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# Hybrid Team-Based Learning-Personalized Education (HTBL-PE)—A New Teaching Strategy to Maximise Success

## ABSTRACT

Epidemiology, a core discipline of public health, requires knowledge and skills for explaining different health outcomes across populations. Students of epidemiology must learn how to apply their knowledge and skills to solve complex and emerging public health problems through assimilating content, independent critical thinking skills, and lifelong learning. In Australian universities student populations are becoming increasingly diverse, including in terms of age range, life experience, previous qualifications, and level of English competency. Therefore, to maximise academic success in epidemiology while catering to students with diverse learning needs, epidemiology academics developed the Hybrid Team-Based Learning and Personalised Education (HTBL-PE) teaching strategy. HTBL-PE systematically builds upon students' capabilities and strengthens self-confidence whilst harnessing team capabilities to strengthen individual capabilities. Student experience of HTBL-PE was formally evaluated at the beginning and end of the epidemiology course. Seventy-three out of 84 enrolled students provided data at both time-points (87%). By the end of the subject, the majority of students indicated their interest in epidemiology had increased (93%), their critical thinking skills had improved (92%), and their confidence as independent learners had increased (86%). Students' final mark, 87%, was significantly higher than their weighted average mark (WAM) of 70% prior to the semester with no failures. HTBL-PE resulted in positive learning outcomes, more self-confidence in learning, increased interest in epidemiology, and higher overall scores. These results indicate HTBL-PE is a simple and effective teaching strategy which systematically supports students to succeed academically whilst building critical, independent lifelong skills and confidence in order to prepare them for solving future public health problems.

## KEYWORDS

Hybrid-Team-Based Learning, personalized-education, public health education, epidemiology education, student-centred learning

## INTRODUCTION

For almost two decades, higher education in Australia and globally have experienced significant changes in student demographics through targeted policies that widen participation as well as higher international student intakes. As students from more backgrounds access university study, diversity becomes evident in areas such as educational attainments, life experience, and English language competency levels, to name a few. It is also common that a mix of students from different degrees undertake similar subjects/courses (Maringe and Sing 2014). The practice of public health and epidemiology, in particular, requires that students acquire rapid assimilation of content which is then applied to emerging scenarios beyond the experience of the practitioner; for example, epidemiology students derived COVID-19 prevention strategies at the beginning of the pandemic. In order for public health practitioners to apply knowledge to different scenarios and populations in order to solve future health challenges, they need to be independent learners and critical thinkers. The ability to effectively communicate and collaborate with other health professionals and the general public are also critical; clear and correct dissemination of public health messages enable more effective translation of interventions to the intended audience. To ensure the sustainability of competent future epidemiologists and public health practitioners graduates should be lifelong learners with an interest in epidemiology (Bennett, Lilley, Yeatman, Parker, Geelhoed, Hanna, and Robinson 2010; Chand, Eio, Alysandratos, Thompson, and Ha 2021).

Given that the primary objective for public health students is to develop the skills to rapidly assimilate content and apply it to the complex problems of the future, epidemiology associate professor (TH) developed a new teaching strategy to better cater to diverse student populations in tertiary education. Solving complex problems not only involves mastery and higher order application of content; it also helps students develop a belief and confidence in themselves, enabling them to achieve more than they think they can.

### Team-Based Learning (TBL) teaching strategy

Team-based learning (TBL) is a teaching strategy with great potential in public health courses, such as epidemiology. TBL has been used since the 1980s when founder Professor Larry Michaelson introduced it in courses for the business school at the University of Oklahoma (Michaelsen and Sweet 2011). The main purpose of TBL is to maintain the interactions and active engagement of small group sizes so that they promote deeper discussion, comprehension, and application of content, even when class sizes are larger. TBL is a student-centric strategy that rapidly takes a student from recall of content to higher order application of content, such as synthesis, application, and evaluation (Adams 2015).

TBL is defined as “an active learning and small group instructional strategy through a sequence of activities that includes individual work, teamwork, and immediate feedback” (Parmelee, Michaelsen, Cook, and Hudes 2012, 275). TBL consists of several chronological phases: out of class pre-readings, individual readiness assessment test, group readiness assessment test, feedback, and application (Gullo, Ha, and Cook 2015; Michaelsen and Sweet 2008). TBL requires a high level of independent learning skills. For students from diverse backgrounds or pathways to tertiary study, prior knowledge of these skills cannot be assumed and should be explicitly taught.

As a student-centric teaching strategy, TBL goes beyond the transfer of content to higher order learning, such as the application of content through problem solving, as in Bloom's taxonomy (Michaelsen et al. 2008). Health and medical educators have modified TBL and used in their courses, especially because of its efficiency in helping students assimilate and apply concepts to complex problem-solving (Alizadeh, Masoomi, Mafinejad, Parmelee, Khalaf, and Norouzi 2024; Attia and Mandour 2023; George 2024; Huang, Zhou, Wei, and Ding 2024; Lin, Tan, and Foong 2023; Matsuda, Falcon, Porter, Royer, Mohnkern, Vergara, and Valiente 2024; Medlinskie, Hill, Tweddell, and Quinn 2024; Murata, Asakawa, Kawamura, Yamauchi, Takahashi, and Henker 2023; Zhang, Wei, Guo, Wang, and Chen 2024).

TBL has been shown to be more effective than traditional didactic lectures. In clinical nutrition students, Alamoudi, Al Shawwa, Gad, and Tekian (2021) observed its efficacy for recall and reasoning (Alamoudi et al. 2021). Students taught using TBL also perceived accountability and teamwork more positively compared with students who received content only via didactic lectures (Alamoudi et al. 2021). Undergraduate nursing courses in India and Thailand used TBL to develop interpersonal skills, to promote active and effective content learning, and to increase overall student performance (Gandhi and Mhaske 2016; Jiratchayaporn and Christraksa 2020). Other disciplines used TBL as the main method of instruction, such as in online business management in the USA (Choi, Slaubaugh, and Tian 2021). In Australia, instructors integrated the learning of interpersonal skills in a masters-level social research methods subject with TBL (Barraket 2005).

