

Statistically significant learning experiences: Towards building self-efficacy of undergraduate statistics learners through team-based learning

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Abstract

Competence in statistics is a fundamental component of a biological scientist's toolbox. However, anxiety often affects undergraduate students' development of their statistical capability and previous research has shown that perceived self-efficacy for statistics is correlated to academic performance. Self-efficacy may be promoted by reducing anxiety around statistics as well as allowing students to practice their skills in groups to model approaches used and gain feedback from their peers. We undertook action research to investigate how a change in teaching method from a passive individualist approach to more active team-based learning (TBL) affected our students. The first iteration of the teaching with Year 2 students led us to change our delivery to allow more time for team-working for the next iteration with Year 1 students. We found that some measures of self-efficacy were correlated with a post-TBL summative test performance in Year 1 and Year 2 students. However, listening to the student voice revealed that Year 1 students were less positive about TBL, and corroborated quantitative findings revealing that they had lower collective efficacy than Year 2 students, despite teams performing as well during formatively assessed TBL. We draw on self-efficacy theory (Bandura, 1997) to better understand why students perceive and report differing learning experiences, and to make recommendations for designing teaching and learning that helps learners at different stages of transition to university build their self-efficacy.

Keywords: Team-based learning, statistics, programming, undergraduate, life sciences

Introduction

The ability to analyse data is an essential skill that scientists require to answer questions posed during their research. The teaching of statistics is, therefore, an integral component of undergraduate science degree programmes. This research paper recounts the journey of three action researchers to better understand the experiences, perceptions and misconceptions of Year 1 and Year 2 undergraduate biological science students as they develop their statistical ability, programming skills, and team working approaches. In doing so we surface and address our own incorrect assumptions and pedagogical discomfort, test out educational theory and evaluate the process of action research in this context. We begin by presenting the challenges and issues in practice that our action research sought to address.

Identifying the challenges in practice

When talking to students about data analysis one quickly comes across the well-established phenomenon of statistics anxiety, “the apprehension that occurs when an individual is exposed to statistics content or problems” (Macher et al. 2015, 1). This can result in procrastination, inefficient study strategies (ibid.) and can impact performance (e.g. Paechter et al. 2017). The *R* programming language is becoming the choice medium for teaching statistics to biological sciences students because of its high uptake by the professional community (e.g. Lai et al. 2019). We have observed that this further requirement for proficiency in programming when learning statistics adds to student anxiety. Some students report weaving their way through our BSc Biological Sciences degree programme to avoid modules requiring *R* and statistics. Such negative perceptions may also be due to previous learning experiences being too passive, with not enough opportunity for practice and application, as highlighted in student evaluation feedback.

An action research approach

Recognising the need for change and to gain insight into the effects of pedagogical change, we embarked on an action research project. Given the wider institutional context of a new, ambitious Learning and Teaching Strategy leading to university-wide

curriculum review and a pedagogical transformation project, this presented an opportunity both to engage students in curriculum development, and to reflect on and develop our teaching practice in an informed way (Laudonia et al. 2018). With cross-university colleagues keen to both adopt theoretically underpinned and evidence-based pedagogical approaches that promote active and inclusive learning *and* develop pedagogical research approaches, including action research, our work offers potential for wider institutional learning. Bandura's (1997) concept of self-efficacy, the extent to which one believes one has the capability to successfully complete a given task, is useful for thinking about how to help our students, especially as there is a link between increased self-efficacy and increased performance in statistics (Finney and Schraw 2003; Lane, Hall, and Lane 2004).

By adopting an action research approach, we hoped to advance the pedagogical knowledge base (Arnold and Norton 2018) around understanding the role of university teachers in the process of building self-efficacy (including to address statistics anxiety) through educational design. This is important given growing concern about students' well-being (Neves and Hillman 2019) and the positive relationship between increased self-efficacy and well-being (Paciello et al. 2018). In light of disagreement about the role of academics in student well-being (Ecclestone & Hayes 2019), a focus on developing self-efficacy, within disciplinary teaching and learning, offers potential for embedding well-being in the curriculum (Houghton & Anderson 2017) in a meaningful and sustainable way.

As key stakeholders, students were engaged in conversations about their learning throughout and in focus groups. Learning technologists were heavily involved in the educational design and in real time discussions to enhance the learning technology.

We used Lewin's model of action research (Smith 2007; Figure 1) to plan, evaluate our teaching, and reflect on our beliefs and values. Having identified *The Problem* as a need to change our teaching of statistics in *R* software, we undertook *Research* to inform our *Planning* of a more active learning method and took *Action Step 1* (Year 2 teaching). *Evaluation of Action Step 1* allowed us to refine our pedagogical approach for *Action Step 2* (Year 1 teaching). *Evaluation of Action Step 2*, analysing quantitative and qualitative data, and *Reflecting* on the whole process has enabled us to make recommendations for *Future Action*, in our own and colleagues' practice.

[Figure 1]

Research & Planning

In this section we outline Bandura's theory of self-efficacy and give an overview of the principles of the team-based learning (TBL) approach we implemented (Michaelson and Sweet 2008). Our intention is to demonstrate how we have drawn on the principles of self-efficacy to increase learning through TBL.

Self-Efficacy

There is general consensus that self-efficacy beliefs correlate with academic performance (Zimmerman, Bandura, and Martinez-Pons 1992; Honicke and Broadbent 2016). Students with high levels of self-efficacy are confident, enthusiastic, hard-working, focussed and resilient (Bandura 1997).

