies to TBL used in the development of critical thinking and teamwork

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skills. Edmondson, Dillon [5] discuss three perspectives on team learning: outcome improvement, task mastery and team process. Bell, Kozlowski [6] emphasise three foci of team learning; multilevel (individual and team, not individual or team), dynamic (iterative and progressive, a process not an outcome) and emergent (outcomes of team learning can manifest in different ways over time). Decuyper, Dochy [3] base their discussion around general system theory and complexity theory to capture the dynamic and complex nature of team learning in their model. System theory has been used to elaborate dynamic nature of teamwork, in which input conditions are transformed via optimum throughput processes into maximal outputs [7]. Hence, input-process-output model is frequently used as a common framework for conceptualising teamwork. Tuckman [8]'s behavioural stages of team dynamics- forming (the establishment and formation of the team), storming (team conflict and fragmentation), norming (the development of team norms), performing (the working stage) and adjourning or mourning (the disbanding stage)— are important considerations that help to plan, implement and monitor team learning activities and processes in sequential time domain. This paper neither attempts to explore these theoretical foundations in depth nor does it intend to develop a new theory of team learning. Instead, it focuses on developing a simplified framework to guide engineering academic staff and engineering schools to plan team learning, to implementation and monitor teamwork processes and to address issues of team learning in their engineering subjects.

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 [9]. Moreover, most engineering academic staff are neither expert in team learning nor there are rigorous academic staff development and training programs regarding learning and teaching teamwork at engineering schools. They usually depend on educational psychologists' theoretical literature. Even though these theoretical aspects of team learning are important, they are heterogeneous, generative, occasionally confusing, and difficult to comprehend and implement in an engineering subject. Moreover, most engineering academic staff simply do not have sufficient time and adequate resources available to implement team learning considering theoretical concepts thoroughly in their subjects as they need to cover a huge chunk of subject specific learning materials. Too often engineering academic staff include teamwork, yet without adequate preparation and with little understanding about how to use their times and resources to achieve the greatest gains for themselves or for their students.

Team learning subjects, training manuals, guidelines, tools and other resources developed mostly by educational psychologists at an academic institutional level, for example, Harvard University [10], Carnegie Mellon University [11], CDIO [12], Monash University [13], Griffith University [14], Deakin University [15], are less helpful for engineering subjects as they are usually based on theoretical foundations, such as why teamwork is important, how a team-based learning is aligned with constructivist theory of education, what dynamic and complexity theories define team learning, how socio-psychological theories underpin team learning, what types of common team learning models have been identified and so on rather than facilitating engineering academic staff on how the team learning in a particular engineering subject can be adequately and sufficiently managed. As a result, engineering academic staff do not prefer to include teamwork in their subjects. Even if they are asked by engineering schools and program directors to incorporate team learning in their subjects, they usually take the lowest obstacle path by simply asking students to complete a learning task or assessment item in teams. They may also include teamwork if they believe it reduces the marking workload, especially in large student cohorts. Both these practices do not help to develop adequate teamwork knowledge, skills, products and experience and hence the core teamwork-based learning outcomes.

Simply asking students to complete a task or assessment item in teams is not the same as developing teamwork knowledge, teamwork skills, teamwork products and good experience. The team-based assessment items without addressing core teamwork-based learning outcomes is recognised as a significant problem [16]. Research demonstrates that placing students into teams without preparation, scaffolding and facilitation does not result in higher academic achievement nor the achievement of learning outcomes related to skill development and attainment, and can result in unclear goals, mismanagement, conflict and inequalities [2]. Teamwork and associated skills and capabilities are not acquired nor developed without scaffolding and facilitation [17]. There is an acknowledgement that teamwork has long suffered as a result of inadequate epistemology, and that principles of 'good practice' need to be identified and adhered if effective team learning outcomes are to be realised [18].