Barraket (2005) found that student-centred teaching approaches provided a strong social context for learning and a common experiential framework to explore technical aspects of the curriculum. However, students in Barraket's study placed more value on formal teaching methods, so they derived the value of student-centred techniques more from the way these were amalgamated into more didactic teaching practice. This older study provided a foundation for developing a more systematic, structured, and tailored teaching strategy to strongly scaffold and support students during their educational journey. However, when the study took place, less diversity existed within "traditional" student populations, as the researchers completed the study prior to the implementation of widening participation policies in Australian higher education (Bradley, Noonan, Nugent, and Scales 2008). In the years since, it cannot be assumed that all students, and undergraduate students from diverse backgrounds in particular, have the initial independent learning skills to embark on TBL and fully utilise its potential.

Studies in medical education suggest TBL may be superior for teaching clinical reasoning of complex neurological problems compared with lectures (Ong, Ng, Tan, and Tan 2022). Sim, Myo, and Sohail et al. 2023 also demonstrated that TBL resulted in enhanced student learning and an improved understanding of course topics in undergraduate fifth year medical students on their surgical posting; specifically, TBL helped students in that study achieve learning objectives by encouraging teamwork and discussions. Several studies have found that TBL results in deeper understanding of content (Barraket 2005; Choi et al. 2021), with some students attesting to the transferability of TBL skills to other contexts (Barraket 2005) and reporting a positive student experience and academic achievement well above traditional lectures (Fatmi, Hartling, Hillier, Campbell, and Oswald 2013; Reimschisel, Herring, Huang, and Minor 2017).

In public health education, solving complex problems involves students being able to work effectively in teams. With the support of the team, individuals then develop critical thinking, lifelong learning skills, and the self-confidence to solve complex problems. These skills are in addition to developing core epidemiological numeracy skills for the analysis and interpretation of data. TBL may also enhance numeracy skills (Carpenter, Coyne, Silberman, and Takemoto 2022), promote critical

thinking skills (Silberman, Carpenter, Takemoto, and Coyne 2022; Zeb, Mahboob, and Shaheen 2022), and support collaboration in teams to optimise patient care (Jackson and Otaki 2023); theoretically, TBL should foster these skills when applied in public health education.

There are, however, limited studies directly examining TBL in the public health discipline. Van der Putten and Vichit-Vadakan (2010) conducted a pilot to determine how TBL impacts graduate public health ethics students in Thailand and found that it encouraged student preparedness, increased active learning and supported students at risk of failure through peer teaching activities. Students also found TBL useful in translating content into applicable knowledge (Van der Putten et al. 2010). As far as we know, no other studies have examined TBL in public health education or have thus far been published on teaching strategies that systematically assist students from diverse backgrounds and learning needs as they develop the core knowledge, skills, and attitudes needed for public health education.

## The University of Wollongong context

At the University of Wollongong, Australia, undergraduate students are able to select additional elective classes outside their degree's compulsory core subjects. Most lectures at the University of Wollongong do not require mandatory attendance, so student motivations can be as diverse as the student population itself. Class sizes have also increased over time, creating the need to develop innovative strategies to ensure consistent, effective, deeper learning for all students—a requirement in the higher education sector where students must develop critical thinking skills beyond rote memorisation. The flipped classroom is an approach which has become popular and increasingly adopted as an alternative low-cost method of delivering content in lieu of lecture attendance. Ozdamli and Asiksoy (2016) point out that while there are varied definitions of flipped learning, the basic premise is that the responsibility for learning is transferred from the lecturer to the student. The "flip" approach involves (F) flexible learning (i.e., content is delivered outside the classroom, and students are expected to learn the content themselves independently), (L) learning culture (i.e., student-centred rather than teacher-centred), (I) intentional content (i.e., how to develop cognitive understandings) and (P) the active involvement of a professional educator (Ozdamli et al. 2016). Unless flipped learning is well designed, it may present challenges to some students. In particular, students from recognised equity backgrounds (which indicates systemic educational disadvantages) often have other competing responsibilities outside of study (such as work or family) or they may be first in their family to attend university and are not yet familiarised with university culture and expectations (Delahunty, O'Shea, May, and Stone 2024), including the shifts in responsibility inherent to flipped learning. Therefore, to set up students for success, teaching requires going beyond the recall of content to higher order application of the content.

For public health subjects, such as epidemiology, a more defined version of flipped learning is necessary. Using structured methods of instruction based on TBL will not only develop autonomous, critical thinkers but will meet the requirements of the Australian Qualifications Framework (AQF), a national policy for regulated qualifications in Australian education and training. The AQF requirements for bachelor degrees include coherent theoretical and technical knowledge, well developed cognitive skills to apply methods for information analysis, and the skills to generate solutions for complex problems and to transmit knowledge to others. Graduates at this level will be able to apply knowledge and skills to demonstrate autonomy, well developed judgement, and responsibility in contexts that require self-directed work and learning (Framework 2013).

*Purpose of developing a new teaching strategy HTBL-PE*

To meet the challenges of teaching a public health subject to diverse students, the development of a new teaching strategy was paramount. This strategy would need to provide all students with the "tools" needed to effectively assimilate and apply content knowledge to new and unfamiliar scenarios. To achieve this, the researchers developed a more directed, deliberately scaffolded and individualised teaching experience that could maximise each student's potential.

