Exploring Team-Based Learning in a Year 1 Programming Module

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In Singapore's polytechnics, a sector-wide transition to Flipped Learning is being implemented to foster students' self-directed learning abilities. Central to this approach are Online Asynchronous Lessons (OAL), where students engage with pre-reading materials to familiarise themselves with key concepts before attending face-to-face classes (In-Person Lessons, IPL). During these in-person sessions, students seek clarification and delve into more complex ideas.

This paper explores the integration of Team-Based Learning (TBL) within the Flipped Learning framework for a Year 1 common engineering module, Programming, at Ngee Ann Polytechnic during the Academic Year 2024/25 Semester 1. As part of OAL, students complete an Individual Readiness Assurance Test (iRAT), which is then followed by a Team Readiness Assurance Test (tRAT) during IPL. After discussion and completion of tRAT, a tutor-facilitated review takes place and students embarks on practical exercises in the application phase.

The student cohort comprises 944 individuals from a range of engineering diplomas with diverse academic backgrounds and abilities. The use of TBL leverages on this diversity and enriches discussions, allowing high-achieving students to deepen their understanding by teaching peers, while students with lower abilities gain support in mastering fundamental concepts.

Consistent with existing TBL research, students generally perform better in group tRATs compared to individual iRATs. In addition, preliminary results from our study indicate that more students completed end-of-chapter competency tests earlier in the semester than previous cohort. This suggests that TBL's collective knowledge-building approach facilitates quicker mastery of key topics. Student survey results, along with peer lesson observations by teaching staff reveal mostly positive outcomes, with some areas identified for further improvement. Specifically, the structured preparation and discussion inherent in TBL encourages the sharing of diverse perspectives, fostering deeper, collective learning. However, careful attention to the facilitation of TBL is necessary, as deviations from its core principles may affect outcomes. These challenges will be addressed in future recommendations to refine the pilot implementation.

Keywords: *Team-based Learning, collective knowledge-building, Flipped Learning, Programming, engineering*

Introduction

Conventional educational approaches typically involve direct transmission of curriculum content from teachers to students in classroom settings. This teacher-centric model, characterised by lecture-style delivery can lead to passive learning behaviours, where students rely heavily on explicit teacher instructions regarding what and how to learn. Dudley-Marling (2018), Mason (2021), has demonstrated the limitation of this approach, particularly in developing critical thinking and independent learning skills. In response to these limitations, several studies have advocated for student-centred, active learning strategies.

One such approach is flipped learning, a pedagogical model popularised by Bergmann and Sams (2012). This approach reverses the traditional instructional sequence, by moving initial content delivery outside the classroom through various means including pre-recorded video lectures, allowing students to engage with the material at their preferred pace and revisit complex concepts as needed. Classroom time is then repurposed for higher-order learning activities such as problem-solving exercises, peer discussions, guided practice with lecturers facilitating rather than lecturing. , Research by Keengwe et al. (2014) demonstrated that this restructuring of learning time, fosters deeper engagement and promotes active learning.

Another effective active learning strategy is Team-Based Learning (TBL). TBL is a structured methodology where students complete pre-class preparatory independently, followed by in-class Individual Readiness Assurance Tests (iRATs) and Team Readiness Assurance Tests (tRATs). The teacher then provides targeted clarification addressing specific conceptual gaps identified during the RATs. . Subsequently, students collaborate in teams to solve complex application problems that require higher-order thinking skills. The process often concludes with peer evaluation to encourage individual accountability (Michaelsen, 2008). Although TBL has been predominantly used in medical education, recent research by Parappilly et al. (2021) from Flinders University has demonstrated its successful application across STEMM disciplines (Science, Technology, Engineering, Mathematics, and Medicine).

Studies by Burgess et al. (2019, 2021) have shown that TBL promotes both individual accountability and collaborative learning, learning to enhanced knowledge construction.

Nevertheless, as Johnson (2013) argues, the success of these approaches is significantly dependent on students' intrinsic motivation. Students need to be self-directed during the pre-class preparation phase to prepare for their in-class activities and learning. Lack of preparation can result in reduced participation in discussions, compromised team performance and poorer learning outcomes.