According to Bandura (1994-2008) individuals derive their self-efficacy beliefs from four sources of information that are concurrently assessed (Gallagher 2012):

- *Mastery experiences* that provide the opportunity to practice and overcome difficulties;
- *Vicarious experiences* that involve observing and learning from models;
- *Social persuasion* and encouragement from credible persuaders; and finally,
- *Physiological and emotional states*, that is the positive or negative interpretation of physiological and emotional reactions stimulated by pre-empting or experiencing the given task.

These sources will be explored in more detail later as we draw on them to interpret our findings.

Designing a curriculum that develops students' self-efficacy is difficult. Van Dinther et al. (2011) suggest that curricula be structured to encourage students to practice and build up mastery by frequently applying their knowledge and skills to authentic, diverse and complex situations with opportunity for self-reflection, self- and

peer-assessment and small group learning. Kalaian and Kasim's (2014) meta-analysis revealed that small group learning methods can increase performance in statistics. Group work, however, is challenging; it can increase students' anxiety through feeling exposed (Russell and Topham 2012) and enables freeloading where some students gain benefit with little input (Dommeyer 2007). Mitigating against these negative perceptions is essential as teamwork is a highly valued graduate skill (Taylor 2011). One form of small group learning that aligns with van Dinter et al.'s (2011) advice, is beginning to gain notice for teaching statistics (St. Clair and Chihara 2012), and that we have experience of (Greetham and Ippolito 2018), is TBL.

Principles of TBL

TBL is an iterative teaching method, repeated a number of times during a term or semester-long course (Parmalee et al. 2012). TBL is structured with distinct stages delivered in a three-step cycle (Parmalee et al. 2012): learner preparation (pre-work), in-class readiness assurance testing (RAT) and an application-focused exercise (tAPP; Figure 2 right).

[Figure 2]

The rationale for assigning pre-work is to free-up class time for learner interaction. In class, students complete an individual readiness assurance test (iRAT) designed to assess conceptual understanding gained from the pre-work. This is followed by a team readiness assurance test (tRAT) where students discuss and answer the same multiple-choice questions (MCQs) in pre-allocated teams. Class discussion of the answers is held after the tRAT to correct widely misunderstood concepts and prepare the teams for the application exercise (tAPP) stage.

The tAPP stage presents opportunity for teams to apply conceptual understanding to solve authentic, novel problems whilst developing their team working skills. It requires the team "to make interpretations, calculations, predictions, analyses ... and make a specific choice from a range of options" (Parmalee et al. 2012: e227; Figure 2). Further class discussion encourages students to explain their rationale and provides feedback and clarification. Teams may challenge the "best" answer in the RAT and tAPP, and a successful appeal would result in additional marks.

The final element of TBL is peer assessment, whereby students grade, and give qualitative feedback on, each other's contributions. This holds students accountable for their contributions, encouraging them to modify any unwelcome behaviour, such as freeloading or dominating.

Self-Efficacy and TBL

In Figure 2 we attempt to show how the different sources of self-efficacy align with the different stages of TBL. Research on the effect of TBL on student self-efficacy is limited to quantitatively comparing the self-efficacy of students experiencing a traditional didactic approach to TBL (e.g. Loftin and West 2017). Our research was designed to help to fill the gap in knowledge into *how* self-efficacy is affected by TBL through qualitatively exploring students' views of their TBL experience.

Research Design

The compulsory statistics courses are delivered as single blocks of teaching over six (Year 1) or eight (Year 2) consecutive teaching days for each year group, followed by a summative individual test. Despite TBL usually being spread over a term/semester, we were hopeful that this format would build self-efficacy as students would only be learning statistics during this period, and so would be practicing and building up their skills and knowledge with their team each day. The spring-term Year 1 course starts with introduction to programming in *R*, data manipulation and visualisation, and then moves on to basic statistical tests (i.e. t-test, F-test, linear models). The autumn-term Year 2 course starts with a refresher of the Year 1 course and then progresses to more advanced statistical tests (e.g. analysis of covariance). Student feedback that the previous teaching method was passive, suggests that students took a surface approach to their learning, sometimes cutting and pasting *R* code from the workbook and not taking time to actively process material.

Action Step 1 (Figure 1) was to implement TBL for Year 2 students. Teams consisted of 5-6 students to aid cohesion. They were strategically formed to include an approximately equal mixture of students of academic abilities (based on Year 1 statistics test results), gender and Home/Overseas fee status. We judged that this combination would aid peer learning and inter-team competition, and help to build

connections between students that we observe do not naturally choose to learn together (Ippolito, 2007).

We tried to reduce anxiety in three ways. Firstly, assessment of TBL was formative rather than summative, as we did not wish to over-assess students in such a short timeframe. Secondly, acknowledging that group work may increase anxiety, we allowed students to work individually during an in-class workshop before the iRAT to familiarise themselves with concepts they would later make sense of together. Thirdly, a ‘catch-up’ session during the course, gave students a further opportunity to clarify their understanding.

TBL occurred during five of the six consecutive teaching days with the remainder of each day allocated to completing pre-work for the next TBL. The timings for the in-class sessions was: 120 min workshop, 15 min break, 16 min iRAT answering 8MCQs, 16 min tRAT, and 45 min tAPP (Figure 3).

[Figure 3]

Our learning technologists developed a Qualtrics® electronic scratch card system that gave a platform to submit and monitor iRAT and tRAT marks in real time. Teams could see whether their tRAT answers were correct immediately, and additional written feedback on RATs was sent at the end of the day. Teams submitted their tAPP answers (including *R* script and graphical images) in a Blackboard® quiz. Marks and written tAPP feedback were usually sent by the start of the next TBL session with a discussion at the start of the session to clarify misunderstanding. Anonymous peer feedback was collected after the 4th TBL session, allowing students to act upon it during the final session. We felt that students would be more likely to give constructive feedback to peers if the process were anonymous (Lu and Bol 2007). Students were given guidance on peer-evaluation and constructive feedback in summer-term Year 1 TBL exercise, and were reminded of these guidelines.