This new teaching strategy became The Hybrid Team-Based Learning-Personalised Education (HTBL-PE), an innovative way to effectively teach epidemiology at the University of Wollongong. As a hybrid strategy, HTBL-PE uses elements of TBL with innovative personalised education strategies. A number of theoretical approaches as well as the premise that learning is a socially constructed activity where meaningful and authentic team activities enhance individual knowledge, skills, and overall competency informed the development of HTBL-PE. With this approach, it's essential to involve an expert guide for directing peer-to-peer interaction towards knowledge building, supporting learning, and increasing learners' expertise and skills over time. The approaches include Team-Based Learning, discussed earlier (Michaelsen et al. 2008) (Michaelsen et al. 2011), Vygotsky's notion of scaffolding (Verenikina 2003; Vygotsky 1978; Whittaker 2015), Bloom's taxonomy (Adams 2015), Social Learning Theory (Bandura 1977, 2018) and innovations in personalised education and facilitation strategies (Gullo et al. 2015).

With HTBL-PE, the researchers aimed to develop a systematic, structured teaching strategy that would maximise student success by scaffolding content and building competency. This is achieved firstly by utilising the strength of the whole class (i.e., interactive lectures), and secondly, by engaging learners in smaller group work (tutorials) and finally, by assessing individual competency (post-class quiz and blogs). The HTBL-PE strategy enhances the student learning experience, providing most students with an environment and circumstances that maximise their success.

The overall strategy, found in Figure 1, includes pre-readings, pre-class quiz, interactive lecture, interactive higher order tutorial, post-class quiz, and reflective blogs. Layers of carefully developed teaching strategies are embedded in these phases in order to maximise a student's success. Figure 2 outlines the details of the HTBL-PE strategy and what happens in each phase.

There are clear weekly learning objectives, so students know exactly what they need to be "able to do" before they attend the first weekly face-to-face session (interactive lecture). HTBL-PE starts with pre-readings that are varied and cater to different learning needs with an array of content presentations (e.g., written articles, various texts, audio visual resources, short videos, worked examples, and exercises). The scaffolding of student learning commences with students doing a pre-class quiz to test their competency of the pre-readings. This sets the stage for students to further build content during the interactive lecture. As they have an idea of what will be taught through completing the pre-readings and pre-class quiz, they are more likely to come ready to build on what they already know, to learn further, and to discuss their learning gaps.

*Approaches informing HTBL-PE*

The approaches informing HTBL-PE are scaffolding, Bloom's taxonomy, and Social Learning Theory. The interactive lectures in class activities build on content delivered by the lecturer, using Vygotsky's scaffolding principles with Bloom's taxonomy. The interactive activities are designed to stretch the student's level of knowledge and competence, moving knowledge construction from lower to higher levels of Bloom's taxonomy. Instructors also purposefully designed innovative teaching to reach those levels systematically. For example, in the first few lectures, instructors asked students to answer questions or participate in activities as a whole group using an approach that ensures

complete anonymity, building an individual student's confidence (e.g., using Plickers or QR codes to provide answers). Participation then moves to working in pairs, which provides some anonymity in a safe place while further building up confidence. Finally, participation moves from the "safety" of anonymity through using an online wheel to randomly pick students. This means all students must be prepared to answer the question, further building up their confidence. The gradual step by step and multilayered approach of the interactive lectures utilises the strength of the groups in order to increase the confidence and capabilities of the individual students. The questions asked and types of activities experienced in the interactive lectures increase students' competence through the guidance of Bloom's taxonomy for building levels of difficulty for cognition.

HTBL-PE utilises Vygotsky's scaffolding in multiple ways. On a superficial level, the scaffolding and assurance of learning occurs from the pre-readings to the pre-class quiz, then the interactive lectures to the interactive tutorials (higher levels of Bloom's taxonomy). The tutorial questions are more difficult and smaller groups of students work on the questions together before they sit for the post-class quiz as individual students at the end of the tutorial. Continuous assessment means students need to immediately address learning gaps, which increases their ability to scaffold content from one week to the next.

Each phase of HTBL-PE, from each assessment and pre- to post-class quiz to the activities in the interactive lectures and tutorial questions, features increased complexity. Learning is further ensured by two formative assessments that determine if learning objectives in weeks one to four and weeks five to nine are met.

The approach uses Bloom's taxonomy extensively: in pre- and post-class learning objectives; pre- and post-class quizzes; interactive lectures; interactive tutorials (using the power of groups to improve the individual's competency); and blogs. Altogether these build up competency and skills throughout the whole semester via varied but interconnected activities. The pre-class learning objectives and quizzes assess the first three levels of Bloom's taxonomy (e.g., recall of foundational epidemiological concepts for disease burden) and essentially ensure that the students completed the pre-readings. Reaching the very top levels of Bloom's taxonomy is the aim for the interactive tutorials (e.g., developing a new study design to answer a revised research question). Higher order learning is gradually achieved by questions and learning objectives at increasingly higher levels of Bloom's taxonomy from the pre-class objectives through to individual post-class quizzes, which ensure the competency of the individual students as our future public health practitioners.