The success of a team learning is measured in two important aspects- students learn and accomplish teamwork-based learning outcomes and team mem-

bers are highly satisfied. In order to successfully satisfy these two aspects, engineering academic staff need be mindful of a number of components of team learning. They include, specifying learning outcomes of teamwork, identifying appropriate approaches to achieve these learning outcomes, judging the suitability of teamwork-based learning in a particular educational context, developing a clear plan for implementing teamwork, implementing and monitoring teamwork, and reflecting and re-evaluating teamwork. The goal of this paper is to facilitate non-expect engineering academic staff by developing a simplified framework for managing learning teams in engineering subjects that integrate these important components of team learning by reviewing literature evidences on theoretical conceptions, empirical evidences and anecdotal practices.

2. A Framework for managing learning teams

Using a thorough and an extensive review of scientific literature, team learning subjects and trainings offered, teamwork tools and guides developed by educational institutions and other organisations and anecdotal practices at engineering schools, a simplified framework for managing learning teams in engineering subjects is developed and presented in Fig. 1. The framework accommodates several aspects and components of team learning. The framework starts with specifying intended learning outcomes of teamwork and concludes with teamwork reflection. Although the framework is presented in a linear fashion, most components interact in complex relationships and often are not sequential. The components of this framework are elaborated in the subsequent sections with the help of literature evidences.

2.1 Learning outcomes of a teamwork

Even though teamwork has been commonly listed as an important graduate attribute of all engineering programs, it is often unclear what it specifically includes. It is crucial to reconsider the learning outcomes associated with teamwork, as their articulation will have direct follow on effects on subsequent steps and components of the framework presented in Fig. 1. Breaking down into a number of distinct learning outcomes a particular subject is intended to achieve from teamwork would determine how to proceed further. Team learning outcomes can be broken down into four major categories, (i) to understand and comprehend the teamwork knowledge (features, processes, principles, theories etc.), (ii) to develop and apply teamwork skills by practising them through teamwork processes (both team and task processes), (iii) team-based learning to help students achieve subject learning outcomes and/or improve the quality of teamwork product, and (iv) to experience teamwork for professional engineering workplaces. Similar to any other learning outcomes of an engineering subject, students' achievement on these teamwork-
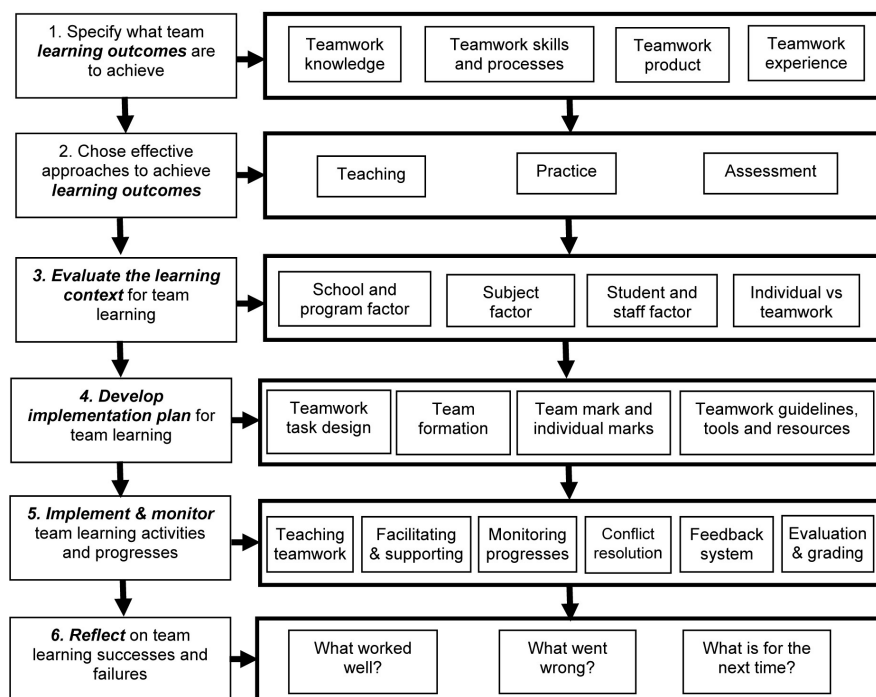