We continued with the action research (Figure 1) by evaluating Action Step 1 (Year 2 statistics teaching) in order to undertake Action Step 2 (Year 1 statistics teaching).

Data collection and analysis

The whole year cohorts of 149 Year 1 and 135 Year 2 students, and teaching team comprising 3 teaching fellows and 2 learning technologists, participated in this action research. Multiple sources of data were collected between November 2018 and May 2019 following approval obtained through the University's Education Ethics Review Process.

Student performance

We accessed students' formative TBL and summative statistics test results. The summative test was computer-based, open-book, and internet-enabled with access to *R* software. The tests took place 15 days after the final TBL session for Year 1 students, and one day after the final TBL session for Year 2 students.

Surveys

Year 2 students were invited to complete a pre-TBL teaching survey, administered in Qualtrics® software, that comprised of the Self-Efficacy to Learn Statistics (SELS: Cronbach's $\alpha = 0.98$), and the Current Statistics Self-Efficacy (CSSE: Cronbach's $\alpha = 0.94$) instruments from Finney and Schraw (2003). These instruments related to concepts that students met in Year 1 and would revisit in Year 2. Students were asked, for example, to rate their confidence to *learn* (SELS) or their *current ability* (CSSE) to "identify the scale of measurement of variable" and "interpret the probability value (p-value) from a statistical procedure". 41% of the Year 2 cohort responded to the survey.

Year 1 and Year 2 students were invited to take part in a post-TBL surveys. The surveys consisted of the CSSE (Cronbach's α : Year 1 = 0.89, Year 2 = 0.92), the Collective Efficacy (CE) instrument developed by Lent, Schmidt, and Schmidt (2006), and the Team-Based Learning Student Assessment Instrument (TBL-SAI)® developed by Mennenga (2012). The CE instrument was modified slightly so that Question 2 now read "Find ways to bridge individual differences (e.g. personality) between team members" and Question 4 now read "Develop a workable approach in a reasonable amount of time" (Cronbach's α : Year 1 = 0.95, Year 2 = 0.94). Two questions (Q23 and Q31) from the TBL-SAI were omitted from analysis as the Year 1 students had not undertaken exams where TBL had been used. Cronbach α for the revised total scale was

0.91 for Year 1 and 0.77 for Year 2, both exceeding the suggested minimum of 0.70 for reliability (Tavakol and Dennick 2011). In the TBL-SAI, Q43 is a free text question that asks students to “Please add any comments you may have about your experience with team-based learning”. Response rates for Y1 and Y2 were 24% and 36% respectively.

Focus Groups

We invited volunteers to participate in a Year 1 or Year 2 focus group interview as we wanted to gain understanding, through group discussion, about a social learning experience with peers aware of the same context. We anticipated the risk that participants may feel silenced, influence each other or say what they considered socially acceptable, rather than what they really perceived (Savin-Baden & Howell-Major, 2013). In reality diverse and strong opinions were shared. To reduce coercion and power imbalance Kate Ippolito, who has no involvement in teaching or assessment of these students, recruited and facilitated both focus groups which both comprised 6 participants. Focus groups were semi-structured, guided by open questions allowing students to talk about challenging and valuable aspects of their TBL experiences. Questions were not informed by self-efficacy theory to avoid biasing the data. At the end of the teaching cycle, focus group data were transcribed, anonymised, and coded independently by two of the authors. Codes were then compared, discussed and organised into themes. Given that our aim for this action research process was to understand in what ways we succeeded in developing self-efficacy around statistics and programming, as well as what created barriers or reduced self-efficacy, our data analysis was theoretically driven rather than inductively driven (Braun and Clarke 2006; Grothérus, Jeppsson and Samuelsson 2018).

Results and Discussion

Teaching team’s Evaluation of Action Step 1: Year 2 Teaching

Our in-class observations were that students were more engaged, attendance was higher

for all sessions than the previous year, and teams appeared to be cohesive and functioning well. We could see that peer-learning was effective as real-time learning analytics showed that student scores increased from iRAT to tRAT.

On the basis of this evidence we felt the change in teaching was beneficial to students and were pleased that the majority of students who responded in the post-TBL survey found TBL a better way to learn statistics than the previous approach. However, we felt we could improve the teaching design for Year 1 students.

Firstly, the in-class workshop was reduced to 60 min to emphasise the team-based activities in the tAPP, and to reinforce the need to complete the pre-work in advance and not during the workshop. The revised timings were: 60 min. workshop, 15-min. break, 16-min. iRAT answering 8MCQs, 16-min. tRAT, and 105 min. tAPP (Figure 3). Although Year 2 students did not complain about any of the timings, allocating more time to the tAPP could alleviate possible time pressures and anxiety experienced by the Year 1 students.

Secondly, the learning technologists used teacher and student feedback to improve the user experience of the software. For example, written tRAT feedback was provided immediately to Year 1 students after answering each tRAT question. This enabled students to reflect in real-time and discuss the feedback further with their peers.

Finally, we felt more time was required to introduce Year 1 students to *R* programming, and thought this best served by scheduling the first two sessions without TBL to allow students more time to go at their own pace. TBL started when we moved from programming *per se* to teaching statistics.

Teaching team's Evaluation of Action Step 2: Year 1 Teaching

An anonymous survey of students asked: "Did you do the pre-work?" The responses: None = 6.25%; Some = 21.25%; Most = 40%; All: = 32.5% coincides with observations that students spent class time completing the pre-work, despite the emphasised requirement to complete it in advance. We also observed that team cohesion was not as strong as in Year 2. There was also a reluctance of students to find the solution to a query themselves, through 'Googling' or using the help function in *R*, with noticeable frustration around this.

