The use of team-based, guided inquiry learning to overcome educational disadvantages in learning human physiology: a structural equation model

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Rathner JA, Byrne G. The use of team-based, guided inquiry learning to overcome educational disadvantages in learning human physiology: a structural equation model. Adv Physiol Educ 38: 221–228, 2014; doi:10.1152/advan.00131.2013.—The study of human bioscience is viewed as a crucial curriculum in allied health. Nevertheless, bioscience (and particularly physiology) is notoriously difficult for undergraduates, particularly academically disadvantaged students. So endemic are the high failure rates (particularly in nursing) that it has come to be known as “the human bioscience problem.” In the present report, we describe the outcomes for individual success in studying first-year human physiology in a subject that emphasises team-based active learning as the major pedagogy for mastering subject learning outcomes. Structural equation modeling was used to develop a model of the impact team learning had on individual performance. Modeling was consistent with the idea that students with similar academic abilities (as determined by tertiary entrance rank) were advantaged (scored higher on individual assessment items) by working in strong teams (teams that scored higher in team-based assessments). Analysis of covariance revealed that students who studied the subject with active learning as the major mode of learning activities outperformed students who studied the subject using the traditional didactic teaching format (lectures and tutorials). After adjustment for tertiary entrance rank (via analysis of covariance) on two individual tests (the final exam and a late-semester in-class test), individual student grades improved by 8% (95% confidence interval: 6–10%) and 12% (95% confidence interval: 10–14%) when students engaged in team-based active learning. These data quantitatively support the notion that weaker students working in strong teams can overcome their educational disadvantages.

HUMAN BIOSCIENCE, including anatomy, physiology, pharmacology, pathology (pathophysiology), microbiology, and immunology, underlies the practice of Western medicine (11). Consequently, a good knowledge of these disciplines is an essential distinction between being a practitioner and a technician in the delivery of patient care and treatment (11, 25, 31).

The teaching and learning of human bioscience is a major hurdle in nursing education (at the undergraduate level) (9, 10, 13–15, 17, 18, 21–24, 27). Indeed, feelings of incompetence and inadequate preparation are major reasons for nursing students discontinuing their nursing studies at universities (1, 8). Studies have consistently shown that success in first-year undergraduate human biosciences is strongly correlated with prior experience in chemistry and biology as well as overall high school achievement (8, 12, 18, 27, 30). Thus, it is remarkable that direct entry from secondary school into Bachelor of Nursing programs do not require some form of general science prerequisite.

In Australia, and similarly in the United Kingdom, entry into many vocationally oriented allied health programs is direct from high school. In Australia, selection into a particular discipline is based on the Australian Tertiary Admissions Rank (ATAR) and meeting specific year 12 subject prerequisites determined by the university. ATAR evaluates all year 12 leavers in Australia according to a formulation of their performance in each of their final high school year subjects (19). Thus, discussion in this report may be more comparable to entry-level anatomy and physiology in the United States tertiary education experience, where students often complete preclinical science subjects at community college before applying for entry into nursing degree programs.

Since anatomy and physiology underpin our understanding of human biology, these subjects are essential in allied health courses. At La Trobe University, all allied health students (physiotherapy, exercise physiology, podiatry, speech therapy, paramedic practice, and nursing, among others) study human biosciences together in the first and second semester of the first year of their degrees. La Trobe University has four campuses throughout the State of Victoria (Australia). The main campus in metropolitan Melbourne has roughly 1,300 students enrolled in first-year Health Science. In the Rural instance of the subjects, roughly 420–450 students are enrolled in the subject across 4 campuses, with roughly 50% nursing (for more detail on the cohort makeup, see Ref. 26). This mixed cohort of students means that entry into first-semester physiology comprises students whose ATAR ranges from 95.9 (Physiotherapy) to 50.45 (Nursing) (20), and published ATAR data do not account for students entering university via alternative pathways. In 2010 and 2011, roughly 30% of students failed first-year physiology. As has previously been reported, success in physiology is directly correlated to tertiary entrance rank (12). Since there is no senior high school science requirement for entry into the nursing degree and given the low tertiary entrance criteria, it is not surprising that large numbers of nursing students fail first-year physiology.

In response to high failure rates, teaching staff have redesigned the first-year physiology subject presentation and assessment to focus more on team-based and active learning. A full description and justification of the changes have been published elsewhere (26). The team-based learning approach takes advantage of the mixed cohort of students enrolled in the...
subject by facilitating peer-to-peer interactions between students in different disciplines and with very different tertiary entrance ranks. Within a team of five to six students, there could potentially be students who have entered university in the top 10% of their school leaver year based on academic achievement working with students ranked at the 50th percentile.

