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Team-Based Learning: Promoting gender inclusive development of teamworking skills in engineering education

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ABSTRACT

Team-based Learning (TBL) has been reported to be an inclusive pedagogic model because it facilitates to reduce attainment gaps between different ethnicity and gender groups. However, no empirical studies have demonstrated whether TBL develops consistent teamworking skills across demographic factors such as gender. In this case study, 24 diverse and gender-balanced teams quantitatively assessed the teamwork abilities of their peers using a digital peer-assessment tool after completing a 10-credit TBL module. The collected data was subjected to a statistical test (Mann-Whitney U) to infer the significance of the students' gender upon their teamwork skills.

Our results indicate that TBL had no statistically significant impact on prompting the development of teamworking skills for any particular gender group. Particularly, we have observed consistent perceptions of team performance, adjustment and support, and decision-making abilities when comparing male and female students. Underpinned by the social constructivist learning framework, TBL applied to teaching engineering appears to promote gender-inclusive teamwork.

KEYWORDS

Active learning, Engineering Curriculum, Gender, Inclusivity, Team based learning

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INTRODUCTION

Calls from industries, governments and businesses for new graduate skills are driving steep transformations in higher education visions and strategies, with substantial investments underway than can help to align educational outcomes with these required skills (Beichner et al., 2007; Dori et al., 2003; Mitchell, Nyamapfene, Roach, & Tilley, 2019; Shinde & Kolmos, 2011). In this regard, the large-scale adoption of active learning methodologies has been reported to facilitate the development of these new skills (Freeman et al., 2014; Hartikainen, Rintala, Pylvas, & Nokelainen, 2019; Hernández-de-Menéndez, Vallejo Guevara, Tudón Martínez, Hernández Alcántara, & Morales-Menendez, 2019; Prince, 2004; C. E. Wieman, 2014). Active learning explicitly directs students to develop expertise through effortful mental practice and feedback working on a variety of tasks as opposed to traditional-based lectures, where students are expected to passively absorb the knowledge transmitted by the teacher. The cognitive effort required to complete such tasks has proven that, if well implemented, active learning can lead to an average increase in examination results of ca. 6% and an average 33% reduction in failure rates, reducing the often observed gap with underrepresented minorities (Freeman et al., 2014).

Team-based learning (TBL)

One of the most popular active learning models is team-based learning (TBL), derived from social-constructivist educational theory (Hrynchak & Batty, 2012). TBL shows promising outcomes in supporting the development of professional competencies (Betta, 2016), explained by the unique motivational context emerging from peer interactions and social learning that happens when teams make evidence based decisions to solve a problem (Michaelsen, Sweet, & Parmelee, 2008).

For a module designed on the basis of TBL, each learning unit is split into three distinct stages as shown in Figure 1. Firstly, individual study is required where the student becomes familiar with the key theoretical concepts via pre-reading documents or watching instructional videos (pre-work). Secondly, a readiness assurance process (RAP) takes place in-class, where students undertake an individual multichoice test (iRAT). This test allows them to check whether they have understood the concepts presented in the first stage. After the iRAT, the same test is presented to the whole team so all the peers can complete it working as a group; this is called the team test (tRAT). Scratch cards revealing the correct answers to the tRAT are normally used as a mechanism to provide instant feedback to the team members before the teacher provides more general verbal feedback to the whole class focusing on the questions that have been answered incorrectly by multiple teams. The RAP phase has been found to increase student motivation, mainly by self-regulation and perceived competence and autonomy mechanisms in TBL classes (Jeno et al., 2017). The third and final stage - tAPP or team application

exercises - is dedicated to bringing the team members to work together to solve a variety of application exercises by applying, analysing, synthesising and evaluating higher cognitive level concepts that build on the acquired knowledge during the RAT stage (Whitley et al., 2015). A list of possible answers to each of the application exercises is usually provided, and the teams are expected to use relevant evidence to inform their decisions. After a few minutes, usually 5 – 15 minutes depending on the difficulty of the task, all the teams are asked to report their solutions at the same time using a flash card with the printed answer (eg A, B, C or D). The teacher then initiates a collaborative discussion with all the students, comparing different views, thoughts and responses, and offering immediate formative feedback (Michaelsen et al., 2008).