Quantitative results

The SELS instrument in the pre-TBL survey is a measure of confidence related to learning how to complete given statistics tasks. SELS was correlated with summative test grade for Year 2 students (Pearson's correlation coefficient, $r = 0.42$; $t = 3.32$; $p\text{-value} = 0.002$). There was a significant increase in current statistics self-efficacy over just one week of teaching as the CSSE increased by 25.10 between the pre-TBL and post-TBL surveys (Welch's two-sample paired t-test: $t = 11.28$, $df = 28$, $p\text{-value} < 0.001$). However, post-TBL CSSE measured *after* the summative test was taken was not significantly correlated with the summative test grade. In contrast, post-TBL CSSE was measured *before* the test was taken for Year 1 students and was significantly correlated with the subsequent performance in the summative test (Pearson's correlation coefficient $r = 0.4$; $t = 2.53$; $p\text{-value} = 0.02$).

Overall, therefore, the results indicate that some measure of self-efficacy for statistics is correlated with summative test grade in both years, and for Year 2 there was an increase in CSSE self-efficacy during the course. As correlation does not equal causation, we cannot be certain that the TBL had a causative effect on self-efficacy. However, peer learning did result in students performing better, on average, on the first attempt of the tRAT than the iRAT in each TBL session.

In terms of applying knowledge to new problems in their Year-specific tAPPs, Year 1 teams performed as well on average as Year 2 teams with mean tAPP scores of 71.5% ($SD = 12.44$) and 69.2% ($SD = 11.83$), respectively. However, Year 2 students had a higher collective efficacy (Lent, Schmidt and Schmidt 2006) than Year 1 students, suggesting that they had greater confidence in their team's capabilities (mean CE score = 77.29 versus 70.25; Welch's t-test, $t = 2.18$, $df = 56.50$, $p\text{-value} = 0.03$). Moreover, there was also a difference between the years in their assessment of TBL. Year 2 students who completed Mennenga's (2012) TBL-SAI had a higher score than Year 1 students suggesting they had a more positive experience of TBL (mean of 117.85 versus 106.94; Welch's two-sample t-test: $t = 3.30$, $df = 51.5$, $p\text{-value} = 0.002$).

Qualitative Results: Post-TBL survey (Q) and Focus Groups (FG)

Guided by Kulhanek et al. (2019) we present our findings below according to theme rather than action research cycle.

Differences between Year 1 and 2 student perceptions

Although our action research approach intended data to be used iteratively not comparatively between year groups, we were struck by strong differences that the anonymised post-TBL questionnaires completed by the 45 Year 1s and 40 Year 2s revealed. These gathered qualitative responses around perceived value and triangulated well with the quantitative results, including the post TBL-SAI surveys in which Year 2 students were also resoundingly more positive than Year 1 students. Views from the focus groups were similarly polarised, although it was difficult to separate out how much this was influenced by more vocal participants (Savin-Baden & Howell-Major, 2013), particularly in the Year 1 focus group. As anticipated, a significant factor for the Year 2 students was that relative to their more passive Year 1 experience TBL had been much more engaging and valuable as the following quote indicates:

“I think that a TBL approach for statistics is definitely a keeper. I mean in comparison to what we had last year...there was a bit of self-learning, there was team tests, there was discussions, and then especially with the tAPP where you kind of created your own things, I think everyone really enjoyed it and, yes, you just learned from each other.” (Year 2, FG).

We were delighted about the extent to which Year 2 students understood the rationale for TBL stages and recognised its impact.

Although some Year 1 students were very positive about their TBL experience, unlike most Year 2 students, many were not convinced by the active approach:

“Overall, I prefer lectures to TBL because I feel they are more focused than TBL, which personally makes them more efficient. Additionally, TBL is slower and it is harder to go over tasks in the same way compared to tasks designed for independent study, and it is harder to record the stuff taught, unlike lectures which have Panopto [lecture capture].” (Year 1, Q).

The need to be efficient and pedagogical features that were perceived to promote efficiency was a strong theme amongst Year 1 students but much less apparent amongst Year 2 students. In part this difference can be attributed to students’ developing conceptions of what university learning and teaching feels like, their exposure to different strategies and evaluation of the relative merits based on those experiences. What students *perceive* they learnt can be very different to what they *actually* learnt, especially when unfavourably comparing active learning to traditional lectures

(Deslauriers et al. 2019). Year 2 students had participated in TBL twice before and articulated which topics and learning outcomes they felt TBL was best suited to, statistics being one. They saw TBL as a way to build everyone's competence: "We were not really good at R at the beginning but we were all engaged." (Year 2, Q). This also reflects the high level of collective efficacy in their team that Year 2 students possessed relative to Year 1 students. Year 1 students had not experienced TBL before, and were more likely to attribute teamworking experiences to good or bad luck, suggesting a lack of agency for influencing the team dynamic, for example, "I was lucky that I had a good group so it was sort of OK, some people learnt nothing and hated it because of a bad group." (Year 1, Q).

Year 2 students also seemed less fixated on summative assessment, which is well-recognised as directing student attention and effort (Boud and Falchokov 2007). For some Year 1 students this keen focus on summative outcomes prevented them seeing the value of the formatively assessed teamwork, deliberately designed to be developmental, low stakes and less anxiety-provoking (Jessop and Hughes 2018). Comments included: "At the end of the day we're here for a degree, we have to get a decent grade." (Year 1, Q). Other students held broader conceptions, for example: "It is important to develop communication skills to be a balanced person and despite the fact that my grades may not show a massive increase, my soft skills improved significantly." (Year 1, Q).

