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ABSTRACT

Bioscience is a foundational unit (subject) of undergraduate allied health degree programs, providing students the scientific basis underpinning their clinical practice. However, despite its significance, bioscience is a difficult academic hurdle for many students to master. The introduction of active learning strategies including small team-based guided inquiry learning approaches, has been shown to significantly reduce this hurdle and improve assessment outcomes for the learner. Guided team based activities can aid in this approach by also building broader skills and capabilities like teamwork and communication, as well as subject specific knowledge and skills, thereby positively influencing students assessment outcomes. This paper details the redesign and evaluation of two first-year Bioscience for Paramedics units with the introduction of guided inquiry learning, as well as other active learning strategies and assesses their impact on student performance. Results indicate that active learning used within a classroom and in the large lecture theatre setting, improved students' grades with positive student perception of their learning experience.

KEYWORDS*:* active learning, bioscience, first year transition, guided inquiry learning, paramedic,

INTRODUCTION

Advances in physiology and medical knowledge require allied health professionals to possess an advanced understanding of many fundamental bioscience concepts. Bioscience provides clinicians with the scientific basis underlying clinical practice, continuing education and development of best practice, as well as enabling future study pathways into related professions, such as research or specialisation. However, despite its significance, bioscience units, in tertiary education, prove to be a difficult hurdle to master for many students (16, 35) resulting in disproportionately high failure rates. These high failure rates have often been attributed to external factors such as lower university entrance scores and lack of previous science study (7), yet curriculum design and teaching approaches may also play a central role. In contrast, an understanding of the mechanism of disease has been shown to ultimately improve patient care and outcomes (10, 26, 36). Thus, the importance in succeeding in anatomy and physiology (A&P/bioscience) forms the foundation for future success in allied health courses as a whole.

Bioscience for Paramedics 1 (BIO 1, semester 1) and 2 (BIO 2, semester 2) are first year introductory units for the study of anatomy and physiology taught across two semesters. These units are a component of an Australian accredited Bachelor of Paramedics Degree, and are taught at Victoria University at a single campus with approximately 180-250 students enrolled in a given year. It is important to note that there is minimal literature available on A&P pedagogy in a paramedic education context (35). Our first year students often struggle with both the content volume as well as complexity of the concepts contained within these units. The reasons for this are multi-faceted, including a lack of relevant high school preparatory subjects, specifically chemistry or biology (7); a larger number of mature-aged students within these units who are returning to formal education after a significant break (12); anxiety towards studying science

based subjects (7) or simply lack of engagement. Despite the introduction of peer-assisted study sessions in 2010, the overall failure rate in 2012 continued to remain relatively high, at approximately 13% in an A&P unit for semester 1 of year 1 of the degree (12). Furthermore, as the BIO 1 unit is a prerequisite for BIO 2, the second semester unit, students who fail need to add an extra year of study to their course. Consequently, many students who fail a BIO unit inevitably need to change their enrolment status to part-time, transfer to a different course or leave the University altogether. Available data have shown high attrition rates at the first year level for many health-related courses (14).

Previous teaching activities in these A&P units included formal lectures (with large student numbers of 200) and tutorial classes (smaller numbers of 25-35 students). The focus of these units was teacher centered through lectures and tutorials. The re-designed units explicitly shifts the focus of learning away from a didactic approach to an inquiry based approach (5). To improve student outcomes, we introduced unit curricula changes, employing a range of active learning strategies, such as: (1) guided inquiry learning in small group based tutorials; (2) use of audience response systems in large group lectures; and (3) use of pre-tutorial quizzes prior to weekly tutorials.

There is extensive literature supporting active learning as beneficial to significantly improving student performance in science and physiology (8, 11, 21). Research has also shown that critical factors such as transition, diversity and design should be taken into account for development of curriculum that will lead to a successful first year experience (17-19). The guiding principles suggested by Kift (17) are as follows:

- Transition – *it should allow a smooth transition from previous learning experience*
- Diversity – *it should be attuned and inclusive to the diverse range of students*
- Design - *it should be learning focussed and scaffold for student success*
- Engagement - *it should involve active learning and engage students*
- Assessment – *it should give students regular feedback on their progress*
- Evaluation and Monitoring - *it should be regularly evaluated and improved*

Kift states that "The curriculum and its delivery should be designed to be consistent and explicit in assisting students' transition from their previous educational experience to the nature of learning in higher education and learning in their discipline as part of their lifelong learning" (17). We focused on the guiding principle of student engagement and as such, the active learning strategies employed in this study formed an important consideration in the re-design and delivery of our first year university program, so that students are engaged "through the intentional integration and sequencing of knowledge, skills and attitudes" (3, 17).