Fig. 1. Simplified framework for managing learning teams.

based learning outcomes can be aligned to several levels of competency: aware, basic, proficient, advanced and expert. A particular engineering subject can accommodate all or some of these teamwork-based learning outcomes at various levels of competency, as required by an engineering program structure. It is usually unnecessary to cover all these teamwork-based learning outcomes in a single engineering subject but scaffolding and mapping of subjects within an engineering program help to identify what aspects of team learning are needed to be covered in a particular subject. It may be a good idea to accommodate low-level teamwork-based learning outcomes such as teamwork knowledge and basic teamwork skills in Year 1 and Year 2 and high-level teamwork-based learning outcomes such as advanced teamwork skills, teamwork products and teamwork experience in Year 3 and Year 4 of four-year undergraduate engineering programs.

Teamwork skills include, among others, organisation skills, coordination (of tasks, roles and responsibilities) skills, communication (oral, written, technical) skills, interactive (interaction, negotiation, discussion) skills, creative thinking (idea generation, evaluation and selection) skills, decision-making skills, leadership skills, conflict management skills, mentoring (coaching, mentoring, counselling, feedback) skills and diversity (culture, age, gender, race, religion, political persuasion) awareness. Teamwork is not the only way to achieve some of these skills, but teamwork 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 [19, 20]. Most research has concentrated on addressing team-building challenges, processes and performance, rather than examining whether or not teamwork tasks contribute to the students' achievement of stated learning outcomes [21]. A clear distinction about the learning outcomes of teamwork and the required levels of competency achievement is the starting point of managing learning teams.

2.2 Approaches to achieve learning outcomes of a teamwork

The framework presented in Fig. 1 depicts that a clear understanding and specification of learning outcomes of teamwork helps to identify appropriate (i) teaching, (ii) practice and (iii) 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 assessments. However, in order to develop teamwork skills by practising them

through teamwork processes, it may be necessary to teach, practise and assess these skills.

When a learning outcome of a teamwork of a subject is to use team-based learning to improve the quality of the teamwork product and/or to help achieve subject learning outcomes, it may not be necessary to assess the teamwork knowledge, skills or processes as the assessment of teamwork product may be sufficient to make judgements. One of the major problems with only the assessment of a teamwork product is that it is difficult to assign different individual marks from the team mark. On the other hand, if the learning outcomes of teamwork are to assess the teamwork knowledge, skills or processes, it may not be necessary to assess the quality of teamwork product. One of the problems with the assessment of only teamwork knowledge, skills or processes is that the teamwork does not necessarily lead to a meaningful product. However, if the subject learning outcomes are focused on improving a teamwork product using teamwork knowledge, skills and processes, a typical curriculum for the majority of engineering subjects at universities, it is important to adopt an approach that assesses all teamwork knowledge, teamwork skills and processes, and teamwork product [22]. Quality teamwork experience can only be possible after rigorous teamwork exercises and reflective practices. As the 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 not always easy to analogise the inputs, processes and outputs between learning teams and professional engineering teams. Hence, how a teamwork activity relates to and mirrors an authentic real world experience is to be considered deeply if the engineering students are to have teamwork experience for engineering workplaces. Research has begun to identify the conditions under which team learning translates into workplace situations [23].

2.3 Evaluation of learning context for teamwork

Before incorporating teamwork as a part of learning outcomes in an engineering subject, it is important to evaluate whether the learning context is suitable for efficient and effective team learning. The framework presented in Fig. 1 identifies a number of factors that are to be taken into consideration, including (i) requirement from school and from engineering program perspective, (ii) suitability of a subject's learning materials for teamwork, (iii) both quantity (e.g., class-size) and quality (e.g., previous teamwork experience, socioeconomic attributes etc.) of student cohort, (iv) expertise, experience and motivation of academic staff, and (v) proportions of teamwork-based learning and

individual-based learning components in the subject.

