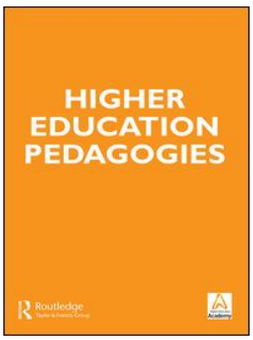

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Higher Education Pedagogies

ISSN: (Print) 2375-2696 (Online) Journal homepage: https://www.tandfonline.com/loi/rhep20

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To cite this article: Matthew Greetham & Kate Ippolito (2018) Instilling collaborative and reflective practice in engineers: using a team-based learning strategy to prepare students for working in project teams, Higher Education Pedagogies, 3:1, 510-521

To link to this article: https://doi.org/10.1080/23752696.2018.1468224

Published online: 13 Oct 2018.

HIGHER EDUCATION PEDAGOGIES
2018, VOL. 3, NO. 1, 510–521
https://doi.org/10.1080/23752696.2018.1468224

Higher Education Academy
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ARTICLE

Instilling collaborative and reflective practice in engineers: using a team-based learning strategy to prepare students for working in project teams

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ABSTRACT

This case study from the Civil and Environmental Engineering department of a UK university presents an educational design that uses team-based learning (TBL) to prepare students prior to undertaking a group project. Our aim is to show how the established TBL approach can be used in a novel way as a precursor to a group project to improve the achievement of learning outcomes. The purpose of the TBL was to ensure pre-reading was completed, to instil a sense of subject matter mastery, to allow students to discuss complex issues and to develop collaborative and inclusive behaviours. These skills and knowledge were necessary to successfully complete the follow-on group project and importantly for success in their future careers. Student's end of module reflective statements indicated that they positively collaborated and communicated when working on a group project.

ARTICLE HISTORY
Received 2 June 2017
Revised 20 October 2017
Accepted 9 April 2018

KEYWORDS
Employability; team-based learning; collaboration; civil engineering; reflective practice

Introduction

Civil engineers build, maintain and operate infrastructure assets, such as roads and bridges that support the effective functioning of society. In order to do this they understand the forces that act on these assets and how the construction materials respond to these forces. These fundamental concerns lead to design decisions, which are further influenced by financial, social and environmental factors. In addition, to achieve these aims requires the cooperation and coordination of many stakeholders from across society, government, the engineering companies themselves and their supply chain. The wide array of knowledge and skills necessary to complete such complex tasks means that civil engineers must fulfil a number of roles from project managers that have a surface understanding of broad areas to the specialist with a deep knowledge in a particular technical niche. The educational design of civil engineering degree programmes mirrors this need. Students are required to have a foundation of technical knowledge alongside collaborative working and communication skills so they are ready to enter and thrive in the profession. This paper sets out a case study of an educational design that uses the team-based learning (TBL) (Michaelsen, Parmelee,

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McMahon, & Levine, 2008) approach as an effective means to develop students' technical knowledge and collaborative working skills needed to complete a subsequent group project.

The organisational and historical context

Civil engineering master's degree programmes are typically based on the core technical disciplines underpinned by technical skills, such as mathematics. Students are taught the fundamental principles of, for example, mechanics of materials and apply this knowledge to design an asset. Following the design stage in a typical engineering project lifecycle are the procurements and construction stages. These stages require an understanding of commercial or professional fields of knowledge that are often less well served in degree programmes.

This case study focuses on the *Construction Week* module that, along with three other modules within the four year MEng in Civil Engineering, supports development of professional skills. The module *Professional Engineering Practice* precedes *Construction Week* and seeks to develop the students' independent research and critical thinking skills. The *Business and Project Management* module follows and is designed around the concept of risk management and further develops the students' knowledge of civil engineering contracting practice in preparation for *Constructionarium,* where the students work in teams to actually construct a physical asset, such as a tower or a bridge.