RESEARCH REVIEW

Active Learning in Small Class Tutorials

BIO 1 and BIO 2 are first year introductory units for the study of anatomy and physiology for the paramedic degree. Students typically enrol in 4 units, which run concurrently for a 12 week semester or term. Other units of study include clinical practice, social policy, and professional practice. These A & P units are also pre-requisites to other units, such as, clinical practice and pharmacology in second year. Each A & P unit consisted of 3 hours of traditional large lecture with PowerPoint and 1 hr of teacher centered didactic small class tutorials. There were no labs in these units except for a single infection control lab in BIO 1.

The questions in the tutorial or study material were designed by the teaching team using a guided inquiry learning method, closely following the principles of Process Oriented Guided Inquiry Learning (POGIL). Tutorials were designed around students learning a particular concept

and the questions are structured in such a way that it allows the students to think about the critical aspects of the concept, which also includes application questions demonstrating how the concept applies to real life situations. The use of POGIL, a group-based, inquiry and active learning approach has been shown to significantly improve assessment outcomes in physiology (4, 15, 31, 34). It has been shown via active learning approaches for facilitating students to learn together, that people learn better when they interact with others (8, 28, 32). Peer-to-peer learning encourages the students to engage in cognitive processes, and to develop their own explanations and metaphors as they instruct their fellow peers about the unit material. Engaging these cognitive processes reinforces and consolidates the content as previously shown (8, 28, 32).

Students were randomly assigned into a tutorial group (30 students total). Each group was further subdivided into teams consisting of between 4-6 students, in which they remained for the entire 12 week semester. In 2012, tutorials were of one hour duration, employing a traditional didactic based tutorial activity. From 2013-2016, a *process* based approach was used, where students within each team organised themselves into roles of either manager, presenter, recorder, reader, facilitator and researcher (33). The rationale behind *process* is to make each student accountable for understanding the group activity. The guided inquiry questions provide students with information, such as, diagrams, graphs or data, followed by leading questions designed to guide students to formulate and construct a deeper understanding of core concepts. The last part of this process is for students to use this acquired understanding and apply it to a clinical scenario. The teacher serves principally as a facilitator to observe and guide the process, addressing individual and whole class concerns as they might arise.

There was no assessment activity on team participation or function in 2012. From 2013-2016, a small proportion of the unit grade consisted of participation within the weekly tutorial team. This varied from 20% (2013) to 10% (2014-2016) and was earned by each tutorial team submitting their weekly team submission from work done during the tutorial (29). Critically, this also serves as 'just-in- time' feedback mechanism for students as to how they are progressing in the unit. Each student team was given feedback, when completed worksheets were returned to the team in the subsequent weekly tutorials. The classes are broken up into 10-15 minute segments: Teams work on the questions together, and at the end of the time segments, the teams report their responses back to the entire class. The facilitator (teaching staff) then adds to this ongoing discussion. At the end of each tutorial session, the teams are required to submit their completed guided inquiry worksheet (a selection of 1-2 questions from the entire inquiry session) which are graded by staff (who provide feedback to their responses) and has an assessment weighting (Table 1). The intra-semester weighting increased due to the allocation of assigning a grade item to teamwork. Hence, the final exam summative task weighting decreased slightly. It is important to note that the final exam assessment did not change in content or academic rigour across years 2012-2016 and were validated each year by staff external to the unit.

Teaching staff comprise of lecturers (1-2) and part-time instructors (5). Lecturers were consistent across years with minor changes in instructors (2% at most). Staff are given a description of roles assigned for students and the key academic for the unit runs several instructional workshops on how best to facilitate class sessions. The tutorial itself is based on the corresponding weeks lecture, so tutorial questions are closely aligned to the learning content in lectures.

Active Learning in Large Lecture Settings

The audience response system (ARS) we used in the large lecture setting engaged students as active participants in learning and provided them with instant feedback on their responses. Clicker technology was used in a large lecture setting to promote a review of information covered, discussion as well as integration of that information. As explained by Lucas, feedback is the student's primary mechanism to determine their progress within a learning task (20). The immediacy of this feedback has been reported as being important for learners to understand if there are gaps in their knowledge, and to gain the necessary level of competence in the unit (20).

We utilised ARS technology that allows students to respond using a handheld remote keypad (clicker), to questions that lecturers pose in class. The ARS was employed here as the active learning tool intervention in a large lecture setting. Lecturers presented multiple choice or true/false questions in the lecture, which were embedded within typical PowerPoint presentations. Questions (5-10 in number) were embedded every 15 minutes with a usual 2 hour lecture. After student responses to the lecturer's questions, using the keypad, the aggregate class responses were instantaneously displayed in the PowerPoint presentation, allowing students to monitor their performance to the rest of the class (10). We also spent considerable time reviewing the answers to questions and possible misconceptions. Past research has used multiple choice questions as interactive engagement exercises within lectures (6, 24). In this study, the use of clickers has provided us with valuable insight into what makes a 'good question'. The questions used in ARS were similar in content to the weekly online quiz questions and were developed similarly (see below). Difficult questions often challenge students and we see a spread of answers, highlighting where common misconceptions might exist. The process of designing

these clicker sessions provides an insight on how best to present lecture content and to provide adequate scaffolding for students, so that they are better able to grasp the content more effectively (6).