2.3.1 School, program and subject factor

From program and subject curriculum and engineering schools' perspectives, it is important to choose suitable (not necessarily all of them) engineering subjects to implement team learning which can help achieve learning outcomes of teamwork more efficiently and effectively. The author was unable to find literature evidence on relative suitability of engineering subjects for team learning. However, anecdotal evidence suggests that in theoretical and fundamental subjects such as mathematics, physics, mechanics, geology etc. which require students to grasp 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 subjects but learning outcomes in these subjects may be better achieved while learning individually. However, for professional practice and engineering design subjects such as engineering practice, project management, infrastructure design, engineering projects where teamwork skills play an important role, team learning can be instrumental and effective for students' deeper learning.

2.3.2 Student and staff factor

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 teamwork [24]. Both the quality and quantity of students (cohort size, teamwork experience and attitude) and academic staff (number, expertise, experience and motivation) 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 which roughly equates to 5 to 20 teams. It, however, also depends on the time and resources available for the subject. Moreover, when the academic quality and previous teamwork experience are similar among students, learning in teams can be easier to manage compared with the huge variations of cohort's academic quality and previous teamwork experience. Vast majority of students have mixed feelings about and diverse attitudes towards teamwork [17].

2.3.3 Team-based vs. individual-based tasks

The author was unable to locate literature evidence on proportions of individual-based and team-based summative assessment tasks or items in an engineering subject. Although teamwork-based assessments can be of any proportions ranging from 0% (all individual-based tasks) to 100% (all team-based tasks) in a subject as widely seen in practice, it may not be a good idea to have more than 50% team-based assessment items in a subject. This would prohibit free-riders to pass the subject 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 team member in the subject and hence may be suitable. Teamwork-based assessment items of less than 20% may not effectively help to achieve intended learning outcomes of teamwork as students may not fully commit towards teamwork. Literature suggests to use teamwork-based assessment items only when they are absolutely essential to achieve the intended learning outcomes of a teamwork as overuse of them may adversely affect on achieving learning outcomes of the subject effectively and efficiently [14].

2.4 Development of implementation plan for teamwork

Once the decision is made to include teamwork in a subject in order to achieve specific learning outcomes of teamwork using appropriate approaches, the next step is to develop a plan for teamwork implementation as shown in Fig. 1. Providing the opportunities and training for students to develop mastery in teamwork skills requires careful thought and subject design. The plan includes, but not limited to, (*i*) designing a teamwork task or an assessment item, (*ii*) forming learning teams (size and composition), (*iii*) developing a process of identifying individual contributions that help to allocate individual marks from a team mark and, (*iv*) preparing context-specific teamwork guidelines, tools and resources. The information regarding the implementation plan 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.

2.4.1 Designing a team task or assessment item

A learning task or an assessment item for teamwork needs to be designed based on both collaborative

(constructivist approach) and cooperative (sharing of ideas) learning theories and pedagogies [17, 25–28]. In order to create an authentic teamwork-based learning task or assessment item, it is important for students to see the relevance of such a task. It needs to be designed considering students' workload, has clearly defined team learning outcomes, contains clear criteria against which learning outcomes are assessed- either by an assessor or in conjunction with the students, provides clear understanding of a variety of roles and responsibilities, allows scope for creativity, requires a team 'product' that can be assessed collectively, and requires for high level cooperation [14]. Designing effective, robust and collaborative student teamwork tasks and assessments help students understand the process of working effectively within a team to achieve a common goal [15]. There also need to be effective, clear and separate marking rubrics for team-based assessments. Team tasks need to be carefully designed so that they allow for creative problem solving; provide opportunities for inputs from every member of the team; have a clearly defined focus on either the end product or the team process itself, or a balanced mix of the two; and can be assessed on the basis of individual, team or a combination of individual and team performances [14]. When designing a team task, it is important to consider whether it should be assessed at all; whether it will achieve the intended learning outcomes for the subject; whether it is beneficial to assess individual performance and learning outcomes, team performance and learning outcomes, or a balanced mix of the two; how an academic staff negotiates assessment criteria with the students; and how an academic staff asks students to self-assess their performance in a reflective journal or log. Where a sufficient time and resources are available, team learning assessment tasks can be designed in three phases- a prior learning assessment, readiness assessment and assessment on learning materials. An engineering teamwork task should promote learning, team development and product quality.

