

1 A combination of active learning strategies improve student academic outcomes in first year
2 paramedic bioscience
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12 Running Head: ACTIVE LEARNING IN FIRST YEAR BIOSCIENCE

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24 **ABSTRACT**

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

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

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

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

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

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

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

87

88

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

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

102 **RESEARCH REVIEW**

103 *Active Learning in Small Class Tutorials*

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

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

114 and the questions are structured in such a way that it allows the students to think about the
115 critical aspects of the concept, which also includes application questions demonstrating how the
116 concept applies to real life situations. The use of POGIL, a group-based, inquiry and active
117 learning approach has been shown to significantly improve assessment outcomes in physiology
118 (4, 15, 31, 34). It has been shown via active learning approaches for facilitating students to learn
119 together, that people learn better when they interact with others (8, 28, 32). Peer-to-peer learning
120 encourages the students to engage in cognitive processes, and to develop their own explanations
121 and metaphors as they instruct their fellow peers about the unit material. Engaging these
122 cognitive processes reinforces and consolidates the content as previously shown (8, 28, 32).

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

135

136 There was no assessment activity on team participation or function in 2012. From 2013-
137 2016, a small proportion of the unit grade consisted of participation within the weekly tutorial
138 team. This varied from 20% (2013) to 10% (2014-2016) and was earned by each tutorial team
139 submitting their weekly team submission from work done during the tutorial (29). Critically, this
140 also serves as ‘just-in- time’ feedback mechanism for students as to how they are progressing in
141 the unit. Each student team was given feedback, when completed worksheets were returned to
142 the team in the subsequent weekly tutorials. The classes are broken up into 10-15 minute
143 segments: Teams work on the questions together, and at the end of the time segments, the teams
144 report their responses back to the entire class. The facilitator (teaching staff) then adds to this
145 ongoing discussion. At the end of each tutorial session, the teams are required to submit their
146 completed guided inquiry worksheet (a selection of 1-2 questions from the entire inquiry session)
147 which are graded by staff (who provide feedback to their responses) and has an assessment
148 weighting (Table 1). The intra-semester weighting increased due to the allocation of assigning a
149 grade item to teamwork. Hence, the final exam summative task weighting decreased slightly. It
150 is important to note that the final exam assessment did not change in content or academic rigour
151 across years 2012-2016 and were validated each year by staff external to the unit.

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

158

159 *Active Learning in Large Lecture Settings*

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

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

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

185 *Active learning in an online space*

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

199 **METHOD**

200 *Demographics*

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

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

213 *Analysis*

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

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

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

239 In addition to this inferential statistical comparison, mean ratings of quality in an
240 institutional annual quality survey (Student Evaluation of Unit or SEU) were presented from
241 2013 to 2016. This quality survey asks students for their perceptions of several aspects of the
242 unit, is made up of ten questions with a 5 point response range and also invites students to make
243 comments. A thematic analysis was conducted from the data extracted from the qualitative
244 questions in the opinion and SEU surveys, where the most common and frequent themes were
245 highlighted. Open-ended items were analysed thematically similar to Page et al (25). Student
246 comments were categorised according to content and meaning. The absolute number of
247 comments in each theme was tallied to provide a semi-quantitative measure of the extent
248 students reported on a particular theme.

249

250

251 Table 1

252 Key changes in the unit design for the first semester, first year Human Bioscience unit BIO 1 and
 253 BIO 2. The key changes to the unit are (1) introduction of 1 hour team based Active Guided
 254 Inquiry Learning (2) pre-tutorial online quizzes. In 2013, team participation weighting was 20%
 255 which was reduced to 10% (2014-2016). Abbreviations: LMS; learning management system,
 256 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	<ul style="list-style-type: none"> LMS Blackboard 			<ul style="list-style-type: none"> 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		60%	Final Examination		55% BIO 1; 60% BIO 2
	MCQs and SAQs		& 70% BIO 2 (no labs)	MCQs and SAQs		

257

258 **RESULTS**

259 Analysis of the grades for both units across the 2012-2016 shows significant difference in
260 the final grade percentage for both BIO 1 ($F(5, 1357) = 15, p < 0.0001$) and BIO 2 ($F(5, 1269) =$
261 $8.3, P < 0.0001$) (Fig. 1A and B respectively). Mean marks for the first year physiology unit
262 increased by 8% (Fig. 1A 2012: $64\% \pm 1.2, n=244$, 2013: $74 \pm 1.0, n=282$, Mean \pm SD
263 $p < 0.001$, one-way ANOVA).