As we have previously reported (26), team-based learning and (in particular) team-based assessment do improve success in outcomes measured by grades and pass rates. A much more difficult question to address is as follows: Within the team-based pedagogy, do individuals actually learn more? In the present report, we used a structural model approach to attempt to quantify the impact of team-based learning on individual success in physiology learning. For the cohort studied, the model implied that a combination of active learning and team-based assessment contributed to a significantly better achievement working with students ranked at the 50th percentile.

What we Teach

All students enrolled in the Health Science degree at La Trobe University study a common core first-year curriculum including subjects designed to develop academic and team interaction skills. All subjects have variations of enquiry-based learning as their pedagogical basis. Human bioscience (physiology) is part of the first-year core (CFY) and during 2011 and 2012 underwent a major subject redesign; the key features of this redesign are shown in Table 1 and have been previously described in detail elsewhere (26). Health science students are a mixed cohort of students in allied health disciplines. Included in the intake are students directly studying for the Bachelor of Nursing degree. The exact composition of the student cohorts (based on graduate destinations) entering into the CFY Human Biosciences course in the academic years of 2011 and 2012 is shown in Table 2. Intake into health science and nursing at La Trobe University is largely governed by ATAR (19, 20), with an exception for students who enter their degrees via alternative entrance pathways. For the purposes of this study, we have understood ATAR to be a reflection of the students’ innate scholastic skills. ATAR could be replaced by the Scholastic Assessment Test (SAT), other forms of psychometric testing, intelligence quotient, or even socioeconomic status (16). Here, we used ATAR due to previous reports linking success in first-year physiology in allied health to ATAR and because of its ready availability while acknowledging some limitations in a sole focus on ATAR as a measure of scholar ability.

In both 2011 and 2012 cohorts, students were centrally assigned to a workshop team. Workshop team assignment was intended to shuffle the students, so that any one team was (as far as possible) a cross section of students from different disciplines. Students did have the option in week 1 of semester of swapping workshop times to resolve timetable or work/life conflicts (amounting to ~10% of all students in the subject; personal observations). Teams were made up of between four and six students, and these teams, after week 1 of the semester,

Table 1. Key changes in the subject design for the first-semester, first-year Human Bioscience subject

<table>
<thead>
<tr>
<th>Description</th>
<th>Lectures</th>
<th>Workshops</th>
<th>Online support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nature of the workshops</td>
<td>Three 1-h Lectures covering all learning objectives</td>
<td>Two 1-h lectures covering only core learning objectives</td>
<td>LMS and forum discussion</td>
</tr>
<tr>
<td>Description</td>
<td></td>
<td></td>
<td>LMS, forum discussion</td>
</tr>
<tr>
<td>Percentage of the subject grade</td>
<td>50</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>What was assessed</td>
<td>Each assessment assessed test material taught since the last assessment</td>
<td>Assessments only assessed core learning objectives</td>
<td></td>
</tr>
<tr>
<td>Tests</td>
<td>Two online multiple-choice tests</td>
<td>Weekly hurdle quiz</td>
<td></td>
</tr>
<tr>
<td></td>
<td>One online assignment</td>
<td>Workshop (team participation grade)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>One in-class multiple choice test (25 multiple-choice questions)</td>
<td>Week 6 collaborative test (40 multiple-choice questions)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Week 13 collaborative test (40 multiple-choice questions)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Week 13 of the semester (6% individual and 15% team)</td>
<td></td>
</tr>
<tr>
<td>Final exam</td>
<td>Cumulative content (80 multiple-choice questions)</td>
<td>Assessed only extension learning objectives (60 multiple-choice questions)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50% of the final mark</td>
<td>40% of the final mark</td>
<td></td>
</tr>
</tbody>
</table>

The key changes to the subject were 1) the introduction of 2-h team-based active guided inquiry learning and 2) the division of the subject into core and extension learning objectives. In both 2011 and 2012, a final intrasemester test was held. Although there were significant differences in the value of the individual assessments, the lower value of the individual assessment for 2012 should reduce the motivation for strong individual accountability (a bias arguing against the changes in the subject structure).
Table 2. Numbers and disciplines of students studying first-semester, first-year human bioscience in each cohort analyzed