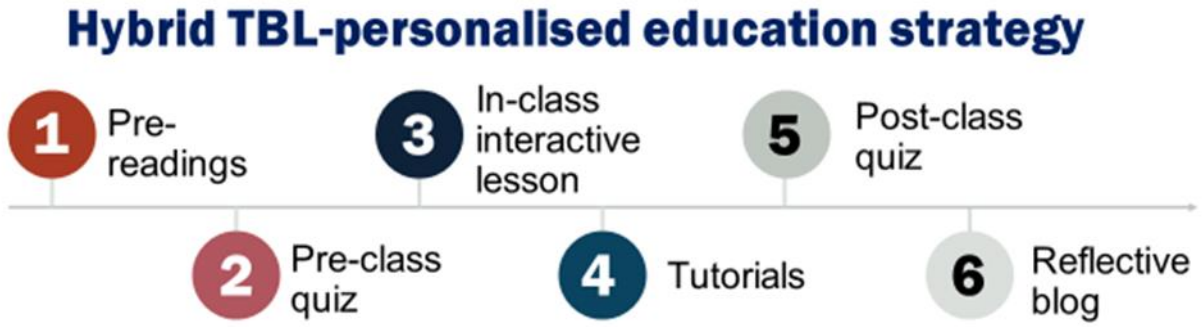
The blog aims to support the student as they take the learning experiences to a deeper level via reflective learning. Students reflect deeply on the week's learnings and extend their thinking by applying what they know to scenarios that are new or unknown to them. Ultimately, public health practitioners and epidemiologists require deep reflective learning because it is crucial to utilising all the skills learnt and applying them to new and unknown situations in the future. Students are required to write a deep reflective blog by the end of each week to link what they have learnt with what they may not yet know and to reflect on how their learnings may be useful in different scenarios. To acknowledge deep reflection and foster a community of practice, blogs that help their peers learn and receive higher marks.

The emphasis of Social Learning Theory is on learning through social interactions. To foster sociality, the instructor places students in smaller tutorial groups where they remain for the entire semester. Tuckman's stages of group development (forming, storming, norming, performing, and adjourning from an entire semester of being together) will allow them to strongly utilise the strength of the groups in order to increase an individual's competence (Bonebright 2010). Facilitation strategies to enhance group performance, such as getting them to introduce their new teammates

and describing a crazy fact about themselves, quickly breaks down barriers; if students are brave enough to share a crazy fact, they will be courageous enough to ask questions (multiple times if need be) regarding content they are not sure about.

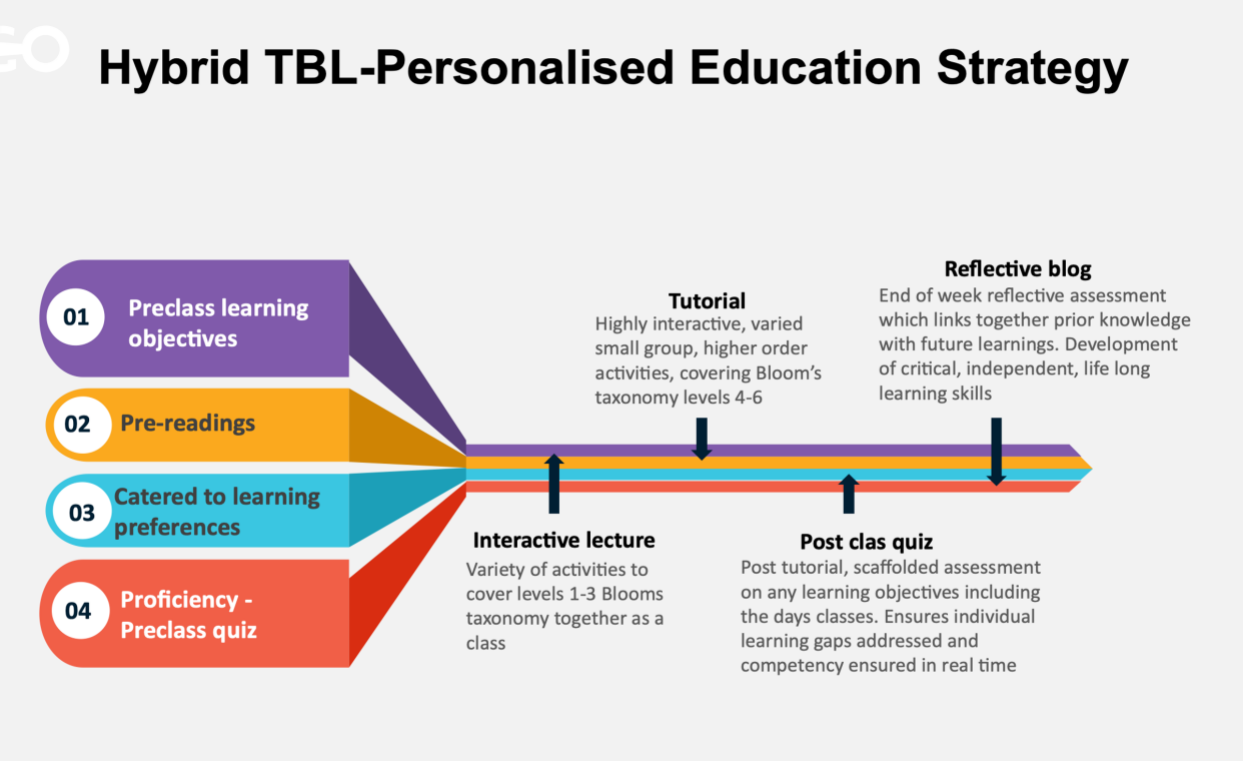
An app called Realtimequiz, designed by the lead author of this paper (TH), enhanced the personalised education aspect of HTBL-PE. In the app students identify their learning gaps and can more efficiently address them immediately and during revision. The lecturer can identify learning gaps and adjust the teaching strategy in real time by using different scenarios that explicitly address the students' learning gaps. The app is easy to implement in low resource settings and can be used seamlessly by one academic in the class.