Active learning in an online space

Weekly online quizzes were embedded into the learning management system which enables flexible delivery of formative assessment. There were usually 10 multiple choice questions that ranged in levels of difficulty, using Bloom's taxonomy, that is, including questions that require remembering (level 10), understanding (level 2) and analysis (level 3) (1). The immediate release of results provided students with feedback as to their level of understanding of each topic in the unit. This quiz is modelled in part on a backward learning model/flipped classroom, which requires students to complete quizzes before the tutorial, to ensure that they are properly prepared for the class (having completed the required reading) and to identify the areas of student weaknesses (29). Pre-tutorial quizzes attempt to ensure that students had reviewed their lecture notes prior to the tutorial, as attending the tutorial without adequate preparation would limit the students' ability to participate in the tutorial activities. The students had unlimited access to the quizzes and it was noted that students accessed quizzes at the start of the week before lectures and tutorials and at the end of each week.

METHOD

Demographics

The opportunity to access and succeed in higher education should be available to everyone, be as inclusive as possible and allow students from all backgrounds to fulfil their academic potential, as per the University ethos. The teaching challenge is how to cater for a student cohort with a diverse demographic background such as the one we have in this study.

Measuring student success can be influenced by many external aspects including a low socio-economic background, being the first in the family to attend University, or having a culturally as well as linguistically diverse heritage. In our student population, many of the students are not entering tertiary education directly from secondary school (non school leavers) and are entering higher education years after an intermission from formal education (mature age entrants). These students are often training for a mid career change. Analysis of the student demographic data in this study showed a slightly older student cohort, which was representative across years. Eleven percent (11%) of the student entry have a low socioeconomic status (SES).

Analysis

This study was approved by the Ethics Committee at Victoria University (HRE13-064). Statistical Analyses were conducted comparing the 2012 (non intervention year) and 2013-2016 (intervention years) cohorts on total scores for the unit and expressed as mean percentage and standard deviation (SD). Total marks for the unit were calculated based on a formula that weighs each piece of assessment and produces a score ranging from 0-100 and changes in weightings for individual assessment tasks across years was taken into account. One-way ANOVA tests were used to compare final grades for BIO1 and BIO 2 in years 2012-2016; post hoc Tukey's multiple-comparisons tests were used to determine which differences were significant using Prism (GraphPad Software), with results considered significant if $P < 0.05$. The percentage of students who received HD (>79.5), D (>69.5), C (>59.5), P (>49.5) and N (<49.5) were also determined and presented graphically. To determine whether the proportion of students falling into each grade category (HD, D, C, P, or N) had changed across unit delivery periods, chi-square (χ^2) tests of independence were undertaken. These tests compared student grade category distributions across year and delivery period for each unit.

An opinion based survey was conducted at the end of each semester in 2013 and 2014. The survey consisted of 10 closed questions and one open-end question: “Any additional comments about group work”. The survey was distributed via e-mail using the Qualtrics software (for both units). All students enrolled in the unit were invited to participant in the project. Likert items were summed to generate a Likert Scale score out of 50.

On the opinion based survey, students were asked to rank the value of each of the learning activity. A single ranking for each resource was determined by calculating the weighted average response at a particular rank (expressed as a percentage – weighted average was calculated by assigning a top ranking the value of 5, and a bottom ranking a value of 1 and multiplying the percentage of respondents at that rank by the assigned value). The weighted averages were then collated and given a score out of 5 for each resource as per Page et al (25) .

In addition to this inferential statistical comparison, mean ratings of quality in an institutional annual quality survey (Student Evaluation of Unit or SEU) were presented from 2013 to 2016. This quality survey asks students for their perceptions of several aspects of the unit, is made up of ten questions with a 5 point response range and also invites students to make comments. A thematic analysis was conducted from the data extracted from the qualitative questions in the opinion and SEU surveys, where the most common and frequent themes were highlighted. Open-ended items were analysed thematically similar to Page et al (25). Student comments were categorised according to content and meaning. The absolute number of comments in each theme was tallied to provide a semi-quantitative measure of the extent students reported on a particular theme.

Table 1

Key changes in the unit design for the first semester, first year Human Bioscience unit BIO 1 and BIO 2. The key changes to the unit are (1) introduction of 1 hour team based Active Guided Inquiry Learning (2) pre-tutorial online quizzes. In 2013, team participation weighting was 20% which was reduced to 10% (2014-2016). Abbreviations: LMS; learning management system, MCQ; multiple choice question, SAQ; short answer questions