2.4.2 Team formation

In the best of all possible worlds, teams are formed deliberately and carefully to meet learning and working needs that an individual cannot meet as effectively [1]. Learning team formation (both size and composition) is one of the most important aspects to manage learning team and to reduce student complaints. It directly affects teamwork skills, processes, outcomes and experience. Existing studies suggest that team learning is a function of the number, composition, type of roles team members play and the amount of work required for a teamwork task or an assessment item. An effective team usually includes a mix of team roles [14]. It is also important to make team formation process transparent. Teams can be formed and their activities can be documented online using several learning management systems.

The optimal learning team size and composition is highly debated and contested topic in existing literature and will vary depending on a number of factors including teamwork tasks at hand. Small teams of 3 or less lack enough diversity and may not allow divergent thinking to occur. Teams that are too large (>10) create free-riding environment where not all students in a team participate. Most studies have suggested the team size between 3-10 members. Moderate team size of 4–5 members in an inexperienced team and 4-6 members in an experienced team is suggested as optimal team size. Although larger teams have more collective intelligence, smaller teams develop team cohesiveness more quickly, thereby enhancing their initial team performance [29]. In addition, larger teams usually have poorer team processes operating under relatively high pressure to innovate than large teams that do not have a high requirement to innovate [30].

A number of methods are available to allocate students into teams (i) *self-selection*: students decide team members (ii) *random allocation*: academic staff randomly assigns students into teams (iii) *deliberate allocation*: academic staff assigns students into teams, based on some attributes and criteria (e.g., academic performance, physical location or proximity, on-campus and off-campus, skills and knowledge, social and cultural mix, availability for the meetings, topic of interests etc.), (iv) *pairing*: both students and academic staff are involved in selection [31] and (v) *role-based allocations*: academic staff outline different team roles and students choose their preferred roles based on personality types of individuals for team roles and responsibilities. Team roles and responsibilities are discussed extensively in Jung [32], Myers [33] and Belbin [34]. There are advantages and disadvantages associated with each method of allocating students into teams but social and cultural diversity in teams have been identified as beneficial for team learning. Learning teams are to be formed with maximal diversity in the knowledge and experience within the team and relative evenness between the teams for homogeneous learning [4]. This is accomplished by deciding what the key characteristics of individual team members are to promote success of a team and then distributing students with these qualities evenly between the teams [35].

2.4.3 Team mark vs. individual marks

Existing literature suggests that a number of methods can be used to award team mark and individual

marks. Lejk, Wyvill [36] have summarised nine (9) methods of assigning team and individual marks. Seven (7) approaches to assign team and individual marks were explored by Race [37]. Collectively, these methods include, (*i*) using the same team mark for all team members [38], (*ii*) using the same team mark for all team members with exceptional intervention by academic staff [39], (*iii*) yellow and red cards approach [40], (*iv*) assessing separately team processes and products and summing them together [41–43], (*v*) splitting up team task and individual tasks and assessing them separately [44, 45] (*vi*) dividing up the assessed team task and assessing each components separately [38], (*vii*) adding contribution marks by awarding for the product of the team and asking team-members to peer-assess an additional marks for their contributions [38], and (*viii*) adjusting team mark by using individual contributions. Team mark is usually obtained by assessing the teamwork product (product or output assessment) and a number of approaches are used to elicit an individual team member's contribution to a teamwork (process assessment). Co-, peer-, self- and academic staff-assessments have been commonly used to assess teamwork process. Individual team member's contributions are used to reward above-average contributors and to penalise below-average contributors (i.e., free riders). Several methods for refining peer and self-assessment scores have been proposed in existing literature [46–50]. The aims of these refinements are to ensure the validity and reliability of these scores and to discourage extreme cases such as self exaggeration, one team-member being panelised, creative accounting and overgenerous cases. Most of these refinements use some sort of agreement correlation procedure by estimating the variances of the scores.