The *Construction Week* module was initially developed with a major Civil Engineering contractor and emphasised the commercial aspects of construction. Based on student feedback the aims were expanded specifically to:

(1) Gain knowledge related to

- Commercial aspects of the civil engineering contracting industry
- Management of risks on construction sites specifically focusing on health and safety management
- Social and environmental sustainability impacts of construction
- Project management planning

(2) Improve their skills related to

- Managing inter-personal aspects of team work
- Critical thinking and independent research
- Written communication

(3) Start to deliberately reflect on the behaviours of themselves and others related to

- Collaboration
- Inclusivity

During *Construction Week* students work in teams to develop a *Response to Tender* (RTT) to provide a service to the main contractor for the transport and disposal of

material excavated from a tunnel. The *Invitation To Tender* documentation and process of briefing the teams is identical to engineering practice. Students are not expected to cost their RTT but only to complete the quality submission, that is, they provide a construction method with a risk assessment and a health and safety plan whilst highlighting the social and environmental benefits their solution could bring to the project. The module runs full-time for five days at the end of the first year. The first two days of the module are taught using TBL. Each TBL session was led by a subject matter expert and a teaching assistant that managed 12 teams of seven or eight students. Student teams then work autonomously for the remaining three days.

The module is assessed by (1) performance of the team in TBL sessions (20%); (2) an Interim team report that focuses on the management of the project (10%); (3) final team report (50%); and (4) a personal reflective statement (20%). The students receive individual marks based on their personal reflective statements and the final report. Teams were asked to submit a form signed by everybody quantifying each person's contribution to the final report. If they agreed everyone made an equal contribution, that is, five students in the team all contributed 20%, they received the same mark. If the team agreed that an individual made a contribution that was 5–10% more than the majority that student's mark for the final report was increased by 5%, and visa versa. A contribution of more than 10% up-lifted their mark by 10%. This provided the team with a performance management mechanism and the students showed no difficulty with assigning these weightings. The majority of the teams submitted equal weighting, and no complaints were received from students that received lower contribution ratings.

Theoretical underpinnings

TBL is a teaching strategy that offers the benefits of small group learning within large classes by creating opportunities for students to apply their conceptual knowledge through a systematic process of preparatory work, individual assessment, teamwork and immediate feedback (Michaelsen, Parmelee, McMahon, & Levine, 2008). Introduced by Michaelsen in the 1970s, TBL has been gaining popularity predominantly in health professions education (Parmelee, Michaelsen, Cook, & Hudes, 2012), and to a lesser extent in STEM subjects, such as engineering (Najdanovic-Visak, 2017), Physics (Parappilly, Schmidt, & De Ritter, 2015) and Biology (Imperial College London, 2017). Much literature in this area cites a specific benefit of TBL as being enhanced assessment outcomes when compared to other teaching methods, particularly lectures (Behling, Kim, Gentile, & Lopez, 2017; Thomas & Bowen, 2011; Vasan, DeFouw, & Compton, 2011), with greatest impact being for the lowest performing students (Koles, Stolfi, Borges, Nelson, & Parmelee, 2010; Nieder, Parmelee, Stolfi, & Hudes, 2005). Behling et al., (2017) highlight the ongoing, formative impact TBL has on enabling learners to identify gaps in their knowledge and improve their understanding. Further, Belske et al., (2016) report that 'Learning outcomes and student confidence in performing higher-order tasks were significantly higher with TBL (2016, p. 120). Other studies cite high engagement (Haidet, O'Malley, & Richards, 2002) and positive feedback from learners (Parmelee et al., 2012; Zgheib, Simaan, & Sabra, 2010) and faculty (Conway, Johnson, & Ripley, 2010). Of particular significance to our context are findings that TBL has a positive influence on the way that students perceive the value of contributing to teamwork and collective learning (Koles, Nelson, Stolfi, Parmelee, & DeStephen, 2005;

Vasan et al., 2011). Limitations include concerns over TBL's lack of impact on long-term knowledge retention (Emke, Butler, & Larsen, 2016) and conclusions that, depending on the desired learning outcomes, teaching methods, such as Case-based Group Discussion (CBGD) and Problem-based Learning (PBL) may be more effective choices (Dolmans, Michaelsen, van Merriënboer, & van der Vleuten, 2014; Koles et al., 2005). TBL is an example of *active learning*, a process understood to have a positive impact on student outcomes, including retention, when compared with traditional lecturing (Freeman et al., 2014). Its main aim is to shift the emphasis of learning from a process of familiarising learners with concepts, to enable them to use those concepts to solve complex problems as a team (Michaelsen & Sweet, 2008). As educators we know that developing students' capacity to solve problems and to work effectively in teams is challenging for students and staff but that these attributes are key to equipping graduates to take on 21st century problems. When considering employability, complex problem solving heads up the 'Top 10 Skills for 2020' identified by the World Economic Forum (Gray, 2016) along with coordinating others, emotional intelligence and negotiation. These are skills that TBL supports the development of, as we shall see. Furthermore, and of importance, when critically reviewing the balance of learning outcomes within STEM curricula, the World Economic Forum (2016) report that:

> '[o]verall, social skills – such as persuasion, emotional intelligence and teaching others – will be in higher demand across industries than narrow technical skills, such as programming or equipment operation and control. In essence, technical skills will need to be supplemented with strong social and collaboration skills.' (World Economic Forum, 2016, p. 3)

The TBL process comprises three main phases. The preparatory phase typically involves students independently studying pre-reading and/or instructional videos. This is designed to introduce them to the concepts they need to be familiar with in order to participate in subsequent stages and works like a flipped classroom, freeing up the face-to-face session for student interaction.

In the second phase, each student completes a multiple choice question (MCQ) test termed the individual readiness assurance test (iRAT) based on the pre-reading. This reassures the learner that their preparation is helping them to learn key concepts and achieve learning goals (Parmelee et al., 2012). This is followed by a team readiness assurance test (tRAT) where the entire team collaborate to answer the same set of MCQs. The team check their answers using the immediate feedback assessment technique (IF-AT) (Parmelee et al., 2012) that makes use of a scratch card to reveal the correct answer. This stage of the process enables peer teaching and learning through the sharing of knowledge and understanding between team members and motivates through competing with other teams (Najdanovic-Visak, 2017). After the tRAT the teacher has the opportunity to clarify any misunderstandings.

The final phase is the team application (tAPP) exercise where team members work together to apply, and hence reinforce, the concepts they have grappled with in earlier phases to solve more involved problems. Parmelee et al. (2012) state that tAPPs should follow the 4 S's principle: problems should be *significant* – worthwhile and motivating for teams to solve. The questions should be the *same* for all teams so they have an interest in other teams' responses and justifications. The team must decide on a *specific* choice from multiple possible answers achieved through discussion, justification and persuading of teammates as to the correct choice. All teams present their decisions

simultaneously and subsequently the teacher addresses any misunderstandings. The students can challenge and negotiate 'correct' answers through an appeals process following both the tRAT and tAPP stages (Parmelee et al., 2012).

In terms of educational theory, TBL works by harnessing a combination of learning processes and sources of learner motivation. This includes behaviourist drivers, such as being rewarded for carrying out preparatory tasks and for contributing to successful team decisions. It aligns with constructivist perspectives, such as learners being enabled to 'compare their current understandings with those of the group . . .integrating information obtained by new experiences into existing mental schemes' (Hrynchak & Batty, 2012, p. 799) and to critically reflect on their experience. TBL also incorporates social constructivist approaches as learners develop collective strategies for solving real problems through negotiation and critical reasoning with peers (Hrynchak & Batty, 2012) and as they challenge teacher perspectives through the appeal process.

Strategic rationale

The previous version of the module was a full day programme of lectures followed by a series of timetabled workshop sessions facilitated by industry practitioners. At the workshops students worked in groups on essentially the same main technical task as this case study and verbally presented the results to an expert panel at the end of the five day period. On reviewing the module we felt that students needed more scaffolding to help them to apply their existing analytical skills to this new area and an incentive to complete the pre-reading.

The TBL approach expects that the students come to the class having completed the pre-reading so they can tackle the iRAT and tRAT. This case study used selected sections from Institution of Civil Engineers (2016) as it contains relevant material written at an appropriate level. It was felt that students would more actively process the material through independent study rather than being lectured to, and this was illustrated through the tRAT scores. An example iRAT/tRAT question is given below.