Figure 1. "The Skeleton" Schema-Hybrid Team-Based Learning-Personalised Education teaching strategy (HTBL-PE)




HTBL-PE uses a variety of facilitation strategies to maximise student success. These included a treasure hunt, where questions are posted around the university campus and students are required to take a photo of their groups holding the answer before the next location and question are revealed, and epidemiology charades, where cards with concepts and points on the back reflect a concept's difficulty. Students pick a card and are given one minute to describe the concept to the rest of the class with points allocated to the group(s) who correctly identify the concept. Another interactive activity uses fake money to bet on a series of increasingly difficult questions; groups who answer the questions correctly double their money, whilst groups with the wrong answer lose money. Gamification of the tutorials led to much more student engagement and deeper comprehension of the content as competition with the lure of a possible prize for the winning team was a highly effective teaching strategy. These different modes of delivery vary from traditional TBL, where the application questions are either multiple choice or free response.

Figure 2. Detailed Hybrid Team-Based Learning-Personalised Education (HTBL-PE) teaching strategy




This study aimed to examine the effectiveness of HTBL-PE in teaching epidemiology to undergraduate students. In particular, it examined changes to independent learning, critical thinking skills, confidence, and interest in epidemiology. The conclusions reached are based on data collected in one semester, which was the fifth semester that the course implemented HTBL-PE. Triangulation of different data (pre- and post-semester surveys, student comments/evaluations, weighted average marks [WAMs], final grades, lecturer reflection) formed the basis of the findings. Notably, these are framed within the experience and context of four previous semesters in which HTBL-PE resulted in the extraordinary pass rate of 99%, along with numerous qualitative comments from students that referred to this teaching method used as a contributor to their academic success in the subject.

## METHODOLOGY

### Context

The researchers conducted the study in a three-year bachelor of public health program at the University of Wollongong, a regional, medium sized university in southern Sydney, Australia. Classes comprised both one-hour weekly lectures and two-hour fortnightly tutorials. The subject was an Introduction to Epidemiology subject for undergraduate students and took place during one semester, which was 12 weeks in duration.

### Methods

To explore the effectiveness of HTBL-PE from the student perspective, we used a case study research design. Case study is most suited to a bounded system, such as the temporal boundary of a 12-week semester long study (Stake 1995). Case study research design enables researchers to collect and triangulate various data in order to develop an in-depth understanding of the case. The researchers collected quantitative data, including pre- and post-semester surveys, weighted average marks (WAMs) and final grades. Students could include qualitative comments if they wished, but the

study included no formal qualitative component. The student participants were enrolled in a bachelor of public health, introduction to epidemiology subject (subject code; HAS 251) during a 12-week long semester. Students from any discipline could enrol in this subject, but it is compulsory for the bachelor of public health degree. A case study research methodology enabled us to explore how students experienced learning through HTBL-PE as it was naturally delivered. We conducted this research in real time in a subject taught through this innovative, theoretically informed teaching strategy. To measure changes in students' self-reported experience of the HTBL-PE teaching strategy, we conducted a baseline survey during week 1 and a final follow up survey during the last week of semester. An independent co-investigator who was not involved in teaching the subject administered the studies to maintain objectivity and impartiality. The co-investigator answered any questions from students, obtained informed consent prior to administering the survey and linked the baseline and follow up data, de-identifying the data, and analysis of the data.

The University of Wollongong Social Sciences Human Research Ethics committee approved this research (Ethics number 2019/277). The instructor or lecturer had no involvement in participant recruitment, or obtaining consent or analysis of the results, which strengthens the validity of the findings of this study.

### *Data collection*

We collected data via surveys, which included questions on demographics, students' degrees, and students' experiences of different teaching practices at the University of Wollongong. The survey also captured information on their baseline confidence in critical thinking skills, independent learning, knowledge, and application of epidemiology. The post-survey also included retrospective questions indicating changes in higher-order teaching outcomes after experiencing the HTBL-PE teaching strategy (change in confidence in independent learning, change in interest in epidemiology, change in critical thinking, and whether they had applied the skills in HAS 251 in other subjects and settings).

This study also included analysis of students' marks for HAS 251, as well as their weighted average marks (WAMs) before and after the semester. The university provides WAMs for students who participated in the study directly to the co-investigator, who then de-identified them before analysis. We compared students' WAMs before the semester with their overall marks for HAS 251 in order to provide a proxy measure of the change in students' competence due to HTBL-PE. Overall, HAS 251 marks also indicated students' competency in epidemiology after participating in the HTBL-PE strategy.

### *Analysis*

We used SPSS version 25 to conduct the analysis of quantitative data (IBM Corporation, Armonk, NY, USA). Analyses began with the examination of descriptive statistics, which revealed the presence of small cell sizes in some categorical variables. For example, very few students indicated that their higher-order learning outcomes (e.g., independent learning, critical thinking) decreased or remained unchanged. Therefore, we merged the categories "decreased" and "no impact.". Despite this, some small cell sizes persisted that prevented the use of chi-square tests to explore changes in higher-order teaching outcomes by gender and learning style. Therefore, we explored these changes using Fisher's exact test (for 2x2 tables) or likelihood ratios (for 2x3 tables) (McHugh 2013). Following this, the research team explored the changes in average WAMs before and after the semester using paired-sample t-tests. We also tested the difference between WAMs before the semester and the

average mark for HAS 251, although we used a Wilcoxon signed-rank test in this case because the HAS 251 marks were not normally distributed (Shapiro-Wilk: 0.922, $p<0.001$).

## FINDINGS

A total of 73 out of 84 (87%) students who undertook HAS 251 participated in the study. The average age of the participants was 21.6 years (SD=5.5 years). Table 1 reflects that the majority of students were female (70%). Students in HAS 251 undertook a wide variety of degrees, with the majority enrolled in the bachelor of medical and health sciences (37%) or the bachelor of public health (22%). Students' self-identified learning preferences were spread relatively evenly across visual (34%), reading/writing (30%), and kinesthetic (26%), although few students identified as auditory learners (6%). Students reported that the most commonly encountered teaching method at the University of Wollongong prior to this semester was lectures (75%).