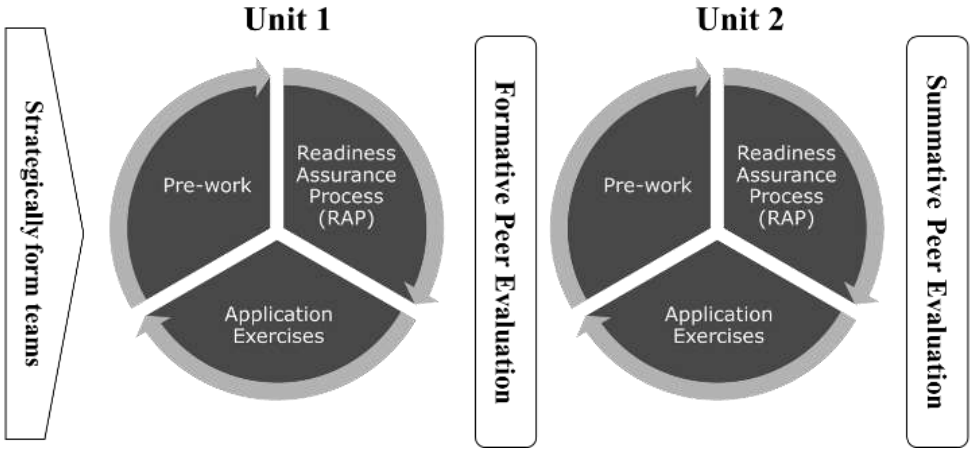

Figure 1. Typical teaching pattern in a TBL module consisting of two major learning units

The module assessment usually incorporates the scores from the iRAT (10%-25%), tRAT (10%-25%, multiplied by a peer-assessment weighting factor), tAPP (0%-25%) and exams. For our case study, the individual weightings were iRAT (15%), tRAT (15%) and exam (70%).

TBL and gender

Although educational research on TBL has reached a mature stage (Haidet, Kubitz, & McCormack, 2014) with most of the research focused on achievement of the learning goals, little has been done to assess in an empirical fashion whether TBL is capable of fostering equal opportunities across genders for developing teamwork skills (Muheidat & Tawalbeh, 2018). For instance, a limited number of studies have explored the influence of gender on the educational benefits provided by TBL. Whilst some studies are focused on the benefits related to the overall student learning experience (Eksteen, Reitsma, Swart, & Fourie, 2018), most of them investigate the learning gains where gender is at least a predictor variable (Chen et al., 2018; Das et al., 2019; Ganguly, Faulkner, & Sendelbach, 2019; Harakuni, Nagamoti, & Mallapur, 2015; Hettler, 2015; Thompson et al., 2015), with virtually no studies focused on the relationship between gender and development of teamwork abilities. Eksteen et al. investigated the perception of 200 students on a TBL experience in a pharmacy course at a South African university (Eksteen et al.,

2018). The authors considered different demographic factors such as ethnicity, gender and age, and concluded that female students (79.5% sample group) had a more negative perception of TBL when first introduced to it (p-value = 0.030) but were held more accountable than their male counterparts to prepare for class (p-value = 0.010), which may justify the higher satisfaction of the latter for working in teams (p-value = 0.020).