> The risks to the successful completion of a project are 'owned' by or allocated to those best able to manage them. Who is most likely to own the risk of the project being delayed due to failure of plant or equipment?
>
> (a) Promoter
> (b) Contractor
> (c) Project Manager
> (d) All of the above

TBL was chosen primarily because of its potential to develop cohesive teams, which would go on to successfully collaborate on a group project. The benefits of students developing effective team working approaches, particularly for enhancing their employability and graduate success, are well recognised (Yorke & Harvey, 2005). Although most university curricula include the requirement to work in teams, educational strategies, such as TBL can be used to better engender cooperative team working and to avoid common issues, such as unequal contribution and freeloading (Maiden & Perry, 2011). With TBL we have found that the IF-AT have a crucial impact on cooperation and contribution for two reasons. First, the IF-AT scratch card provides

the team with immediate feedback on the correct tRAT answer, enabling them to assess their team response and creating an incentive to complete the pre-reading. Second, immediate feedback also dramatically affects team dynamics. For example, we have seen more naturally dominant individuals moderate their behaviours and seek the contributions of others when they see that their iRAT responses do not correspond with the correct answer. Similarly, less vocal members become more assertive when it is apparent that other team members may not have the correct answers. In this way we have observed that team members surprisingly quickly develop an increasing sense of ownership and responsibility for the outcomes of the team. It is these behaviours we wanted to instil in the students to enhance cooperation in the follow-on task and subsequently in their professional life.

Another important goal of TBL 'is to equip groups to succeed by populating them with members who will bring different perspectives to the task' (Michaelsen & Sweet, 2008, p. 10). For this reason our teams were not self-selected and were a mix of academic ability, gender and nationality. This, along with the transparency around team member contribution generated by the IF-AT, creates opportunity to genuinely challenge preconceptions that students have about each other's ability to contribute. In turn, this can promote more inclusive team working that values and draws strength from difference.

The confidence the students gain in their knowledge through the tRAT carries forward into the tAPP process. The importance of the tAPP is that the students are introduced to real world civil engineering problems whose best solution is often highly dependent on the context. As an example, in one of the questions the team must decide on the form of contract to use for a project that is seeking to balance completion time and uncertainty relating to cost and technical engineering problems.

The students experience the anxiety associated with making decisions in an uncertain world in the secure environment of the workshop session, facilitated by a subject matter expert. The subject matter expert can discuss with them after both the tRAT and tAPP stages how answers aren't always black and white and whether their opinions are justifiable. This further allows the facilitator to reiterate key learning points the students need for the follow-on task. Because students get immediate feedback on their thinking the extraneous load caused by the lack of a certain answer is reduced (van Merrienboer & Sweller, 2010). These phases enable students to develop a sense of subject matter mastery and this carries forward into the main technical task where the students appear far more confident and assured in presenting and justifying their opinions.

When compared to non-TBL sessions where teams may remain non-committal, in TBL accountability is emphasised because every team must reveal their tAPP answers simultaneously (Parmelee et al., 2012) and any team member could be selected to explain the rationale for their team's answer. This ensures a sustained and broad contribution across the team throughout the session. The appeals process further instils in the student the process of justifying their rationale and challenging orthodoxy.

Practical implementation issues

In this case study, each of the two TBL sessions lasted two hours and included 10 iRAT/tRAT questions and two tAPP questions. As part of our commitment to inclusive

practice the pre-reading was provided in the week before the module and a slot for the students to complete it was included in the timetable. The slot was of sufficient length for an average reader to complete the pre-reading and review their comprehension, that is, the formal class started at 11:00 am with a 09:30–11:00 slot timetabled for the pre-reading of about 15,000 words. The syllabus necessary to complete the follow-on project task was covered by two sets of pre-reading and hence only two TBL sessions were used.

It is beneficial to have a well-sized room with audio–visual equipment for this class of 96 students . The team size of seven or eight was at the upper limit; any greater and teams' cohesiveness starts to break down. Also the larger the team, the more likely it is that somebody will know the answer to the tRAT questions and getting answers wrong seems to be beneficial to developing the team dynamic as set out earlier. Similarly, the opposite may be the case if the teams are too small.

Achieving the learning outcomes and module evaluation

As a part of the coursework submission for the main technical task, each student was required to submit a reflective statement. The extract from the module documentation states that:

> 'The personal reflective… should be approximately 200 words in length and cover your thoughts on how your team managed the task.
>
> Specifically the personal reflective statement should include;
>
> (1) What worked well in terms of organisation, communication and project management?
> (2) How you might organise and manage the task differently if you were asked to repeat it.'