Mastery experiences

According to Bandura (2008, 169) "The most effective way of building a strong sense of efficacy is through mastery experiences." Bandura's assertion that failure weakens self-efficacy "especially in the early phases of efficacy development when people feel insecure about their capabilities" (169) was something we can identify in students who reported getting stuck. For example, Year 1 students without prior programming competency highlighted a need to reduce the additional pressure of limited time and high volume of input in the early stage.

Other students perceived that they had not yet had adequate mastery experience and their comments revealed discomfort and decreased self-efficacy:

“I cannot attest to the effectiveness of TBL since I have not done examinations. I do know though, that I have gaping gaps in my Stats knowledge despite TBL, that I shall have to fill in by independent study.” (Year 1, Q).

According to Bandura the important factor for building resilient self-efficacy is how this learner recovers from and learns from their ‘set back’, potentially before the summative assessment. Note also how this discomfort influences a learner’s evaluation of the pedagogical approach’s effectiveness. Year 2 students appeared more able to judge the impact of their mastery experience on their statistical and programming ability without validation from a summative assessment:

“I don’t know if TBL improved my grade yet but I definitely feel like the process of learning was better for me in these sessions compared to last year” (Year 2, Q).

Despite evidence that TBL most greatly benefits students with previous assessment results in the lowest quartile (Koles et al. 2010), instinctively students perceived that peers with higher self-efficacy gained more:

“I think the TBL may be more helpful to those who were more confident with the content as they could work through problems together. Whereas those of us who were more confused may have struggled to keep up with them.” (Y1, Q).

Bandura advocates the value of struggle during mastery experiences for building self-efficacy. However, our students often saw it negatively as evidence of not keeping up with others: “You can be really down as well if people are like really good and if you’re just a newcomer to R.” (Year 1, FG). This appears to lower self-efficacy and mood which in turn affect each other.

Given the potential for university learning to seem individualistic, and unhelpfully competitive, it felt important that some students recognise this opportunity to develop social efficacy or as this student puts it: “sometimes at university you feel like it’s an individual... Like you’re in it for yourself, so it is quite nice sometimes having like a bit of a like a mutual goal, like a connection.” (Year 2, FG). This idea of ‘connection’, which other students referred to as a ‘sense of belonging’, resonates with the argument for promoting social support amongst peers as a way to enhance their well-being (Leach 2015). It is a learning outcome that, on reflection, we want to make more explicit from the outset.

Social Modelling

A second means of building self-efficacy is through social modelling. “Models are sources of aspiration, competencies and motivation. Seeing people similar to oneself succeed by perseverant effort raises observers’ beliefs in their own abilities” (Bandura 2008, 169). Various students cited benefiting from and being motivated by peers’ competence when some individuals served as ‘mastery models’ (Schunk and Hanson 1985). For example: “some people have done like lots of maths and stuff at school, but a lot of people on this course haven’t, and so like having a chance to like learn other people’s ways of learning stats.” (Year 2, FG).

Although encouragingly this student referred to their peers’ approaches rather than just their knowledge, they made no mention of the effort they saw peers apply. Amongst our findings we note an absence of reference to ‘coping models’, those who are observed or perceived to have struggled which strengthens self-efficacy in themselves and those around them (Schunk and Hanson 1985). This limited the building of self-efficacy through social modelling and we reflect that we need to encourage ways for the effort involved in learning to be discussed. Conversely, where students reported that teammates had developed programming competency prior to the course and had been unable to observe the effort this required, this hindered self-efficacy building of peers without programming experience: “I feel like only the people who are good in coding/stats do most of the work, that some team members did not learn much from the activity.” (Year 1, Q). Furthermore, this prior experience in peer models appeared to mask any perseverant effort they *were* making in the eyes of ‘struggling’ teammates: “Because someone like who has experienced the coding, they can learn quickly.” (Year 1, Q).

Social persuasion

A third way to promote self-efficacy is social persuasion; encouragement and discouragement from *credible persuaders* shapes our beliefs about our capabilities. (Bandura 2008). We identified three types of potential credible persuaders to provide *enabling guidance* (Bandura 1997): teachers, peers and near peers.

Enabling guidance from teachers. Although TBL requires teachers to observe rather than directly intervene (Parmalee et al. 2012) some Year 1 teams indicated wanting more teacher guidance on how their team should be working. For example, “it’s so obvious to tell a group that’s working together or not... All they have to do is just come over and just say, ‘hey guys’, and give that occasional push” (Year 1, FG). A reoccurring theme amongst Year 1 was for more direct teacher input. Some students did not appreciate effort by teachers to introduce them to support available from the online community of *R* programmers but rather perceived it as an absence of teacher guidance: “just a teacher standing on the side and you put your hand up and say, ‘oh, this isn’t working’. They’ll either change it for you or they’ll like ‘why don’t you Google it?’” (Year 1, FG). We therefore recognise the need to explore the process of team-working and discuss the role of teachers with students before the TBL teaching starts.

Enabling guidance from peers. This action research caused us to critically consider the challenging nature of peer learning for students. Peer learning can require knowledge which may not be evident, for example: “Because there are two people being bad and they can’t help each other.” (Year 1, Q). It requires altruism and patience that cannot be assumed: “I remember I asked someone can you show me how you’ve done that and there was like, ‘yes, in there’. And every time I asked, they just continued doing their own work.” (Year 1, FG). A recurrent theme related to students not having completed the pre-work thus reducing their ability to contribute to their peers’ learning. This put the responsibility on teammates who had prepared and reduced enjoyment: “I felt that most of my teammates did not do the pre-work but because I had they expected me to help them. If everyone had done the pre-work then it would have been a lot more enjoyable” (Year 1, Q). We hoped that peer-evaluation would act as motivation to complete pre-work, however the formative nature of the TBL perhaps over-rode this pressure.