<table>
<thead>
<tr>
<th>Number of Students Enrolled in Each Campus</th>
<th>Number of Students in Each Discipline Studying the Subject in 2011</th>
<th>Number of Students in Each Discipline Studying the Subject in 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bachelor of Health Science (Public Health)</td>
<td>Bachelor of Nursing</td>
<td>Diploma of Health Science</td>
</tr>
<tr>
<td>2011</td>
<td>2012</td>
<td>Number of Students</td>
</tr>
<tr>
<td>279</td>
<td>312</td>
<td>62</td>
</tr>
<tr>
<td>84</td>
<td>71</td>
<td>65</td>
</tr>
<tr>
<td>33</td>
<td>42</td>
<td>25</td>
</tr>
<tr>
<td>4</td>
<td>37</td>
<td>42</td>
</tr>
</tbody>
</table>

Campus 1 is the largest campus, where most Department of Human Bioscience staff are based and lectures are sourced. Campus 2 has one Department Human Bioscience staff member, and roughly a quarter of the lectures originate from this venue. Campuses 3 and 4 are smaller campuses, with no permanent or full-time Human Bioscience staff; all lectures are video conferenced to campuses 3 and 4. Workshops at campus 1 are facilitated exclusively by full-time Human Bioscience staff, and workshops at campus 2 are half full-time staff and half sessional (casual) staff. Workshops are exclusively facilitated by sessional staff at campuses where no Human Bioscience staff are based.

Model Predictions:
- The model predicts that a student's individual score in the final exam (y3) is a predictor of the student's individual score in the week 13 assessment (y2) and final exam (y3). It also hypothesized that the team mark (y1) is a predictor of the student's individual score on both the week 13 assessment (y2) and final exam (y3).
- Structural Equation Modeling was used to develop an algebraic model of the impact of team-based learning on outcomes of individual assessment. As team-based assessment was a feature in the 2012 cohort, structural equation modeling was limited to this year only. Structural Equation Modeling is a statistical tool that allows investigators to explore complex interrelationships between variables and provide paths to test those hypothesized relationships simultaneously. In this instance, the model was used to test the hypothesis that the team mark (y1) is a predictor of the student's individual score on both the week 13 assessment (y2) and final exam (y3).

Three assumptions are made during the statistical analysis: 1) the assignment to groups was without prejudice (i.e., groups were randomly selected), 2) the assignment of similar ATAR groups to students entering Bachelor of Nursing or Bachelor of Health Science was performed by appropriately qualified sessional staff (i.e., students entering Bachelor of Nursing or Bachelor of Health Science were randomly assigned to groups), and 3) a student's performance on a test was a function of the team's collective attribute (i.e., team learning effectiveness during the team active learning activities). It is important to note that in 2012, the division of the subject into two assessment weeks only was not accounted for in the model. Structural Equation Modeling was limited to analysis of the influence of ATAR on student performance in first-year physiology. It was, therefore, not possible to explore the impact of team-based learning on outcomes of individual assessment.

Statistical Analysis:
- All statistical tests were carried out in SPSS (version 21, IBM, Chicago, IL). Structural modeling was completed using AMOS (version 21), a software package for structural equation modeling and path analysis to test those hypothesized relationships simultaneously.
How We Teach

The structural model was calibrated and tested using AMOS. The validity of the model was demonstrated using a $\chi^2$-test. In the $\chi^2$ goodness of fit test, $P$ values of $>0.05$ support the null hypothesis that the data are consistent with the model described above.

Analysis of Covariance

Analysis of covariance (ANCOVA) was used to compare the performance of each of the cohorts (2011 and 2012) on assessments after adjustment for individual ability via ATAR.

Human Ethics Approval

This study was approved by the Faculty of Health Science Human Ethics Committee (FHEC 13/018) as negligible risk, in accordance with the (Australian) National Statement on Ethical Conduct of Human Research (2007).