In recent times, 'adjusting team mark by using individual contributions' has been commonly preferred in existing literature. Existing methods to allocate individual marks by adjusting a team mark using an individual team member's contribution to teamwork include: (*i*) distributing the pool of marks [38, 46, 51]; (*ii*) adding a mark to or subtracting a mark from the team mark based on an individual contribution [36, 46, 51]; and (*iii*) multiplying team mark by a factor derived from an individual's contribution to the teamwork [22, 46, 52–55]. Nepal [56] have extensively reviewed and discussed several approaches to award individual marks by multiplying team mark and individual contribution factors. 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 type behaviours) and

aligns individual contributions with the quality of the teamwork product. Both the method used to assess individual contributions to a teamwork and marking criteria and rubrics of the teamwork product are to be conveyed to the students at the earliest possible time. Nepal [22] reports that providing a clear guidance on how individual marks are allocated at the beginning of the subject session reduces student complaints and teamwork hindrances significantly.

2.4.4 Teamwork guidelines, tools and resources

It is imperative to consider research and to develop guidelines for 'best' practice as there is an educative/personal need and a market/societal need in higher education to produce graduates, who have the capacity to function as members of a team in any context [24]. Available institutional level teamwork subjects, training manuals, guidelines, tools and other resources can be used but it may be beneficial to simplify and contextualise them. They should clearly include 'good practice' information regarding (*i*) stages of teamwork, (*ii*) team and task processes, (*iii*) team roles and responsibilities, (*iv*) process of identifying team and team member's strengths and weaknesses, (*v*) relationship and behaviour management for team cohesiveness, (*vi*) ground rules on norms of team confidentiality, responsibility, accountability, flexibility, equality, creativity, initiative, inclusion and openness (*vii*) characteristics, behaviours, activities, features, conditions, strategies, styles and elements of effective team and teamwork, and (*viii*) teamwork conflict mediation, negotiation and resolution approaches. In addition, team and task processes (transition processes, action processes and interpersonal processes) can be elaborated to include information regarding goal setting; organising, conducting and minuting team meetings; decision making and following actions; strategies for communication and reporting; feedback system; planning, scheduling and execution of team task; strategies for monitoring progresses; strategies for reflection, assessment and self-assessment; procedure for documenting contributions; and skills required for team and team member's maintenance and growth [57]. Skills required for task processes (e.g., technical expertise, conceptual thinking, dedications, achievement oriented, analytical thinking, ability to apply and competency help students to manage teamwork task or assessment) and team processes (e.g., ability to influence, defectiveness, interpersonal understanding, networking ability, organisational awareness and self-regulation) can help and guide students to manage team processes. These resources should form a basis for and reference document of overall teamwork and its processes.

However, it is also important to make these aspects of the resources flexible.

2.5 Implementation and monitoring of teamwork

Implementation and monitoring of team learning activities and processes is the most time consuming and complicated step of all steps in the proposed framework in Fig. 1. As team learning activities and tasks usually form a small component of an engineering subject, the time and efforts required for them is often neglected and taken for granted. Important components of this step of teamwork include (*i*) teaching (*ii*) facilitating and supporting, (*iii*) monitoring progresses, (*iv*) conflict resolution, (*v*) feedback system, and (*v*) evaluation and grading.