Although recognising the educational value of articulating their own understanding, some students felt unable to fill gaps in their peers’ understanding left by lack of required preparation:

“I think for myself, it is really helpful since TBL forced me to describe things I understand and know in words, but I can’t stop but notice some members of the group being unable to join in because he/she haven’t completed a chapter or may

not learn as well as others. There was nothing I could do since it was sometimes hard to teach/explain everything within the discussions.” (Year 2, Q).

Others reported discomfort that their lack of competency in *R* programming and statistics meant they couldn’t contribute to teamworking as they wished to. Despite this there were many examples of peer teaching and learning:

“Particularly in my group, there were a couple of people who had like different ways of looking at bits of code and stuff and like easier ways of doing things, that sometimes the notes explained in a more complicated way. Like they just have little tips and stuff that was really useful to like pick up.” (Year 2, FG).

However, enabling guidance was less evident in other teams and got in the way of developing others’ self-efficacy, potentially also masking gaps in understanding:

“They just literally typed away; did it. And all the others who were trying to figure out from like talking to the side, like, oh, well, how do you do this? ...but at the end of the day just click submit and it looks to you that we’ve done it and we all understand it but the reality is one person’s effort.” (Year 1, Q).

‘Enabling guidance’ from near peers. Some students valued encouragement from senior peers, however, as Bandura warns “Unrealistic boosts in efficacy are quickly disconfirmed by disappointing results of one’s efforts” (Bandura 1995, 4). Rather than being reassured that the spiral curriculum design allows for more mastery experience in later years, this student appears to interpret their lack of current competency as predictive of future achievement, thus reducing their self-efficacy:

“After I asked them when I was getting stuck and they said, ‘Oh, it’s okay, we understand; it’s quite difficult’ ... they said ‘you use *R* in consecutive years’ and if it’s only just been rushed through a week where the learning wasn’t exactly accessible for someone like me, I definitely will struggle later on in year two and three.” (Year 1, FG).

Physiological and emotional states

“People also rely partly on their physical and emotional states in judging their efficacy. They read tension, anxiety, and weariness as signs of personal deficiencies.” (Bandura 2008: 169). Many student responses gave insight into the way they were interpreting

their emotional response to this learning experience and a number of these related to perceived deficiencies. For example, “a couple of days in, my attitude was so negative going into it because I didn’t understand like what was going on.” (Year 1, FG).

Confusion and frustration were common emotional responses that students reported. Rather than framing these positively by reflecting on the outcome at the end of a challenging process, some blamed their lack of efficiency or competency, or problems with the educational design. For example:

“when someone did know how to do something/figure it out, it was usually in a more complicated way than necessary, so confused the rest of the team more...So we wasted a lot of time doing things wrong which was very frustrating and often led to us giving up and still not knowing the correct way to do things.” (Year 1, Q).

Giving up in the way this student describes is a characteristic of low self-efficacy.

Others found working in a team more energising than debilitating and recognised the benefits of connecting with others to learn specific aspects, sharing successes, getting insight into how others learn and feel about their learning, and for some, welcome ‘light relief’. Here it appears that TBL promoted positive mood which in turn enhances self-efficacy (Bandura, 2008):

“I feel like to work in a team is a more relaxed way for me to study. Because I study alone when I get stuck, I feel like very sad. And if I work in a team, I can have the chance to like ask someone else in the team that we can discuss and otherwise we can ask for help.” (Year 1, FG).

Emotion is a significant feature of learning and this action research has highlighted to us the importance of acknowledging and responding appropriately to learners’ emotions. Importantly sometimes responding means not reacting by taking action that is obvious to students but holding their various emotional responses, in particular ‘holding the tension’ (Gilmore and Anderson 2016). This realisation has significant implications for the outcomes of this action research. Where previously we would have tried to adjust pedagogical features that we discovered provoked ‘negative’ emotional responses in students, we now have confidence that this may actually be an activating negative emotion (Cavanagh 2016) and a necessary part of the complex process of self-efficacy building. We will be more explicit about the emotions learners

may experience and encourage them to see relationships between this and self-efficacy building. This is valuable going forward as individuals with high self-efficacy are less likely to experience overwhelming anxiety and interpret their state of affective arousal more positively e.g. as energising (Bandura 1994) which could offer potential to address well-being concerns. Furthermore, O'Brien (2010) highlights the importance of showing how, as university teachers, we care about students and conducting action research is a good way to show we care.

Conclusions and future action

This action research process created a valuable opportunity to engage more deeply with students' views on their learning experiences. Furthermore, we had not anticipated such value in analysing and interpreting data with fellow university teachers in a theoretically-informed way. This has both enabled us to identify locally evidenced action points for our own and institutional practice and make well-underpinned recommendations for others interested in helping students to build self-efficacy.

Our quantitative data provides evidence that TBL is an effective way to teach statistics and qualitative data helps us understand how to refine our approach. Our main learning point was that if we are to support self-efficacy building, students need better equipping to learn from each other in teams, this includes being more explicit about our educational rationale and acknowledging negative learner emotions associated with the effort required to build resilient self-efficacy. Conversely, we are reassured that Year 2 students were better able to collaborate, peer learn and to recognise the value of this, so we increasingly see our role as 'holding the tension' for learners who are at various stages of transitioning to learning in this university setting. Delaying TBL for teaching statistics to Year 2 in response to some Year 1 students' anxiety would simply shift the problem to later. We encourage our colleagues to use TBL earlier in Year 1 teaching in order to develop familiarity and also to build learners' self-efficacy for TBL and collaborative learning more generally.