Harakuni et al. studied the performance of 88 students in a microbiology module at an Indian university, where all students attended lectures on the topic content after which the cohort was split into two sample groups: a control group that relied on self-study time to prepare for the assessment and an experimental group that was taught using TBL (Harakuni et al., 2015). Their findings showed that the TBL group significantly outperformed the control group in the assessment, and that TBL had a more significant impact on the performance of male students (p-value = 0.013) compared to their female counterparts (p-value = 0.101). The authors attributed this impact to the inherent characteristics of the TBL model, whereby the autonomy to choose an appropriate solution, the competence to achieve a fixed goal and the relatedness to actively engage in the learning process are known to have a higher impact on male students (Cortright, Lujan, Blumberg, Cox, & DiCarlo, 2013), with female students being more likely to present themselves as more introspect and self-critical (Wehrwein, Lujan, & DiCarlo, 2007). These results however are in conflict with another study on a group of 100 students that looked into the effect of gender on achievement of learning outcomes in a biochemistry course at an institution in the same country (Das et al., 2019). This study grouped students into a traditional lecture-based and team-based learning groups, where the ratio between male and female students was kept to a similar value (30:18 and 30:16, respectively). The researchers observed that female students performed better in the TBL group (p-value < 0.05), whilst in the traditional lecture group the performance of both male and female students was comparable (p-value > 0.05). This observation was attributed to females preferring learning methodologies that included collaboration and hands-on work (Mann, 1994) whereas males may have preferred sequential learning approaches (Picou, Gatlin-Watts, & Packer, 1998). Similar outcomes were reported by Chen et al., who conducted a meta-analysis incorporating a pool of gender-based TBL studies, and concluded that gender diversity could be a potential source of heterogeneity with regards to the effectiveness of TBL in medical education (p-value < 0.001) (Chen et al., 2018). Hettler investigated students' performance and their TBL experience on the basis of different demographic factors such as age, gender, ethnicity and socioeconomic status in an economics course at a USA institution including 574 students (Hettler, 2015), and they found very few differences with regards to the impact of gender performance between TBL and traditional teaching modes. Performance after TBL was fairly similar among gender groups, with no statistical difference observed (p-value > 0.100). Similar conclusions were drawn by Ganguly et al., who examined the relationship between team composition (i.e., gender, age, ethnicity and socioeconomic status) and TBL outcomes in a first-year medical cohort at a USA medical school (Ganguly et al., 2019). Quantitative analysis indicated that racial diversity was in this case the most significantly associated factor with TBL outcomes (p-value < 0.05).

Despite the educational benefits of social learning that are prompted in TBL, Peters et al. considered that intensive team-based learning environments could become a possible threat to women students in a longitudinal, large scale study that incorporated five years of feedback surveys, focus groups and reflections from staff and students (Peters, Direito, Roach, & Tilley, 2019). However, those fears were mitigated after finding that final year students, regardless of gender, considered team-based activities to be the most beneficial learning experiences during their engineering courses, with team-based problem-solving becoming more enjoyable for female students than initially anticipated.

Although the demographics and subjects are visibly different across these studies, it becomes clear that there is a lack of rigorous learning framework to explain the wide spectrum of observed differences and interactions in TBL classes. More studies are needed that specifically focus on the framing of the TBL methodology within the individual and social factors that shape the attitudes of both teachers and students towards it (Thompson et al., 2015), particularly in the area of engineering education where literature is extremely scarce. In this regard, and to the best of the authors' knowledge, no empirical studies have been published that relate gender factors and the wider social learning context to the effectiveness of teamworking skills development in TBL. Herein, we report for the first time an empirical case study on a large, diverse engineering cohort to evaluate the following research question: *Does implementing the team-based learning (TBL) model promote consistent perceived team performance, individual adjustment and decision-making abilities across genders in a process engineering class?*

METHODOLOGY

Participants

Data for this case study were collected from a year-3 cohort of engineering students at a large UK university.

Table 1 Demographic characteristics of the sample group

Characteristic	Category	Number of students
Gender	Male	61
	Female	26
	Non-binary	0
Ethnicity	White	47
	Asian	30
	Black	4
	Arab	4
	Other	4

All the participants were enrolled in a 10 UK-credit process engineering module, which was delivered following the TBL methodology. Following the suggestions from Takeda et al. (2014), 24 permanent teams of five to seven students were created

ensuring there was a balance of genders, usually 30% - 40% of female students in each team, whilst also ensuring there was a similar level of cognitive abilities based on the individuals' year-2 course averages (Baughman, Hassall, & Xu, 2019; Takeda & Homberg, 2014). The main demographic characteristics of the students in the sample group are summarised in Table 1.