Reflective statements were summatively assessed based on how insightful they were with respect to the behaviours of the group and how they organised the project. As the statements were assessed and the students in each group could read each other's peer feedback comments it should be recognised that these statements may not be an entirely reliable record of their thoughts and actions. They may be influenced by what they thought the assessor wanted to read and concerns regarding their colleagues' reactions. We accepted these limitations as the aim was to encourage students to deliberately reflect on their own behaviours and those around them, even if their written statements were cautious or based on hypothetical or even fictional events. By asking for a written statement it was hoped to encourage them to process these reflections on a deeper level.

The statements also provided staff with useful qualitative data on the problems students encountered when managing the project that could be fed-forward and unpacked in the proceeding module covering project management. The three main themes identified from the first year of this case study (alongside quotes from the reflective statements to give resonance) were:

Leadership and management. As one student wrote:

> '…however it could have been more useful if we elected a definite project leader to be a central point of contact.'

Meetings and collaborative tools. As another student wrote:

> '…However, there are still improvements we could make. For example, we could have a routine meeting every day other than group discussions using online chatting app which is inefficient and unorganised.'

Work breakdown structures and tasking. And from another:

> '…Due to having multiple subgroups working on the same deliverable, a miscommunication, such as the method of material storage, can cause delays due to the dependence on each other's work.'

In order to quantitatively analyse the students' learning from this module reflective statements of six of the 12 groups were randomly selected for post-content analysis (46 students from the year group of 96) based on Cohen, Manion, and Morrison (2011). The sentence was taken as the unit of analysis, where a related sentence enhanced the meaning of the sentence being coded it was taken into consideration. Each sentence was tagged for each relevant analysis category shown on Table 1 and additionally whether the statement was positive, negative or neutral. On average there were 8.7 units of analysis per student and each unit was tagged to 2.8 codes.

As previously stated, TBL was intended to provide students with initial scaffolding for understanding the technical elements of the main project task and to encourage collaborative behaviours. This was expected to reduce the extraneous load in the main technical task, increase student satisfaction, enhance learning in technical areas and instil positive group behaviours.

The analysis of the content of the personal reflective statements showed that the students were positive about how their group approached the task. In the content analysis 55% of the units were coded as positive, 24% as neutral and 21% as negative. This result was not uniform across all groups. The proportion of positive comments ranged from 42% to 74%. The least positive group was not overly

Table 1. Categories and category clusters identified from post-content analysis of students' personal reflective statements.

Cluster: Working together
Collaboration
Face-to-face meetings
Individual behaviours
Individual capability and interest
Individual contribution
Individual development and learning
Leadership
Stress and anxiety
Understanding the role of others
Cluster: Working processes
Baselines and plan revisions
Collaborative tools
Communication
Deliverables and deadlines
Delivering a quality report
Documentation and specification
Initial brainstorming and understanding the task
Tasking – roles and responsibilities
Team productivity
Work breakdown structure
Cluster: Module design and organisation
Course organisation
Link to professional practice

negative (27% against cohort average of 21%) but their statements tended to be neutral statements regarding the processes they followed. The reflective statements revealed that many students of one team felt one member was not contributing adequately. This team did make use of the performance management mechanism by highlighting the individual's reduced contribution but this seemed only to dissipate negative feelings into neutral ones rather than create positive ones.

Table 2 shows the proportion of units coded against the most frequent categories. It can be seen that of the 845 units analysed 161 were coded for collaboration (19%). This suggests that the students were aware that collaboration with their colleagues was an important part of the process.

Figure 1 shows the proportion of units in the categories in Table 2 coded as positive or negative. This figure may reveal the elements of the module that the students were most prepared for. It can be seen that more than 60% of the units coded to Collaboration, Productivity, Communication and Collaboration tools were expressed positively. This could indicate how well the TBL process orientated the students towards functioning as an effective team. The relatively negative view of face-to-face meetings was generally attributed to not having enough meetings rather the behaviour of team members at these meetings. The following quotes taken from students' reflective statements indicate effective, collaborative team working:

> '…There were no imposed tasks and we found that people naturally teamed up to spread the tasks and when they were done they walked around to see what the others were up to and where more help was needed.'

> '…All work completed was shared with the group using Google Drive, which made for improved overall organisation and quick access to documents.'

> '…Working as a team helped me to fill up the gaps in my knowledge, as well as the areas of content that I did not grasp very well, my team members were stronger at, and vice versa.'

The other categories shown on Figure 1 that were considered less favourably related to how the team broke down the task and assigned it to members. Project management processes and techniques related to managing these were not taught in this module. Indeed, it was hoped that students would experience these difficulties so they understand the need for such processes and techniques when they are taught in the following year.