As a result of our research, we will take the following action next year. Firstly, we will facilitate an ice-breaker session in which we foreground the rationale of TBL, the role of the teacher and characteristics of successful teams. This session will allow teammates to get to know each other in a social setting in order to build team cohesion

and reduce social anxiety (Scott-Ladd and Chan 2008). Students will discuss their experiences of teamwork and their hopes and concerns regarding the forthcoming teamwork. With teachers signposting previous teamwork approaches, the teams can discuss how they will manage teamworking, approaches they will use to coordinate tasks in the tAPP, how they will manage conflict, how they will feedback to and support each other, etc. They will also be tasked with producing a team contract. This may help teams agree strategies that will pre-empt the problems they have previously experienced with teamwork (Chang and Brickman 2018).

Secondly, the teaching team will discuss their roles in delivering TBL and agree upon a strategies to support teams experiencing difficulty without using direct instruction, and to aid teams that are not working well together.

Finally, we will revise the allocation of course credit: 75% of the course credit will be allocated to the summative test and 25% will be allocated to TBL. We have chosen to summatively assess the final tAPP stage of the TBL, as given a key learning outcome is teamworking, we want to explicitly reward the collaborative, integrative aspect that applies knowledge gained to the end-product of the TBL cycle. We believe that if students have engaged with all previous TBL stages this will be reflected and rewarded in the tAPP mark. Furthermore, we are still wary of over-assessing students in such a short period of time by also summatively assessing the RAT. We have observed that summative assessment, even of a small weighting, creates anxiety and a distraction from what we feel to be important, such engaging with other perspectives and testing out new understanding. Therefore, we want to contribute to an evidence base to support the aspiration that students can be intrinsically motivated to make effort to achieve as a team rather than the reward be extrinsic motivation of summative marks.

All team members will be required to submit a tAPP answer. Since the teacher will award the team's mark based on a randomly chosen tAPP answer from one member of the team (Roseth, Garfield, and Ben-Zvi 2008), this should provide motivation for completing the pre-work and peer-learning.

Peer evaluation will remain purely formative as we see the main benefit as giving students the chance to develop their ability to give and receive feedback from different perspectives. Having to give peers marks, which may be uncomfortable and can lead to gaming, creates a distraction from our educational intent (Sridharan, Tai, and Boud 2019).

As well as enabling us to develop our teaching of statistics, this action research has allowed us to make general recommendations (shown in Table 1) for other practitioners hoping to help their learners build self-efficacy through collaborative small group learning such as TBL.

[Table 1]

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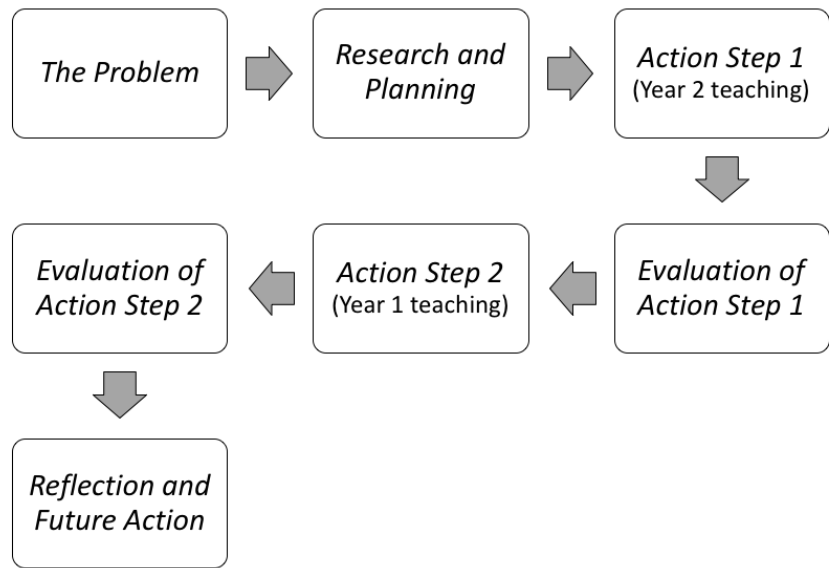
Table 1. Recommendations to help students build self-efficacy through targeting the four sources of information used to judge self-efficacy (Bandura 1997-2008). Team-based learning explicitly targets these sources (see Figure 2)

Source	Building self-efficacy through teamwork
Mastery experiences	• Design teaching to provide cycles of mastery experience, including developing teamworking capabilities and possibility for facing obstacles and setbacks. Students should be aware of and prepared for this. • Plan mastery experiences to become increasingly difficult and create opportunity to recover from setbacks, including time to catch up through support or self-study.
Vicarious experiences i.e. social modelling	• Consider whether learners have enough opportunity to identify, observe and engage with ‘mastery models’ and ‘coping models’ and encourage students to talk about the effort involved in their learning. • Identify how students can be encouraged to invest in peer learning e.g. team contracts and summative marks to award teamworking
Social persuasion	• Provide well-signposted feedback on conceptual understanding, application, and teamworking. • Emphasise self-improvement over comparison with others. • Promote good quality peer feedback.
Emotional and physiological states	• Develop learners’ (and teachers’) emotional awareness. By talking about the emotions involved in learning, they can be better aware of how they perceive, interpret and manage physiological and emotional reactions to learning situations.

Figure 1. Lewin's model of action research (adapted from Smith 2007)

Figure 2. Sources of information for judging self-efficacy align with the stages of team-based learning (TBL). TBL is repeated in a number of cycles during a course. This allows students to acquire and repeatedly apply knowledge to develop mastery, and to use modelling, and feedback on performance to further increase knowledge. These features of TBL together with reducing anxiety where possible should help build self-efficacy. Multiple-choice questions are abbreviated as MCQs.

Figure 3. Timings for each stage of the TBL sessions for Year 2 students (Action Step 1) which were revised for delivering to Year 1 students (Action Step 2).