2.5.1 Teaching teamwork

While most professional engineering works take place in teams and most engineering educators agree that teamwork is important, less is known about how to provide effective instruction about teamwork [58]. As there is an increased emphasis at engineering schools on helping students acquire teamwork-related learning outcomes, engineering academic staff need to teach teamwork to introduce the whole notion of teamwork as an evolving process [14]. 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. However, as learning and working in teams do not start at engineering schools and students might have obtained teamwork experience outside, it is likely that the students are at different levels in regards to their knowledge, skills and experience on learning and working in teams. Depending upon the time availability, it may be helpful to establish what prior knowledge, skills and experience students have had in regards to working in teams prior to determining what needs to be taught. Where necessary, few instructional hours and resources are typically devoted to specifically developing teamwork skills.

In addition to theoretical concepts and literature evidence about teamwork, teaching teamwork involves team building activities and role plays. The idea of using team building activities has often been suggested as a way to increase the overall success of a team [59, 60]. Research have demonstrated a positive correlation between team activities or processes and team performance or achievement [59, 61]. Page and Donelan [61] found that engaging students in transition activities such as establishing team goals, rules and guidelines, assessing member skills and assigning roles are positively associated with goal attainment, student satisfaction and learning through teamwork [24].

Team-building processes can also mitigate many of the problems associated with teamwork, such as specialisation of labour, social loafing, and inadequate rewards [21, 27, 62]. However, anecdotal practices suggest that most engineering academic staff rarely teach teamwork.

2.5.2 Facilitating and supporting teamwork

Academic staff can facilitate and support teamwork from start to finish. Facilitation and support is to help students resolve teamwork issues, highlight teamwork as an important graduate attribute and improve perceptions of the benefits of teamwork [9]. 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 evidence, providing feedback, helping to reach consensus and resolving conflicts. Students are to be given the first opportunity in all these activities and are to be encouraged to find solutions to their own problems or difficulties. Students must receive frequent and timely feedback. It is important to allocate class times (physical or virtual or both) for learning teams to meet, to get to know one another, to establish roles and responsibilities and to clarify teamwork task and learning objectives. While identifying roles and responsibility of team members, it is important to incorporate students' opinion on how best they learn and how best they work in teams.

2.5.3 Monitoring teamwork progresses

Monitoring or checking teamwork progresses and related behaviours benefits overall team performance by enhancing team coordination and the provision of feedback [63]. Sheard and Kakabadse [64] suggest to monitor teamwork in four dimensions: task, individual, team and environment. A proper system of monitoring teamwork progresses can be implemented by establishing alert mechanisms, operating random checks, requesting progress reports, monitoring communications (involvement, frequency, interruptions, silence etc.), monitoring decision making processes (consensus, contribution, voting etc.) and obtaining contribution documents. However, effective monitoring depends on providing a constructive framework for team interactions, gathering information and giving feedback on team interactions and anticipating and preparing for potential problems [11]. A common practice in engineering schools regarding monitoring is to stay way unless there is a seriously reported issue in teamwork. All dimensions of monitoring teamwork- task, individual, team and environment-

can be tracked down by using teamwork log books, communication documents, meeting minutes, progress reports, roles and responsibility sign-offs and interviews. Simplified versions of progress report forms can be used.

2.5.4 Conflict resolution

While some people may argue the best solution of 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 and can be healthy for a team. Conflicts do happen while learning and working in teams due to numerous reasons. Conflicts are part of individual relationships, and no relationship can hope to mature to be successful without being able to resolve conflicts effectively [65]. Conflicts may be perceived or actual [66]. Conflicts in learning teams usually happen due to, but not limited to, unclear team learning outcomes; inadequate team learning approaches; inadequate educational context for team learning; ill-defined team task or assessment; individual differences in academic performance, learning goal and achievement aspiration; individual differences in learning style, personality, motivation, behaviour (individualistic, social, freeloading etc.), commitment and flexibility; lack of proper team and task processes (e.g., communication breakdowns) and external factors such as personal and work commitments. Fortunately, it is possible to take steps to minimise conflicts and to resolve those disagreements that may be dangerously escalating. Conflicts can be reduced by addressing the reasons or sources of the conflicts. Learning teams are to be encouraged to seek help from academic staff when conflict reaches a stage that is significantly affecting the team's processes and outputs. But it is better to let students discuss and manage conflict early within their team so that issues do not get out of hand. It is worthwhile to provide teams with a conflict resolution flow chart or framework (prior to commencing teamwork) showing them a step by step logical pathway on how to address the issue within their own team to raising an issue with an academic staff member [15]. It is also important to depersonalise team's internal conflicts. The conflicts can be resolved internally first, before embarking on mediation journey, by identifying the causes of conflict, stating the effects on team tasks, negotiating solutions that suit team needs, stating solution steps or procedures, documenting the process, and monitoring and reviewing.