**Table 1.** Demographic characteristics, learning types and baseline teaching exposure

| Variable | Categories | N (%) |
|---|---|---|
| **Gender** [a] | Male | 20 (27%) |
| | Females | 51 (70%) |
| **Degree enrolled** | Bachelor of public health | 16 (21.9%) |
| | Bachelor of social sciences | 7 (9.6%) |
| | Bachelor of medical and health sciences | 27 (37%) |
| | Bachelor of health sciences | 1 (1.4%) |
| | Bachelor of science | 3 (4.1%) |
| | Bachelor of arts | 2 (2.7%) |
| | Bachelor of pre-medicine, science, and health | 6 (8.2%) |
| | Bachelor of primary education | 1 (1.4%) |
| | Bachelor of psychological science | 2 (2.7%) |
| | Bachelor of psychology (including honours) | 5 (6.9%) |
| | Bachelor of exercise science | 1 (1.4%) |
| | Other (note stated) | 2 (2.7%) |
| **Learning preferences** [b] | Visual | 24 (34.3%) |
| | Audio | 4 (5.7%) |
| | Read/write | 21 (30.0%) |
| | Kinesthetic | 18 (25.7%) |
| **Most commonly encountered teaching strategy at the University of Wollongong** | Lectures | 55 (75.3%) |
| | Tutorials | 11 (15.1%) |
| | Team-based learning (TBL) | 1 (1.4%) |
| | Laboratory classes | 5 (6.8%) |
| | Others (study abroad) | 1 (1.4%) |

a. Two values were missing for gender.

b. We excluded five participants from analyses either due to missing data for learning type (n=3) or because they indicated their learning type as "other" with no further specification (n=2).

Table 2 highlights students' perceived changes in higher order teaching outcomes over the semester. As a result of their experience in the subject, the vast majority of students reported increases in their confidence as independent learners (86%), interest in epidemiology (93%), and critical thinking skills (92%). None of these changes differed significantly by learning type, although

female students reported increases in their critical thinking skills (96%) at a somewhat higher rate than male students (80%) (p=0.049). More than two thirds of students had already applied learnings from this subject in other settings (67%).

**Table 2.** Change in higher order teaching outcomes after HTBL-PE, total sample and by gender and self-assessed learning type

| | | Total sample (n=73) | Gender[a] | | Sig. | Self-assessed learning type[b] | | | | Sig. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Male | Female | | Visual | Audio | Read/ write | Kinaesthetic | |
| Change in confidence as an independent learner as a result of experience in subject | Decreased / no impact | 10 (13.7%) | 3 (15.0%) | 7 (13.7%) | 1.000 [c] | 6 (25.0%) | 1 (20.0%) | 3 (14.3%) | 0 (0.0%) | 0.091 [d] |
| | Increased | 63 (86.3%) | 17 (85.0%) | 44 (86.3%) | | 18 (75.0%) | 4 (80.0%) | 18 (85.7%) | 18 (100%) | |
| Change in interest in epidemiology as a result of experience in subject | Decreased / no impact | 5 (6.8%) | 1 (5.0%) | 4 (7.8%) | 1.000 [c] | 3 (12.5%) | 0 (0.0%) | 2 (9.5%) | 0 (0.0%) | 0.381 [d] |
| | Increased | 68 (93.2%) | 19 (95.0%) | 47 (92.2%) | | 21 (87.5%) | 5 (100%) | 19 (90.5%) | 18 (100%) | |
| Change in critical thinking skills | Decreased / no impact | 6 (8.2%) | 4 (20.0%) | 2 (3.9%) | 0.049 [c] | 2 (8.3%) | 1 (20.0%) | 3 (14.3%) | 0 (0%) | 0.475 [d] |
| | Increased | 67 (91.8%) | 16 (80.0%) | 49 (96.1%) | | 22 (91.7%) | 4 (80.0%) | 18 (85.7%) | 18 (100%) | |
| Whether already applied learnings to another setting | Yes | 49 (67.1%) | 13 (65.0%) | 36 (70.6%) | 0.824 [d] | 17 (70.8%) | 4 (80.0%) | 13 (61.9%) | 11 (61.1%) | 0.924 [d] |
| | Not sure | 5 (6.8%) | 1 (5.0%) | 4 (7.8%) | | 2 (8.3%) | 0 (0.0%) | 1 (4.8%) | 2 (11.1%) | |
| | No | 19 (26.0%) | 6 (30.0%) | 11 (21.6%) | | 5 (20.8%) | 1 (20.0%) | 7 (33.3%) | 5 (27.8%) | |

Notes:
Bold text indicates statistically significant results ($p<0.05$).

a. Two values were missing for gender.
b. We excluded five participants due to missing data for learning type (n=3) or because they indicated their learning type as "other" with no further specification (n=2).
c. We performed Fisher's exact test because more than 20% of cells had an expected value of less than 5 (2x2 table).
d. We used the likelihood ratio because more than 20% of cells had an expected value of less than 5 (more than 2x2 table) (McHugh 2013)

The WAMs for students before the spring semester in 2019, when instructors first used HTBL-PE, was 69.78, and the WAMs after the spring semester in 2019 was 71.01. The average mark for HAS

251 was 87.14 with no failures. At the end of the semester, students' WAMs had significantly increased by an average of one mark ($p<0.001$). Students' average marks for HAS 251 were substantially above their WAMs prior to the semester (+17 marks, $p<0.001$).

Table 3 presents students' ratings of the most helpful university teaching strategy they had encountered at the beginning and the conclusion of the semester. At the beginning of the semester, most students indicated that they found traditional methods supported their learning the most, especially lectures and tutorials (71%). This finding may reflect the fact that students most commonly encountered these teaching strategies prior to this semester (see Table 1). At the conclusion of the semester, around a third of students still considered lectures and tutorials to best support their learning (33%). However, slightly more students believed that the HTBL-PE approach was the most helpful teaching strategy that they had encountered during university at the end of the semester (35%).