	2012			**2013-2016**		
Lectures	3 X 1Hour Lectures covering all Learning Objectives			3 X 1 hour lectures covering all Learning Objectives		
Tutorials	1 Hour, frequently didactic tutorial			1 Hour, team based Active Guided Enquiry Learning		
Online Support	• LMS Blackboard			• VU Collaborate (LMS)		
Intra-semester assessment	40% of Unit Grade			45% of Unit grade BIO 1; 40% in BIO 2		
				Weekly online Hurdle quiz		0%
				Workshop (team participation grade)		10%
	2 multiple choice test	Week 5 and 8 Semester	15% each	2 online multiple choice tests	Week 5 and week 8	25% BIO 1; 30% BIO 2
	1 Lab written worksheet	Week 2- BIO 1 only	10%	1 Laboratory written worksheet	Week 2	10% BIO 1; no labs BIO 2
End of Semester assessment	Final Exam MCQs and SAQs		60% BIO 1; & 70% BIO 2 (no labs)	Final Examination MCQs and SAQs		55% BIO 1; 60% BIO 2

RESULTS

Analysis of the grades for both units across the 2012-2016 shows significant difference in the final grade percentage for both BIO 1 ($F(5, 1357) = 15$, $p<0.0001$) and BIO 2 ($F(5, 1269) = 8.3$, $P<0.0001$) (Fig. 1A and B respectively). Mean marks for the first year physiology unit increased by 8% (Fig. 1A 2012: 64% +/- 1.2, n=244, 2013: 74+/-1.0, n=282, Mean +/- SD $p<0.001$, one-way ANOVA).

Analysis of the grades demonstrate that not only are more students passing the units as a result of the altered assessment design, students are actually obtaining higher grades overall. The distribution of grades between years, presented as a percentage, demonstrates that students are obtaining higher grades in 2013-2016 compared to 2012. The ratio of students obtaining greater than 70 (D-HD) compared to students earning between 50 and 69 (P-C) (2012- 1.4; 2013- 4.4; 2014- 3.5; 2015-1.6; 2016-1.9, Fig. 1C) shows that greater proportion of students are scoring distinction or high distinction grades in BIO 1. This improved grade is sustained in BIO 2 (2012- 1.3; 2013- 3.0; 2014- 3.3; 2015-1.2; 2016-1.2, Fig. 1D). An overall χ^2 comparing all years and grade categories indicated a significant difference in categorical distributions across years in BIO 1 ($\chi^2(20) = 118.48$, $p<.001$). Similarly, the same overall test showed that grade category distributions differed significantly over the study period for BIO 2 ($\chi^2(20) = 79.78$, $p<.001$).

In 2013 (intervention year), the overall pass rate of 92% was obtained; whereas in 2012, a rate 84% was obtained in BIO 1. This indicates an improvement of 8.0% in 2013 where changes utilising active learning in both lectures (large group) and tutorials (small team based) was achieved. Importantly, this academic standard was maintained in 2014-2016 (Fig. 2A and B).

Student Learning Preferences

Students were asked to evaluate and rank where their learning occurred in the opinion based survey. Students indicated that learning occurred in tutorials (3.6/5; 5 = strongly agree). In response to questions, "Most of my learning occurred in tutorials and "Working in teams encouraged me to come to tutorials prepared for the activities" scored (3.9/5). The questions on the use of clickers such as, "The use of clickers in lectures was a useful tool for assessing my understanding of the material presented"; "The clickers made the learning experience more enjoyable" and "The clickers motivated me to participate more actively in class" scored on average 4.2/5. Results were comparable for BIO 2. Summative Likert Scale scores were calculated for these questions. Summative scores show that students have a generally positive attitude towards teamwork, with an overall average of 73% positive attitude towards teamwork across both units as indicated by the survey. Similarly, audience response systems (clickers) used in lectures were viewed as a positive attribute in the learning experience with the average positive attitude rating of 82%.

On the opinion based survey, students were asked to rank the value each of the learning activity. The value of each learning resource is shown in Figure 3. It is notable that the two teaching/learning resources, where there was face-to-face interaction between instructor and students (lectures and tutorials) were consistently seen as the most valuable teaching/learning

299 resource by students. On the opinion based survey, we gave the students a number of
300 opportunities to suggest qualitatively ways to improve the learning experience of the unit or
301 provide additional comments about the unit design. We also analysed comments from the
302 students in the institutional based unit surveys. Several key themes emerged from the responses
303 of both surveys. Students clearly valued the interactive nature of lectures and peer team based
304 learning (Table 2).
305

Table 2

Qualitative analysis of student perception of their learning. Student responses to extended answer questions in opinion based survey and SEU.