264 Analysis of the grades demonstrate that not only are more students passing the units as a
265 result of the altered assessment design, students are actually obtaining higher grades overall. The
266 distribution of grades between years, presented as a percentage, demonstrates that students are
267 obtaining higher grades in 2013-2016 compared to 2012. The ratio of students obtaining greater
268 than 70 (D-HD) compared to students earning between 50 and 69 (P-C) (2012- 1.4; 2013- 4.4;
269 2014- 3.5; 2015-1.6; 2016-1.9, Fig. 1C) shows that greater proportion of students are scoring
270 distinction or high distinction grades in BIO 1. This improved grade is sustained in BIO 2
271 (2012- 1.3; 2013- 3.0; 2014- 3.3; 2015-1.2; 2016-1.2, Fig. 1D). An overall χ^2 comparing all years
272 and grade categories indicated a significant difference in categorical distributions across years in
273 BIO 1 ($\chi^2(20) = 118.48, p < .001$). Similarly, the same overall test showed that grade category
274 distributions differed significantly over the study period for BIO 2 ($\chi^2(20) = 79.78, p < .001$).

275

276

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

281 *Student Learning Preferences*

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

295 On the opinion based survey, students were asked to rank the value each of the learning
296 activity. The value of each learning resource is shown in Figure 3. It is notable that the two
297 teaching/learning resources, where there was face-to-face interaction between instructor and
298 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

306 Table 2
 307
 308 Qualitative analysis of student perception of their learning. Student responses to
 309 extended answer questions in opinion based survey and SEU.
 310

Theme	Exemplar Responses
More	“Interactive lectures are a fantastic idea for learning. Helped a lot!”
Interactive lectures	<p>“Lectures with interaction i.e. the clickers really helped make things 'interesting' and forced me to think rather than just taking notes, etc.</p> <p>‘Lectures were more fun and helped me understand material better, and pay more attention.’</p> <p>‘It helped me focus on key knowledge in lectures.’</p> <p>‘It made me think more’.</p> <p>“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”</p> <p>“Discussing answers and questions with friends helped understanding topics”</p> <p>“Doing quizzes with friends helped”</p>
Tutorials are valuable	<p>“online quizzes and tutorials summarising what we have learnt in lectures and helps consolidate learning”</p> <p>“Feedback and the smaller group tutorials were of great benefit.”</p> <p>“Working in groups was annoying but I was able to explain stuff to my team, which helped me in the end”</p> <p>“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”</p>
Online quizzes are great	<p>“Multiple choice questions helped me prepare for tests and exams”</p> <p>“I didn’t see the point of doing quizzes before the tutorial. It helped me go over lecture notes”</p>
Other	Comments relate to personal instructor attributes

311
 312

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

319

320 Table 3

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

323

		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

324

325

326 **DISCUSSION**

327 A range of quantitative indicators we have used show a significant improvement in
328 student outcomes for the intervention years (2013-2016) compared to the non intervention year
329 (2012). Student surveys and SEU also support this result indicating high satisfaction with the
330 redesigned student centered tutorial activities. Overall, active learning interventions introduced
331 into the units from 2013-2016, such as tutorial based activities improved student satisfaction in
332 2013-2016 versus 2012, as evidenced by student performance.

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

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

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

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

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

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

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

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

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

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

405

406 **CONCLUSION**

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

417

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501

502

503 **FIGURE LEGENDS**

504 *Figure 1.* Improvement in student grades in first year across first and second semester Bioscience
505 units (A) Grades increased by 8% (significant effect, $p < 0.05$) in 2013 (intervention year) vs 2012
506 (non intervention year) for BIO 1 (B) Grades increased by 9% (significant effect, $p < 0.001$) in
507 2013 (intervention year) vs 2012 (non intervention year) for BIO 2. The percentage distribution
508 of scores for 2013-2016 shows students receiving more distinctions, credits and passes in BIO 1
509 and BIO 2 (C and D).

510

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

514

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

518