**Table 3.** Most helpful teaching method experienced at university

| Teaching method | Pre-survey | Post-survey |
|---|---|---|
| Lectures/tutorials | 51 (70.8%) | 24 (33.3%) |
| Problem based learning | 7 (9.7%) | 8 (11.1%) |
| Team-based learning | 3 (4.2%) | 12 (16.7%) |
| Seminars/workshops | 6 (8.3%) | 0 (0%) |
| Hybrid TBL personalised education teaching method (HTBL-PE) | 0 (0.0%) | 25 (34.7%) |
| Labs/other | 5 (6.9%) | 1 (4.2%) |

## DISCUSSION

Instructors successfully implemented HTBL-PE, a new and innovative teaching strategy, into an introduction to epidemiology subject in the bachelor of public health program at the University of Wollongong. The components of HTBL-PE work together synergistically to systematically achieve the primary objective of maximising a student's chance of success. Content is strongly scaffolded with continuous formative assessments in order to ensure learning and reflective learning strategies that stretch a student's ability to think critically and independently.

The vast majority of the students in the class participated in this study (73/84 = 87%). The instructors used the HTBL-PE method for four semesters prior to the research reported in this paper. The fifth semester presented an opportunity to formally examine students' experiences and the impact of this method on their academic success in more depth.

We used a case study approach as the first initial foray into investigating the efficacy of the HTBL-PE teaching strategy. In an Australian context for research into the scholarship of teaching and learning, it was not ethical to use a more rigorous experimental design, such as a randomised controlled trial, because HTBL-PE appeared to be beneficial, and students typically pick the subjects they would like to study. Additionally in Australia where students are paying substantial fees, it is not feasible or ethical to use an experimental design that includes a control group, because it would be unethical to randomise students to another teaching method at the same time, which may be potentially less effective. The number of students who enrol in the subject and the selected timing of tutorials is beyond the control of the investigators and the teaching staff.

Further, conducting an experimental study was not feasible when there are resource constraints with only one lecturer teaching the entire subject and room limitations across the university. However, it was still important to conduct a study initially examining the efficacy of HTBL-PE, given the many years of positive feedback, high pass rates, and the increasing enrolment numbers

in the subject. The HTBL-PE strategy is easy to design and implement and has been shown to be highly effective.

### Student academic success and confidence

The instructors successfully used the HTBL-PE teaching strategy in the four semesters prior to this study, and each time a pass rate of >99% was observed. There are numerous positive qualitative comments from students in the university subject evaluations. These observations and reflections led to formally investigating students' experiences with HTBL-PE and how this teaching innovation contributed to their education. As an objective measure, we were able to access students' weighted average mark (WAM) prior to the semester in which they experienced HTBL-PE for the first time. We then compared their initial WAM to their results once they had completed the introduction to epidemiology subject. This is one approach to assessing the impact of HTBL-PE on academic success. Students overwhelmingly performed better after HTBL-PE (average mark = 87.14) compared with their WAMs prior to HTBL-PE (WAM = 69.78), indicating positive effect on academic success. The students' qualitative comments from this study also supported the effectiveness of HTBL-PE on their learning experience. These included the increased interactivity, the structure which allows students to keep up to date and better prepare them for higher order learning, and the feeling of being more able to retain and apply more content, to name a few. We did not conduct a formal qualitative analysis, as the study was not set up to do so and we didn't interview students.

### Preference for learner strategies

While students selected lectures and tutorials as the most useful teaching method prior to HTBL-PE, it is likely because their experience with teaching methods thus far would have been traditional lectures and tutorials. Several studies found that TBL was more beneficial in terms of recall and application of content (Barraket 2005; Choi et al. 2021), and the ability to solve problems (Kim, Song, Lindquist, and Kang 2016). HTBL-PE was also beneficial in developing higher order skills, such as critical thinking and independent learning. As HTBL-PE is a personalised teaching strategy, tailoring pre-readings to different learner preferences with regular assessments that provide students with immediate feedback to rapidly scaffold their learning, we expected and found that HTBL-PE would systematically enhance students' experience. The ability to pass the subject is evidenced by the high pass rates (>99%) and high grades in our study. Lectures and tutorials still formed part of the HTBL-PE teaching strategy, but we made many student-focused modifications to improve interaction and to inspire students to teach and learn from each other whilst preparing students systematically to succeed. The enhancements and modifications to traditional TBL personalised the educational experience of the students, catered to different learner preferences, and maximised success. Previous studies have shown that TBL was superior to didactic lectures in achieving higher order application of content (Alamoudi et al. 2021; Ong et al. 2022; Reimschisel et al. 2017). However, HTBL-PE deliberately used assessment tasks that systematically scaffolded learning objectives using Bloom's taxonomy in order to build up student's confidence in achieving higher order learning. The interactive lecture activities provide an initial platform for students to anonymously apply content together in class and close any learning gaps from the pre-readings. Because the instructors did not assess these activities, students rapidly built up confidence and addressed learning gaps. Academic performance significantly improved, as evidenced in higher weighted average marks (WAMs) for HAS 251 when compared to WAMs prior to HTBL-PE. Given the results of this study and that HTBL-PE was only experienced by the student participants in Spring 2019, it can be reasonably concluded that HTBL-PE

was a predictor for academic success, as prior to HAS 251, no survey participants had experienced learning via HTBL-PE.