Theme	Exemplar Responses
More Interactive lectures	"Interactive lectures are a fantastic idea for learning. Helped a lot!"
	"Lectures with interaction i.e. the clickers really helped make things 'interesting' and forced me to think rather than just taking notes, etc.
	'Lectures were more fun and helped me understand material better, and pay more attention.'
	'It helped me focus on key knowledge in lectures.'
	'It made me think more'.
	"The clickers really worked well and I can say that I actually left knowing more on the topic than if I had just been listening"
	"Discussing answers and questions with friends helped understanding topics"
	"Doing quizzes with friends helped"
Tutorials are valuable	"online quizzes and tutorials summarising what we have learnt in lectures and helps consolidate learning"
	"Feedback and the smaller group tutorials were of great benefit."
	"Working in groups was annoying but I was able to explain stuff to my team, which helped me in the end"
	"The tutorial questions were very helpful as related to learning outcomes and matched lecture material; it helped me to understand what I needed to know"
Online quizzes are great	"Multiple choice questions helped me prepare for tests and exams"
	"I didn't see the point of doing quizzes before the tutorial. It helped me go over lecture notes"
Other	Comments relate to personal instructor attributes

University conducted student evaluation of units are presented below for BIO 1 (Table 3). Comparable results were achieved for BIO 2 (not shown here). On a five point Likert scale, respondents were asked to indicate the extent to which they agreed or disagreed with the statements, where: 1 = strongly disagree 5 = strongly agree. Table 3 reports average ratings for each item. There is consistently high student satisfaction with BIO 1 and 2 in years 2013-16 (intervention years). Data not available for 2012 non intervention year.

Table 3

Unit Quality Survey (SEU) Summary of student evaluation of BIO 1 (2013-2016). Results are shown as mean ± SD.

		2013		**2014**		**2015**		**2016**	
		M	SD	M	SD	M	SD	M	SD
Q1	**Clear about the unit.**	4.62	0.65	4.54	0.54	4.58	0.57	4.38	0.89
Q2	**Clear about what to complete.**	4.53	0.76	4.48	0.64	4.52	0.66	4.40	0.94
Q3	**Understood what was expected.**	4.56	0.7	4.43	0.66	4.47	0.68	4.40	0.84
Q4	**Useful learning activities.**	4.4	0.88	4.27	0.76	4.46	0.78	4.44	0.78
Q5	**Well planned learning activities**	4.43	0.79	4.25	0.76	4.52	0.64	4.47	0.81
Q6	**Well managed learning activities**	4.4	0.81	4.24	0.78	4.48	0.66	4.18	0.89

DISCUSSION

A range of quantitative indicators we have used show a significant improvement in student outcomes for the intervention years (2013-2016) compared to the non intervention year (2012). Student surveys and SEU also support this result indicating high satisfaction with the redesigned student centered tutorial activities. Overall, active learning interventions introduced into the units from 2013-2016, such as tutorial based activities improved student satisfaction in 2013-2016 versus 2012, as evidenced by student performance.

The group work fostered an active and participatory learning environment where students and facilitators (tutors) alike receive feedback through dialogue and participation, which then ultimately enables students to develop into independent learners. Small groups provided an excellent environment in which to maximize interaction and discussion and to 'teach students to think and to engage in their own and others learning through the articulation of views and understanding' (30) . Group work with a guided inquiry approach creates a better learning culture for the students, ultimately delivering better learning outcomes (Figures 1 and 2) (30). Our work supports this by showing that students tended to have a positive attitude towards the team based approach employed in this study (Figure 3). Although we did not have comparative SEU data for the non intervention year in 2012, the SEU data in years 2013-2016 were shown here to principally highlight high student satisfaction rates with the units.

The advantage of the guided inquiry learning approach employed here enabled the students to engage in discussions with each other about the learning content and in doing so they built a deeper understanding of the material (13). This stands in stark contrast to the previous didactic learning approach, where students are the passive recipients of knowledge while the so-called 'sage on the stage' talks at the students. In the didactic teaching model, recall of facts or

information is often mistaken for depth of knowledge. In rote learning the material, students may not have sufficient comprehension to apply their knowledge to novel or unusual circumstances. By expecting students to interact with each other, and engage with the learning content, the instructor is asking students to construct their own theory of the content, within a personal framework of understanding, and to compare their framework of understanding with their peers. In addition, the assessment task requiring students to submit their weekly teamwork, encouraged the discipline required to complete work in a timely fashion and engage in the team learning process.

Anecdotally, perception of teaching staff was that teaching in a non-didactic fashion was challenging. They reflected, however, that students appeared much more engaged. We did not specifically investigate perceptions and reflections of teaching staff in these units but consider this a valuable aspect to study in the future.

As a future intervention, another active learning approach in the tutorial setting, such as, collaborative testing could be introduced. Collaborative testing has the virtue of both requiring individual performance in testing and having a team based test, that involves an active learning component (25, 29). Previous work has shown that students have observed that the team part of the test is an effective form of formative feedback of their own learning, as they compare their individual answers, and their thinking in coming up with those answers, against other members of their team (29).

The use of ARS was found to improve student motivation overall, as indicated in the opinion based survey. In this study, it helped the lecturer re-align teaching input based on learners' needs as the feedback from students (ie answers to questions) gives the lecturer a better insight into areas of difficulty or student misconceptions (23) (personal observation). Students

appeared more engaged and feedback from students was that the lectures were “more fun”. Furthermore, Biggs states that employing strategies like this that help to engage and motivate students will result in deeper approaches to learning (2). In addition, contact time with students was used wisely and not wasted on topics or concepts already understood by the class (6). It was also evident that students were engaging in short discussions with their peers after feedback was provided on each question (an informal “think pair share” outcome - personal observation), an indication of learning from peers and the creation of a safe environment for student participation (22). These results warrant further research into the effectiveness of ARS in the teaching and learning of bioscience. We have recently used free online ARS tools such as ‘Kahoot’ which is more game based and requires minimal hardware. Anecdotally students respond to this delivery with great enthusiasm.