Data Collection

This case study was designed taking a quantitative methodology approach to address the question *Does implementing the team-based learning (TBL) model promote consistent perceived team performance, individual adjustment and decision-making abilities across genders in a process engineering class?* After completing the TBL module, *Web-PA* - a digital platform developed at Loughborough and Hull Universities (United Kingdom)- was used to create a peer-assessment questionnaire to measure the perception of students on their peers' teamworking abilities. The questionnaire was constructed based on comparative ratings on perceptions, containing three items aimed at rating the performance, the adjustment and support, and the decision-making competencies of individual students within their teams. A 5-point Likert-scale was used ('1' meaning 'very strongly disagree' and '5' meaning 'very strongly agree') and we incorporated three questions:

Question 1 (Q1): *Student X effectively fulfilled their peer role during the team-tests (tRAT) and application exercises, and their performance met my expectations*

Question 2 (Q2): *Student X adjusted their way of working to actively support other fellow team members during the team-tests (tRAT) and application exercises*

Question 3 (Q3): *Student X actively participated in team decision-making during the team-tests (tRAT) and application exercises*

Individuals were asked to answer to Q1, Q2 and Q3 above for each of their team peers but were not allowed to assess themselves in order to minimise bias on their responses. The questions were designed to guide the student's behaviours during TBL, and the responses were used to generate a weighting factor that was applied over the tRAT scores to prompt students to engage with their teams. The questionnaire was reviewed and approved by the Faculty ethics committee for dissemination of results. All participants were informed of the purpose of the questionnaire and were emailed the link to the peer-assessment questionnaire. Students were given one month to complete it and received three reminders during that time. Furthermore, they signed consent forms as the first question on the survey, and they were allowed to remove their data from the study at a later date if they wished to do so. 88 students submitted their answers and all of them answered the three questions.

Data Analysis

Data for each of the three questions were normalised to gain an insight into how scattered the peer perceptions were within their respective teams. Using this metric, students who are perceived to overperform at teamworking skills get a normalised score above 1, whereas students who are perceived to underperform

obtain a normalised score below. The normalisation procedure was performed using (1):

$$X_i = \frac{\bar{x}_{individual,i}}{\bar{x}_{team,i}} \qquad (1)$$

where X_i is the normalised score for an individual student in question *i*, $\bar{x}_{individual,i}$ is the average rating of such individual student in question *i* awarded by their peers, and $\bar{x}_{team,i}$ is the average score of the whole team in question *i* based on all the team member responses.

The descriptive and inferential statistical analyses were performed using IBM SPSS Statistics version 25. Normalised data were entered into the software to compute descriptive statistics, including means, standard deviations, minimum and maximum values.

Building upon the social-constructivist learning framework, knowledge and skills in TBL classes are socially constructed, with students approaching their teammates showing a set of behaviours completely different to those observed in lecture-based classes (Au, 1998). Therefore, we hypothesise that any potential differences in the development of teamworking skills between female and male students could be minimised, and the following hypotheses selected as null hypotheses, are proposed:

Hypothesis 1: *TBL does not develop significant perceived differences in individuals' performance between male and female process engineering students during teamwork activities.*

Hypothesis 2: *TBL does not develop significant perceived differences in individuals' work adjustment and support between male and female process engineering students during teamwork activities.*

Hypothesis 3: *TBL does not develop significant perceived differences in individuals' decision-making processes between male and female process engineering students during teamwork activities.*

Due to the categorical nature of the data and the data not complying with parametric assumptions (normally distributed data and homogeneity of variances), the non-parametric Mann-Whitney U test was used to compare the mean ranks from the two data categories (males and females). The null hypothesis in this statistical test is that the mean ranks of the two categories are the same. The test statistics U was used to compare the number of times a score from a population category (U_1) ranked higher than a score from a second category (U_2), as defined in (2)-(3):

$$U_1 = N_1N_2 + \frac{N_1(N_1+1)}{2} - R_1 \quad (2)$$

$$U_2 = N_1N_2 + \frac{N_2(N_2+1)}{2} - R_2 \quad (3)$$

where N_1 and N_2 represent the sizes of categories 1 and 2, and R_1 and R_2 represent the sum of the ranks in each category. The U statistics was computed as $U = \min(U_1, U_2)$ and the resulting value compared with the tabulated critical value of U at a 95% level of confidence for the categories' sizes (N_1 and N_2). Null hypotheses were rejected where *p*-values were found to be less than 0.05 (i.e., 95% level of confidence). Cronbach's α for the questionnaire items in this study was 0.973, therefore indicating a good reliability of the questionnaire scales to correctly measure the intended outcomes from Q1, Q2 and Q3, above.