Academic success is an important requirement for students to obtain their degrees. However, it is equally important for public health that students graduate as confident and independent learners who are well equipped to apply their knowledge and skills across different situations. The ability to apply knowledge and skills in a plethora of scenarios has become even more important after COVID-19; the foundational skills of epidemiology (the scientific basis for public health policy and practice) as well as the training of independent thought leaders of the future are vital to society. Therefore, it was important for this study to explore changes in students' perceptions of their critical thinking, confidence levels, interest in epidemiology, and whether they had applied the skills learned from HTBL-PE to other scenarios. This study suggests that, in general, an increase in all these measures occurred, regardless of gender or learner preferences. Students found HTBL-PE of benefit, and many have indicated they have used the skills in other scenarios, suggesting a step towards lifelong independent learning.

Studies on traditional TBL have found that it to be effective for developing interpersonal skills (Choi et al. 2021), active content learning, and overall student performance (Barraket 2005). Jiratchayaporn et al. (2020) also found TBL translated to an increase in student confidence in nursing students undergoing a practicum (Jiratchayaporn et al. 2020), and Frame, Gryka, Kiersma, Todt, Cailor, and Chen (2016) found TBL increased student confidence in self-care concepts in pharmacy.

What sets HTBL-PE apart from TBL is its flipped learning approaches and its ability to personalise a student's experience by catering to a variety of learning preferences and diverse backgrounds. It accomplishes these aims by systematically building up competency and confidence in applying content whilst building critical thinking and independent learning skills. For example, in HTBL-PE very clear pre- and post-class learning objectives guide the pre-reading so students are aware of what they "should be able to do" before attending class and by the end of the week's classes. To cater to student learning preferences and maximise success, pre-readings include a wide variety of resources from videos to journal articles to interactive practice questions. HTBL-PE also uses very different facilitation strategies in order to cater to the new generation of learners. The innovative use of activities and gamification is key to the HTBL-PE strategy. For example, treasure hunt activities enable students to build group work skills whilst engaged in responding to questions posted around the university campus. The facilitation strategy 'show me the money' scaffolds student learning through questions aligned to Bloom's taxonomy, which are designed to enhance their learning. Learning is achieved whilst students wager bets using fake money, earning money for correct answers and losing money for incorrect answers. The sense of competition rapidly increases both the learning and classroom engagement.

### Limitations to the study

As with all studies, there are limitations and biases. With self-reported survey questions, there is the possibility of recall bias. Selection bias and recall bias are potential sources of bias in studies involving people. In our study, both had minimal impact. The high participation rate of 87% of students completing both the pre and post study surveys means that we have captured most of the views of students in the class, implying limited selection bias in our study. The type of questions asked in the week one survey before students experienced HTBL-PE included questions about demographics, teaching strategies that students had experienced thus far, their understanding of epidemiology, and their confidence in applying epidemiological principles at this stage and was not prone to recall bias, as these questions are about their experience in week one thus far. Similarly,

students completed the week 12 survey questions during the last week of their HTBL-PE class when their confidence in epidemiology at this point in time, their change in critical thinking skills, and whether they have used any HTBL-PE techniques in other classes was still fresh. There is a very limited impact of recall bias because of the timing of the questions asked and the type of questions asked.

The authors also used weighted average marks to further triangulate our results as well as the congruence of higher results in HAS 251 compared to WAMS before HAS 251. The increase in student confidence and independent learning further confirmed the significant role HTBL-PE has played in a student's academic success.

The triangulation of results from WAMs prior to HTBL-PE, the average marks for the introduction to epidemiology subject using HTBL-PE, students' qualitative comments of their experience of HTBL-PE, and the survey results pre and post HTBL-PE indicating a vast majority—i.e., > 80% increase in confidence as independent learners (86%), interest in epidemiology (93%) and critical thinking skills (92%)—all indicate that HTBL-PE has been a very positive experience on student's learning and should be investigated further to explore how to apply it to other subjects.

Whilst conducting a longitudinal study would provide further insights into the sustained impact of HTBL-PE, it was not possible in our study because students are only enrolled in a subject for a 12-week semester. Any further or longer than that would mean a different subject with a different cohort of students and hence we would not be measuring the impact of the same cohort and their experience of HTBL-PE.

Many elements of HTBL-PE are already online, for example pre-readings, learning objectives, pre- and post-class quizzes, blogs, and the Realtimequiz app. During COVID-19, the application and adaptation of HTBL-PE was therefore possible and successful. The real heart of the strategy lies in the different phases of HTBL-PE and the quality of the interactive activity questions and tutorial questions. In terms of adapting this strategy in contemporary education, HTBL-PE is adaptable and can achieve higher levels of student success, engagement, confidence, and critical thinking. There was no significant difference in confidence and independent learning by learner preferences, which suggests that HTBL-PE has catered to and benefited all learners and thereby was successful in individualising a student's learning experience.

## CONCLUSIONS

HTBL-PE is an effective teaching strategy for a diverse group of undergraduate students with a significantly improved overall academic performance. Skills important to the practice of public health and the application of epidemiology include critical thinking, independent learning, lifelong learning, and interest in epidemiology; these were stimulated and increased from the experience of learning via HTBL-PE.

HTBL-PE is a much more structured and tailored version of TBL. It uses many different applications of Vygotsky's principles of scaffolding, Bloom's taxonomy, Social Learning Theory and innovative personalised education facilitation strategies, meaning it may be suitable to other scenarios and disciplines where the objective is to rapidly assimilate content and apply the content in different contexts in order to solve complex challenges.

There is potential for other instructors to apply this new teaching strategy to other disciplines where learning outcomes require rapid assimilation of content leading to higher order application in various scenarios. In particular, HTBL-PE demonstrated support for diverse learners to succeed academically and for the development of knowledge and skills essential for work in public health.

## AUTHOR BIOGRAPHY

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## ETHICS

The University of Wollongong Social Sciences Human Research Ethics committee approved this research.

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