Teaching based on a “flipped classroom” approach occurs when students conduct pre-class preparation, including watching pre-recorded lectures, while traditional in class time is reserved for discussion and/or problem solving of the relevant topics (27). In addition to the weekly group inquiry submission worksheets in this study, students were required to complete and submit online weekly quizzes (a pre-class activity) designed to ensure that they have prepared for the in class guided inquiry tutorial. Although the quizzes had no grade value, they form a prerequisite for earning an assessment item in the ensuing tutorial. The purpose of this requirement is to ensure that students who attend the tutorials have previously engaged with the material that is to be covered in the tutorial and be optimally prepared for the face-to-face session. It is hoped that this type of formative feedback encourages students to engage with the content material in advance, and each student will be better prepared to contribute to the groups learning rather than have each group be carried by a few dominant high achievers; minimising

the free loading. We did not study free-loading or group compositional effects and dynamics here. Based on student feedback, we suggest that the use of online quizzes, as homework was a critical motivating factor that likely contributed to the better student participation in classroom discussion and ultimately to increased student performance. In addition, this model provided the instructors with significantly more class time to emphasize important concepts and/or engage students in team based guided inquiry sessions.

The limitations of this study included the inability to make statistical comparisons between intervention and non intervention,groups, as the current design did not have appropriate control groups. The curricula changes were made to the units and extended to all students enrolled.

CONCLUSION

This paper details a multi-component curriculum redesign and evaluation of first-year paramedicine bioscience units which were characterised by a high fail rate. The major components of the curriculum redesign were inspired broadly by guiding principles of active learning, and more specifically small group based guided inquiry learning, principally targeting student engagement with the curriculum. Evaluative results indicate significant improvement in student outcomes post the redesign, as well as high levels of student satisfaction with the new engaging curriculum. We cannot clearly state which of the active learning activities are responsible for the clearly evident increase in student grades and a reduction in fail rates. However, the overall implementation of a variety of active learning strategies simultaneously improved academic outcomes for students, as previously evidenced by others (8, 9, 11, 17).