RESULTS AND DISCUSSION

Table 2 presents the descriptive statistics for this case study including the mean, standard deviation, and minimum and maximum values for each of the questions across the male and female categories. The means across both genders have a consistent value of 1, which indicates that on average, peers within the same team were perceived to equally achieve adjustment and support, decision-making and performance skills. Nevertheless, the standard deviations for females are lower compared to their male counterparts, which suggests that the perceptions of development of teamwork abilities on males are more heterogeneous. The lowest score (0.25) was found across the male cohort whilst maximum scores above 1.24 were achieved by both genders.

Table 2 - Descriptive statistics of the answers to the questionnaire based on normalised X_I values

Gender	Q1: Performance in team	Q2: Adjustment & Support	Q3: Decision-making
Male			
Mean	1.01	1.00	1.00
SD[a]	0.15	0.15	0.15
Minimum	0.25	0.25	0.25
Maximum	1.28	1.28	1.30
Female			
Mean	1.00	1.00	1.01
SD[a]	0.10	0.0	0.10
Minimum	0.74	0.78	0.78
Maximum	1.26	1.24	1.28

SD[a]: Standard Deviation

The inferential statistical analysis based on the Mann-Whitney test was carried out to identify whether the normalised questionnaire scores were consistent across genders. For hypothesis 1, the Mann-Whitney U test showed that there is not a

significant difference (U = 1620.5, *p*-value = 0.230) between male and female students on perceived individuals' performance during TBL teamwork activities – i.e., tRAT and tAPP –. Therefore, hypothesis 1 was accepted. For hypothesis 2, no significant difference was found (U = 1552.5, *p*-value = 0.128) between male and female students on perceived individuals' adjustment and support during such teamwork activities. Therefore, hypothesis 2 was also accepted. For hypothesis 3, no significant difference was found (U = 1718.0, *p*–value = 0.463) between male and female students on perceptions of decision-making during TBL teamwork activities. Thus, hypothesis 3 was also accepted.

Drawing on the principles of the social-constructivism learning theory on which TBL is grounded (Vygotsky, 1980), educators have the role of facilitating the learning process rather than simply transmitting information, and this drives students to construct their learning together with their teammates in a unique social setting that facilitates collaborative decisions underpinned by conflicting data, resources and opinions during authentic teamwork activities. Based on this framework, gender was hypothesised to be a demographic characteristic that should not promote a significant advantage towards the development of teamworking skills, and this has been corroborated by our inferential test. TBL appears to have no significant impact on favouring the promotion of teamworking skills in particular gender groups, at least under the conditions of our case study where students were allocated in gender-balanced groups.

Our findings are aligned with recent, large-sized samples research on gender and performance in TBL modules (Ganguly et al., 2019; Hettler, 2015) and in other active collaborative learning settings (Lorenzo, Crouch, & Mazur, 2006) and prove that the suggestions for different interaction modes merely based on gender differences are perhaps to be revised to advance towards a more inclusive TBL model (Cortright et al., 2013; Harakuni et al., 2015; Wehrwein et al., 2007).

Whilst academic performance and development of teamworking skills can be mutually exclusive (García-Martín, Pérez-Martínez, & Sierra-Alonso, 2015), social learning remains a cornerstone for effective learning in science and engineering (Smith et al., 2009). Interacting with teammates during the learning process that takes place in group-based tasks helps students not only to get timely feedback from their peers but also to develop metacognitive skills through their critique of others' reasoning, and collaborative and teamworking skills (C. Wieman, 2019). Our case study illustrates the importance of such social context to promote inclusive development of teamworking skills.

However, it is important to recognise the inherent limitations of this case study. We anticipate that the heterogeneous background of the students in UK universities brings up a unique social context to the class. Generalisability of the main results may then be limited to similar cohorts of engineering students for whom teams have been deliberately made up to balance genders and ethnicities. Moreover, our sample group was introduced to a teamwork role-based test (i.e., the Belbin's test) before starting the module and this could have potentially led to better teamwork practice in some cases. Students at that stage have had some experience at working together to identify engineering problems and constraints, as well as at making decisions.

The development of rigorous methodological approaches to investigate the social context of TBL, especially in the area of engineering education is still underway, and it is hoped that these approaches will continue to shape the evolution of an inclusive TBL model and consequently, benefit higher education engineering institutions in providing more global and inclusive learning experience models to respond to the 21st century skills requirements of industries, governments and businesses.

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