This study examines a pilot implementation that integrates flipped learning and TBL methodologies in a foundational programming module for first-year engineering students at Ngee Ann Polytechnic. The integration of these two pedagogical approaches aims to enhance student engagement through pre-class preparation, deepen understanding through team-based problem-solving, and improve learning outcomes.

Materials and Methods or Pedagogy

Programming is a core module taken by close to 1000 first year engineering students in Ngee Ann Polytechnic. The 15-week module syllabus introduces fundamental programming concepts using the C programming language. The curriculum progresses systematically through key foundational concepts such as variables and data types, advancing to flow control structures with branching and iteration, lastly culminating in function development. This structured sequence helps students to build a strong foundation in computational problem-solving, essential for their engineering careers.

As part of the Flipped Learning pre-class preparation phase, students are expected to acquire foundational content knowledge via Online Asynchronous Lessons (OAL) which comprises of bite-sized instructional videos and structured guided exercises including formative quizzes and short programming tasks. These activities are designed based on experiential learning principles. For example, students engage with quiz questions require them to execute and observe code outputs. This is followed by reflection on the underlying principles, culminating in guided hands-on programming tasks where students apply their understanding. These carefully sequenced OAL activities ensure students arrive at In-Person Lessons (IPL) with foundational knowledge and practical experience that can allow for in depth application of concepts in class .

TBL is infused into Flipped Learning via Feedbackfruits (FBF),a digital learning platform that enables interactive online assessment. In this modified TBL approach, iRATs are incorporated into the pre-class OAL phase, allowing students to demonstrate their understanding immediately after engaging with the OAL content. This adaptation allows for more efficient use of in-class time while maintaining core TBL principle of individual accountability. The TBL learning sequence comprises of four interconnected phases (Figure 2) as follows:

Phase 1: **<u>Individual Preparation Through OAL</u>**
Prior to each face-to-face session, students engage with preparatory materials through OAL.

- Bite-sized instructional videos and simple exercises to introduce core programming concepts.
- iRAT, which is embedded within the Learning Management System (LMS) as part of OAL allows students to self-assess their understanding and identify knowledge gaps.
- FBF analytics on iRAT enable instructors to monitor student engagement and identify common areas of difficulty before the face-to-face session.

Phase 2: **<u>Team-Based Assessment and Collaborative Learning</u>**
Conducted during the IPL, this phase emphasizes on collaborative learning and problem-solving.

- Tutors provide a brief overview and highlight key concepts to focus on, often guided by iRAT performance.
- Students complete the tRAT in pre-assigned teams of 4-5 members, by answering the same conceptual questions from their iRAT. During this process, team members share their individual perspective and reasoning from their individual preparation phase, engaging in structured dialogue to reach consensus on their team's solution.
- The classroom is specially configured with clustered seating arrangements and interactive display screens to facilitate team discussions.
- The FBF platform provides immediate feedback on team responses in tRAT; while incorrect answers incur minor point deductions, teams can discuss and resubmit their answers,promoting deeper analysis and collaborative learning.
- The weightage for the RAT is evenly split, with 50% allocated to the iRAT and 50% to the tRAT.

Figure 1. Groups having discussion during tRAT

Phase 3: **<u>Facilitated Feedback</u>**
Following the tRAT, the tutors facilitate a structured review session to synthesize key learning points and address emerging conceptual challenges. This critical transition phase bridges collaborative team learning with instructor-guided knowledge transfer.

Tutors utilize FBF analytics to identify specific questions that warrant detailed review, based on patterns of student responses from both iRAT and tRAT. TBL process continues with students sharing their team's reasoning and problem-solving approaches to the entire class. This allows tutor to provide targeted feedback. For instance, tutor might highlight cases where different teams arrived at correct solutions through varying approaches or address persistent misconceptions revealed in teams' sharing or through the FBF analytics. This example is further elaborated as follows:

- The tutor uses FBF analytics to plan and focus the class discussion on specific questions.
- Significant learning takes place when:
    - students who initially answered incorrectly in the iRAT but corrected their conceptual understanding during tRAT, and
    - contrasting answers across teams were analysed, enabling knowledge exchange and promoting cross-team learning.
- The tutor provides targeted explanations/feedback and corrects misconceptions based on student's sharing.
- The tutor offers further insights into the topic by building upon student's contributions.