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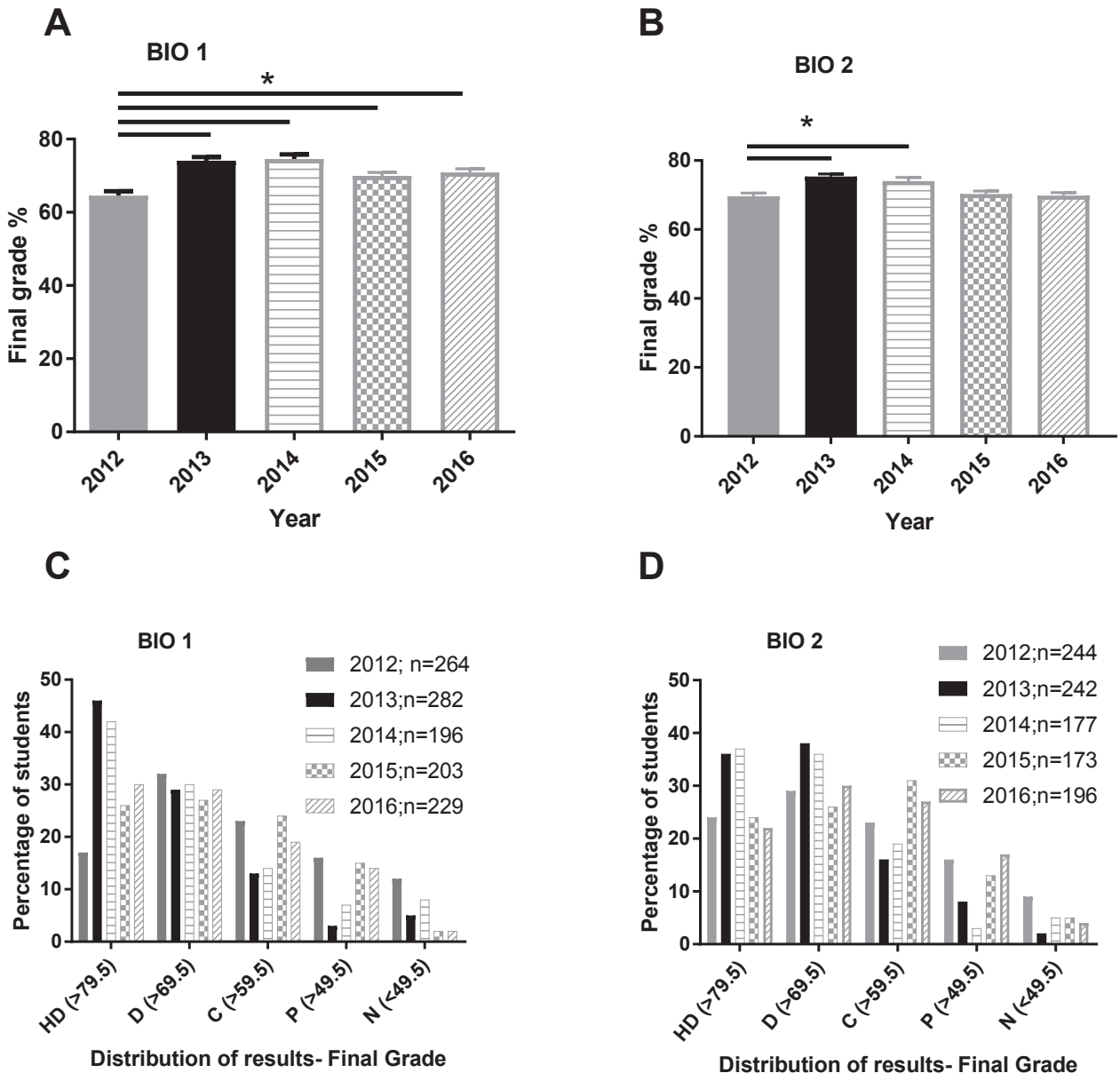
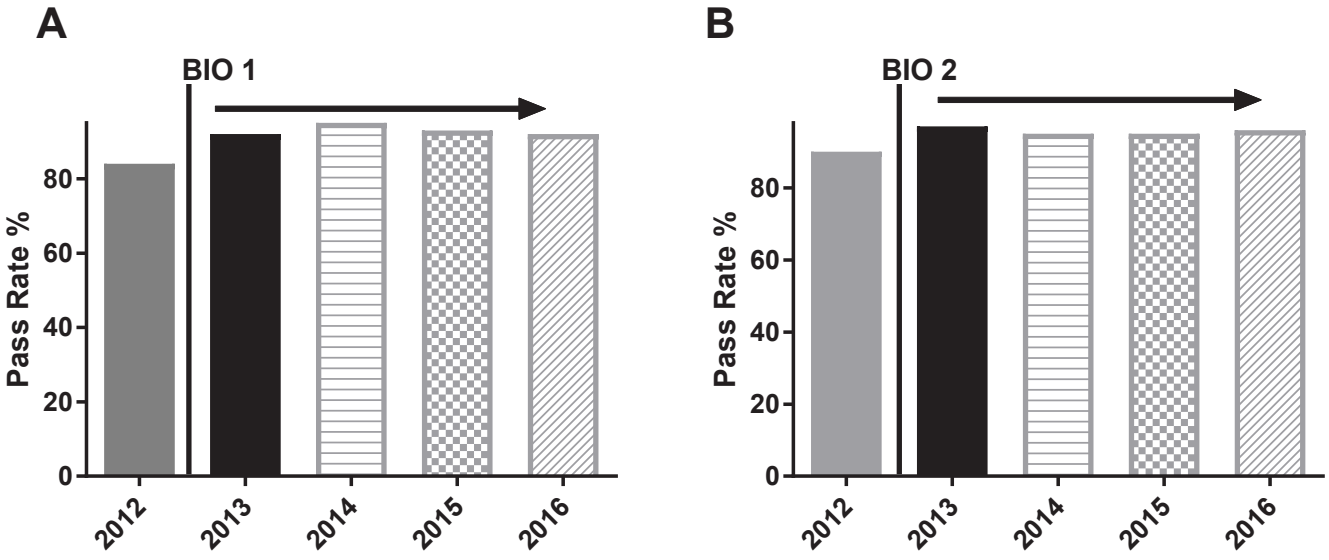
FIGURE LEGENDS