2.5.5 Feedback system

An important component of implementing and monitoring team learning activities and progresses is the inclusion of frequent, timely, and varied types of feedback to students [67]. Two-way feedback system between team/individual team member and academic staff regarding the teamwork is an effective way to improve and manage teamwork. Literature evidence suggests that feedback has a positive effect on motivation, satisfaction, and performance in teams [68]. Regular and timely feedback from student also helps academic staff to monitor the team progresses, to understand issues and conflicts, to devise appropriate approaches and strategies to optimise students' team learning outcomes and to assist in evaluation and grading of teamwork. Form and content of feedback system needs to be worked out carefully [67].

2.5.6 Evaluation and grading teamwork

In an ideal teamwork environment, a team's performance is measured primarily by the products produced collaboratively by the team. However, neither all team members are homogeneous nor they are equally motivated. Students' contribution and behaviour to teamwork is largely dictated by how they are assessed, evaluated and graded. Limited high achievers usually think of maximising their individual academic performance whereas a vast majority of students do what they perceive is just enough to fulfil the requirements for the teamwork task [19]. Depending upon the type of teamwork-based learning outcomes, teamwork knowledge, teamwork skills or processes, teamwork product or output and teamwork experience can be assessed, evaluated and graded. Teamwork can be assessed either solely by academic staff or by both academic staff and students. Knowledge of a teamwork can be assessed by using traditional assessment system whereas teamwork skills and processes are usually assessed through combination of evaluation scale, observation, presentation, viva, traditional assessment system, co-assessment, peer-assessment and self-assessment. Teamwork product can be assessed by using traditional assessment system based on the marking criteria of the teamwork product. Teamwork experience can be assessed primarily through reflection. Assessed and graded components of the teamwork are then systematically processed to award marks and grades.

2.6 Reflection on teamwork

The final step of the teamwork framework prosed in Fig. 1 involves a teamwork reflection. Reflection on teamwork can be a valuable part of learning experience. 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 in industry [58]. Reflection should 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 [14]. Reflection can be during and after the teamwork implementation. It is important to reflect on team and task processes regularly within team. 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. At the end of a teamwork product, reflection can help both evaluation of team learning achievements and planning for the next time. Having discussions during class times, especially at the end of semester regarding the team processes would help. The reflection can also be a part of assessment.

3. Conclusion

This study develops a simplified framework for managing learning teams in engineering subjects by reviewing an extensive list of literature on theoretical conceptions, empirical evidences and anecdotal practices. The aim of the proposed framework is to provide engineering academic staff and engineering schools the step-by-step procedure so that the problems of team learning in engineering may be reduced. Depending upon the availability of time and resources and the suitability of educational context, managing engineering learning teams can be both simple (when only a few aspects of teamwork are taken into consideration) as well as complex (when all or most aspects of teamwork are taken into account). The proposed framework is expected to help devise an implementation approach based on time and resources available at a particular educational context. The proposed framework emphasises that for better management of learning teams, attention should be focused on specifying learning outcomes of teamwork, identifying appropriate approaches to achieve these learning outcomes, judging the suitability of teamwork-based learning in a particular learning context, developing a clear plan for implementing teamwork, implementing and monitoring teamwork and reflecting and re-evaluating teamwork. The next-step would be to implement and monitor these components of the framework in a particular engineering educational context in order to evaluate the effectiveness of the proposed framework. Based on the additional research evidence, the framework can be continuously implemented, monitored and updated.

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