Importantly, no student recorded in their reflective statement any concerns regarding the uncertain nature of the problem they were tasked with. It is hoped that this is

Table 2. Proportion of units of analysis against category code (top 10).

Category code	% of units coded for category
Collaboration	19
Tasking – roles and responsibilities	14
Team productivity	13
Work breakdown structure	10
Delivering a quality report	7
Communication	6
Collaborative tools	4
Initial brainstorming and understanding the task	4
Deliverables and deadlines	3
Face-to-face meetings	3

Total number of coded units in analysis = 845.

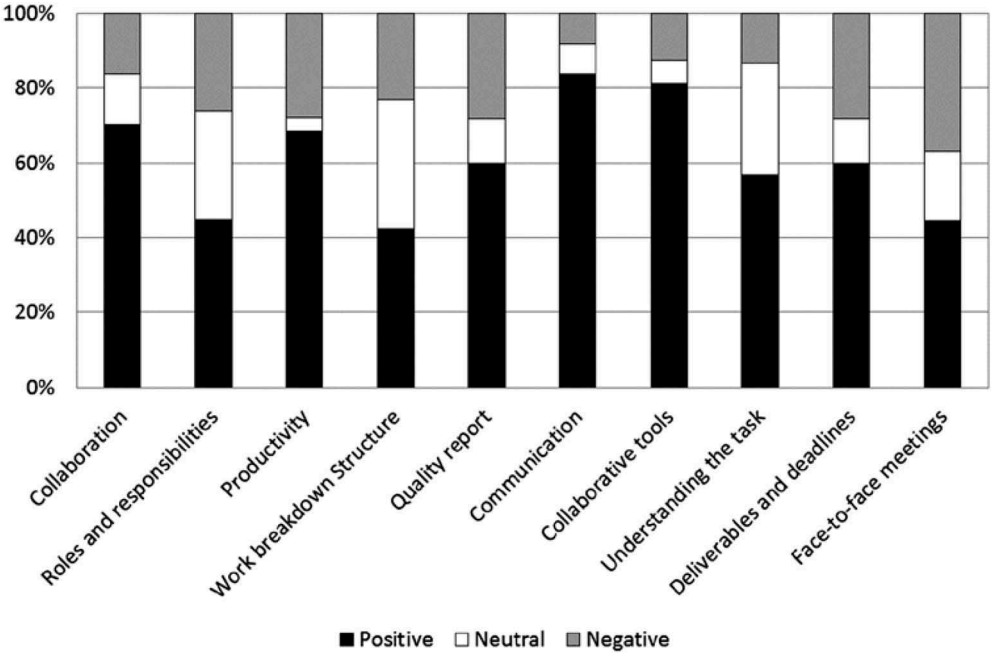

Figure 1. Proportion of units coded by category as either positive, neutral or negative.

attributed to having experienced such dilemmas in the tAPP and being reassured at this time. As previously acknowledged, however, the lack of anonymity may have made students reticent to be openly critical. The following student's reflective statement explicitly identifies the value of TBL:

> '...The ability to work in a group is essential in the professional world and especially in projects with an important stake. I believe that the key for a good group project is speaking. All the teammates have to give their opinion for a decision to move forward. It will also avoid any conflicts. This is what I realized during the TBL sessions...'

Conclusion

Civil engineers fulfil a number of roles from project managers to technical specialists and each role is based on a foundation of core technical knowledge alongside collaborative working and communication skills. University education prepares students for professional life using a mix of strategies, including working in teams, to formulate engineering solutions.

Based on our experience we believe that TBL can be used to maximise the learning gain from subsequent project-based group work. TBL can instil a sense of subject mastery through the pre-reading, readiness assessment and tAPP phases. TBL can also engender more positive team dynamics through the immediate feedback process. This feedback can also support learners in managing uncertainty that exists in all real world problems.

The students were positive about this application of TBL and were able to transfer the knowledge and behaviours developed forward into the main technical task. An

analysis of their reflections on the module revealed that they were positive about how they collaborated, communicated and their productivity as a result. These skills will be further developed and reinforced throughout their degree course and, it is hoped, into their professional careers.

Disclosure statement

No potential conflict of interest was reported by the authors.

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