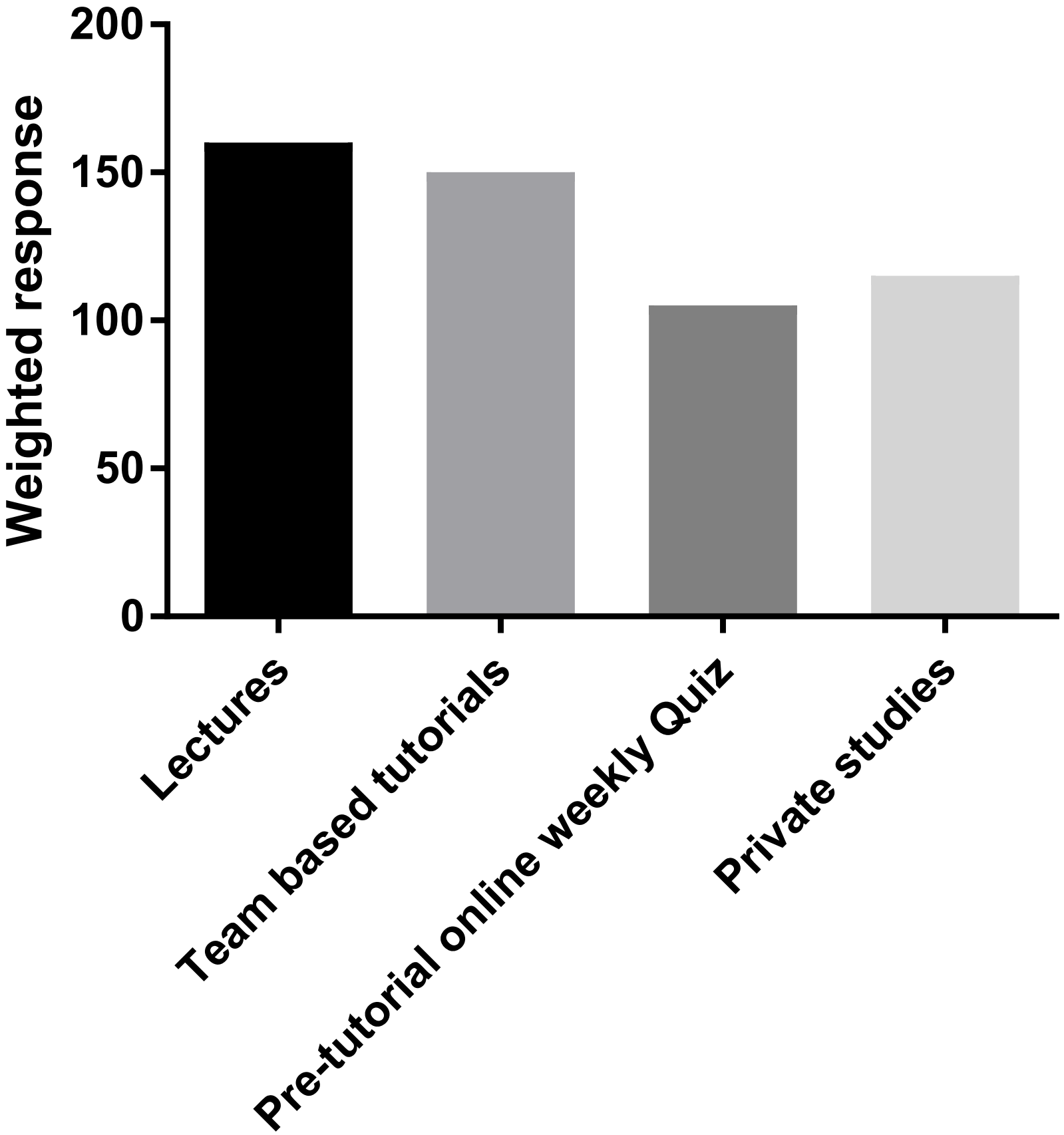
Figure 1. Improvement in student grades in first year across first and second semester Bioscience units (A) Grades increased by 8% (significant effect, $p<0.05$) in 2013 (intervention year) vs 2012 (non intervention year) for BIO 1 (B) Grades increased by 9% (significant effect, $p<0.001$) in 2013 (intervention year) vs 2012 (non intervention year) for BIO 2. The percentage distribution of scores for 2013-2016 shows students receiving more distinctions, credits and passes in BIO 1 and BIO 2 (C and D).

Figure 2. (A) Pass rate for BIO 1 increased significantly in intervention years 2013-2016 compared to 2012 (non intervention year). (B) Pass rate for BIO 2 increased significantly in intervention years 2013-2016 compared to 2012 (non intervention year).

Figure 3. Students ranking of the importance of teaching environments to their learning in first year Bioscience. Ranking method is described in methods section. This data was collected via an online survey via Qualtrics.


A
BIO 1
*
Final grade %
0
20
40
60
80
2012
2013
2014
2015
2016
Year
B
BIO 2
*
Final grade %
0
20
40
60
80
2012
2013
2014
2015
2016
Year
C
BIO 1
2012; n=264
2013;n=282
2014;n=196
2015;n=203
2016;n=229
Percentage of students
0
10
20
30
40
50
HD (>79.5)
D (>69.5)
C (>59.5)
P (>49.5)
N (<49.5)
Distribution of results- Final Grade
D
BIO 2
2012;n=244
2013;n=242
2014;n=177
2015;n=173
2016;n=196
Percentage of students
0
10
20
30
40
50
HD (>79.5)
D (>69.5)
C (>59.5)
P (>49.5)
N (<49.5)
Distribution of results- Final Grade


A
BIO 1
Pass Rate %
0
20
40
60
80
2012
2013
2014
2015
2016
B
BIO 2
Pass Rate %
0
20
40
60
80
2012
2013
2014
2015
2016


Weighted response
200
150
100
50
0
Lectures
Team based tutorials
Pre-tutorial online weekly Quiz
Private studies