This structured feedback phase facilitates knowledge transfer at multiple levels:

i) through peer collaboration within groups,
ii) cross-pollination of ideas between groups, and
iii) expert guidance from tutors to individual, group or entire class.

Phase 4: **Application**

The TBL learning sequence concludes with an application phase where students demonstrate their understanding through hands-on programming tasks. During IPL, students work on their individual programming exercises that reinforce the concepts covered or relevant components of their ongoing programming projects. When IPL time constraints arise, these practical exercises are assigned as bridging activities, strategically positioned between current IPL and the next OAL, ensuring continuous engagement with programming concepts.

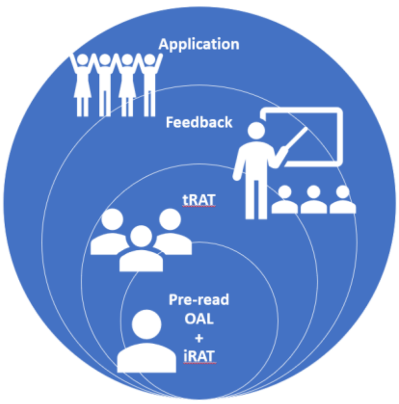

Figure 2. Illustration depicting the 4 phases in a typical TBL

Results and Discussion

Qualitative feedback from tutors indicated increased student participation and deeper collaborative discussions in TBL sessions compared to traditional teaching methods. Tutors consistently reported that TBL support students in clarifying key concepts and facilitated stronger conceptual understanding. Key insights from tutor feedback included:

"*Incorporating TBL highlighted the importance of student-centred learning, encouraging teamwork, and effectively using technology to enhance the learning experience*."

"*Holding students accountable for iRAT and tRAT sets clear expectations and promotes responsibility*."

Students echoed similar sentiments:

"*We can share our own ideas and learn from our mistakes*."

"*The team-based quizzes helped us understand topics better through discussion and peer explanation*."

Students responded positively to the TBL approach, particularly valuing peer-learning opportunities, as some may feel more at ease speaking with peers and able to understand better from their perspective. The survey was conducted anonymously to encourage unbiased responses; however, the sample size was limited, with only 73 students participating, which should be considered a limitation when interpreting the results. Below (Figure 3, 4) shows a pie-chart response from survey open to students.

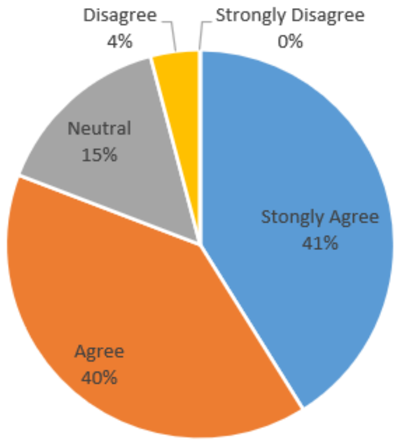

Figure 3. "TBL helped me to obtain a better understanding of the topic"

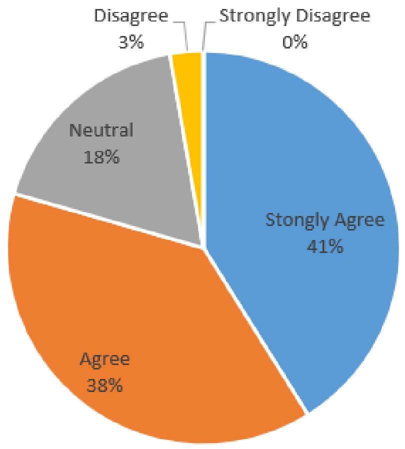

Figure 4. “TBL had a positive impact on my learning experience”

Quantitative analysis revealed consistent improvement in student performance from iRAT to tRAT scores (see Figure 5), suggesting effective knowledge sharing within teams.