Sources of self-efficacy

Mastery
Experiences

Vicarious
Experiences

Social
Persuasion

Physiological &
Emotional
States

Team-based learning (occurring repeatedly during course)

Pre-work

- Examples include
 - Viewing and studying a pre-recorded lecture
 - Reading and studying a book chapter/research paper

iRAT

- Answer MCQs individually. Score 1 mark if correct
- Answers not revealed

tRAT

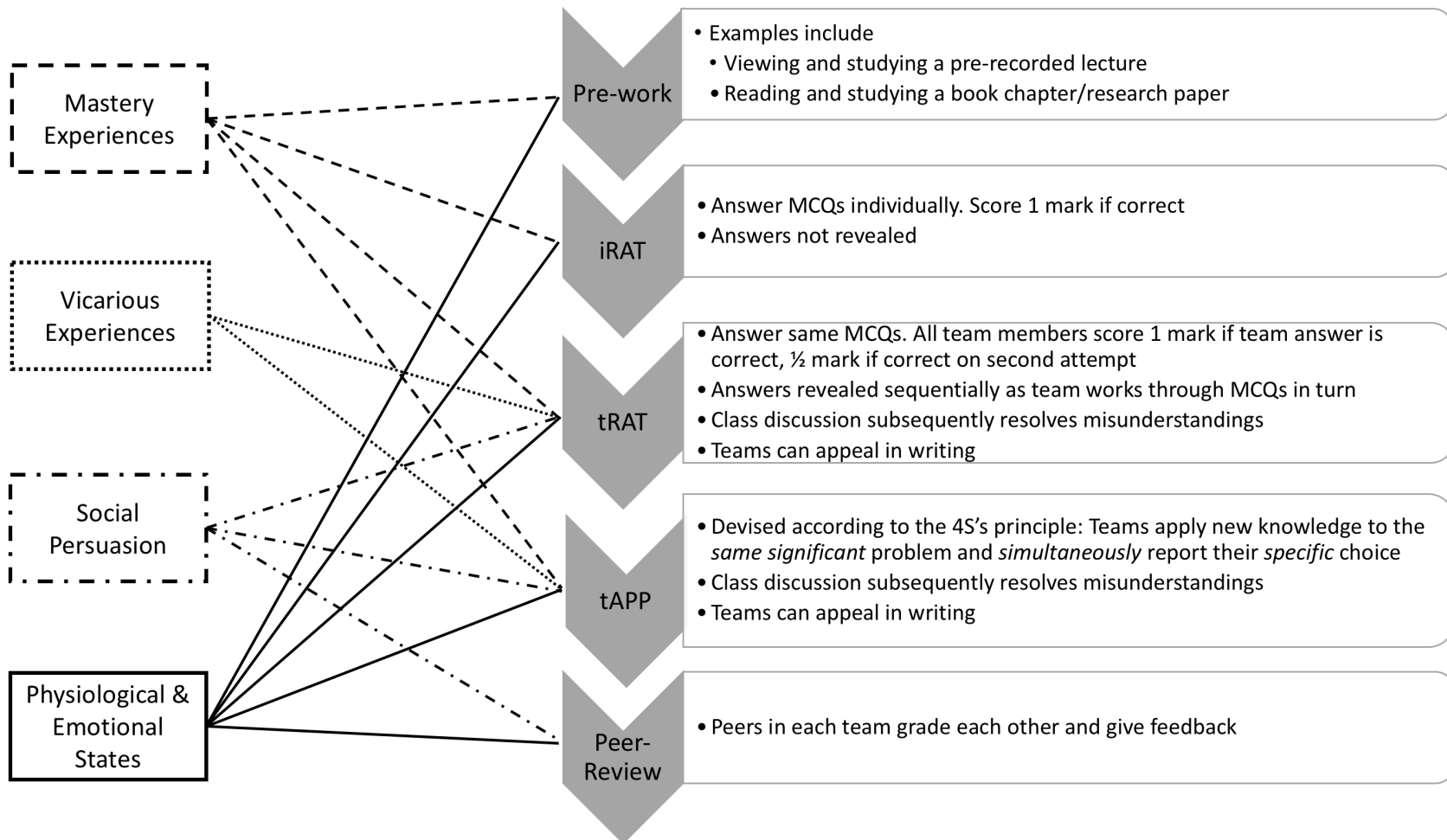
- Answer same MCQs. All team members score 1 mark if team answer is correct, ½ mark if correct on second attempt
- Answers revealed sequentially as team works through MCQs in turn
- Class discussion subsequently resolves misunderstandings
- Teams can appeal in writing

tAPP

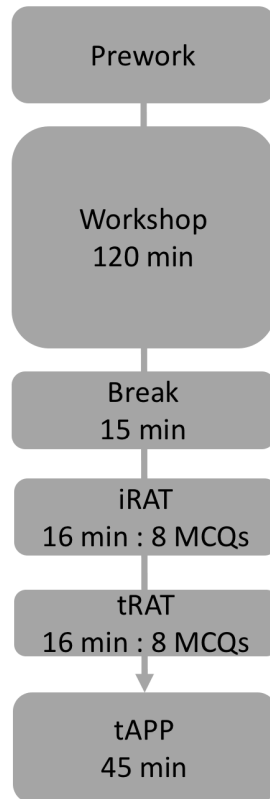
- Devised according to the 4S's principle: Teams apply new knowledge to the *same significant* problem and *simultaneously* report their *specific* choice
- Class discussion subsequently resolves misunderstandings
- Teams can appeal in writing

Peer-
Review

- Peers in each team grade each other and give feedback



Year 2 TBL Sessions



Year 1 TBL Sessions