Name	Take individual test for 50%	Take team test for 50%	Optional grade adjustment	Pub Brig	Overall grade
38PROG_TE08 - 4	40	46.2			
38PROG_TE08 - 2	38.3	46.2			
38PROG_TE08 - 1	39	47.5			
SIM BOON KIAT NP	45	47.5		✓	92.5 %
CHAN JENSON NP	35	47.5		✓	82.5 %
KELTON LIEW TZE HUA NP	40	47.5		✓	87.5 %
ZOU JINTAO NP	35	47.5		✓	82.5 %
TAN PIK HENG NP	40	47.5		✓	87.5 %
38PROG_TE08 - 3	38.3	50			
ANG CHER MENG JAIRUS NP	50	50		✓	100 %
ALIF ANAQI BIN MOHAMAD ...	35	50		✓	85 %
BASKAR KISHORE NP	25	50		✓	75 %
SYAHRUL ANUAR BIN ALI NP	40	50		✓	90 %
COLLIN REYES VINCENT HA...	40	50		✓	90 %
KARTHIKESAN HARIHARAN ...	40	50		✓	90 %

Figure 5. Students achieving higher/comparable tRAT score than iRAT

Additionally, completion rates for end-of-chapter competency programming tests (Figure 6) showed earlier mastery of core concepts compared to previous cohorts, suggesting that the structured TBL environment enhanced the quality of learning.

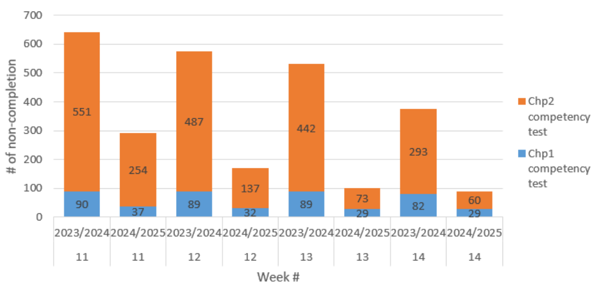

Figure 6. Comparison of non-completion 2023/2024 [before TBL pilot] vs 2024/2025 [TBL pilot year]

While the findings indicate positive outcomes overall, the implementation of TBL also surfaced several challenges:

- **<u>Variability in Class Dynamics</u>**: Observation on some classes revealed varying levels of engagement, with some groups remained reticent despite tutor’s best effort in facilitation. This limited participation affected the quality of peer learning.
- **<u>Insufficient Preparation before IPL</u>**: Students who demonstrated inadequate preparation in Phase 1 were less likely to benefit from subsequent learning phases. This preparation gap created disparities in team contributions and impeded individual learning progression.
- **<u>Learning Approach Preferences</u>**: A minority of students expressed preference for traditional didactic instruction, indicating challenges in adapting self-directed and peer-driven learning methodologies. This resistance has negatively impacted their engagement with collaborative learning activities.
- **<u>Group Dynamics</u>**: Observations revealed imbalanced participation patterns within teams, where more confident students occasionally dominated discussion and decision-making which led to passive acceptance of solution by other team members. This occasionally resulted in group tension, especially when collective decision on tRAT answers turned out to be incorrect.

To address these challenges, implementing a hybrid instructional model offers a promising approach. This model alternates between traditional teaching and active learning weeks, allowing systematic content delivery while creating space for TBL. Instructors should also receive training in discussion facilitation techniques such as wait time management and inclusive questioning strategies, as well as methods for fostering balanced group dynamics and encouraging contributions from all students.

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Conclusions

This pilot study demonstrates the feasibility and potential benefits of integrating flipped learning with Team-Based Learning in a large-scale foundational programming module. The use of iRATs within the OAL framework resulted in learning accountability and engagement during the individual preparation phase. The structured TBL phases promote active participation, peer learning, and conceptual understanding.

However, effective TBL implementation requires careful planning, adaptability, and continued support for both instructors and students. Future work should examine broader application of this hybrid approach in other engineering disciplines, particularly those with similar computational thinking requirements, as well as longitudinal studies to assess the impact on student's problem-solving capabilities, programming proficiency and motivation.

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