RESULTS

Structural Equation Modeling Suggests That Team-Based Learning Can Overcome Previous Educational Achievement Gaps

When the structural model shown in Fig. 1 was tested on the 2012 cohort, statistically significant relationships were found for tested relationships except for the collaborative mark and final exam ($\beta_1$), that is, structural modeling showed no direct effect of team strength on student final exam mark. Consequently, we remodeled the data excluding this relationship (Fig. 2). The tested paths shown in Fig. 2 all demonstrated highly statistically significant relationships ($P < 0.001$). $\chi^2$ testing of the model demonstrated that the model adequately explained the actual student results for the subject ($\chi^2 = 1.447, P = 0.229$). The complete fitted model with intercepts and component fit statistics was as follows:

$$
\begin{align*}
\log y_3 & = \beta_0 + \beta_1 x + \beta_2 y_2 + \beta_3 y_1 + e_3 \\
\log y_2 & = \alpha_0 + \alpha_1 x + \alpha_2 y_1 + e_2 \\
\log y_1 & = \gamma_0 + \gamma_1 x + e_1
\end{align*}
$$

Table 3. ANCOVA output for the final result

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>Degree of Freedom</th>
<th>Mean Square</th>
<th>$F$</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected model</td>
<td>99780.082*</td>
<td>2</td>
<td>49890.041</td>
<td>279.915</td>
<td>0.000</td>
</tr>
<tr>
<td>Intercept</td>
<td>23169.841</td>
<td>1</td>
<td>23169.841</td>
<td>129.998</td>
<td>0.000</td>
</tr>
<tr>
<td>ATAR</td>
<td>40023.577</td>
<td>1</td>
<td>40023.577</td>
<td>224.558</td>
<td>0.000</td>
</tr>
<tr>
<td>Year</td>
<td>60672.646</td>
<td>1</td>
<td>60672.646</td>
<td>340.413</td>
<td>0.000</td>
</tr>
<tr>
<td>Error</td>
<td>132248.551</td>
<td>742</td>
<td>178.233</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2985830.668</td>
<td>745</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected total</td>
<td>232028.633</td>
<td>744</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ANCOVA, analysis of covariance; ATAR, Australian Tertiary Admissions Rank. *$R^2 = 0.430$ (adjusted $R^2 = 0.428$).
issue does not detract from the rather good explanatory power of the models for *week 13* assessment and final exam mark, to which collaborative mark makes significant direct and indirect contributions.

Importantly for our consideration, the standardized path coefficient linking the *week 13* assessment mark to the final exam mark was 3.5 times larger than the coefficient linking ATAR to the final exam mark. That is, how well a student does on the *week 13* assessment is a stronger influence on their final exam mark than ATAR. Crucially, the path coefficient linking collaborative mark (team strength) to the *week 13* assessment was twice the coefficient link of ATAR to the *week 13* assessment. That is, how strong the team is has twice the influence on an individual’s *week 13* assessment mark relative to ATAR. While it is unremarkable that the level of student proficiency in physiology in the last week of the semester is matched by their ability on the final exam, the structural model is consistent with indirect effect of teamwork and team strength on the student’s final exam result.

ANCOVA: Students That Engaged in Guided Inquiry, Team-Based Learning Outperformed Students Who Experienced a More Didactic Class Presentation

**Final mark.** A comparison of student performance between the 2011 and 2012 cohorts and the impact of tertiary entrance rank was performed using ANCOVA. ANCOVA showed that the 2012 cohort performed significantly better ($F = 340.413$, $P = 0.000$) than the 2011 cohort after adjustment for ATAR (Table 3). When the final mark in physiology was plotted against ATAR, the improved performance of the 2012 cohort was demonstrated (Fig. 3). Strikingly, in the traditional didactic teaching model (2011 cohort), the linear relationship between ATAR and final mark indicated that students with low ATAR were unlikely to overcome poor academic backgrounds in this subject. In 2012, it is evident that there were a number of students who entered the subject with ATARs between 40 and 60 who were able to score “A”s in the subject, hinting that the changed pedagogy overcame individual disadvantages upon entry into tertiary education.

**Individual assessment.** To delve deeper into understanding the impact of the changed pedagogy on individual learning, ANCOVA was performed on the two individual assessments being discussed in this report (Tables 4 and 5).

The results from ANCOVA are shown in Table 4, which demonstrated the highly significant relationship between the *week 13* assessment score and ATAR ($P < 0.001$). After adjustment for ATAR, there was also a highly significant ($P < 0.000$) difference of 12% (95% confidence interval: 10–14%) improvement in the mean *week 13* assessment score between the 2012 cohort relative to the 2011 cohort.

ANCOVA comparing the final exam result against ATAR for both the 2011 and 2012 cohorts of students demonstrated a highly significant relationship between the final exam result and ATAR ($P < 0.001$), as expected. After adjustment for ATAR, there was also a highly significant ($P < 0.000$) difference of 8% (95% confidence interval: 6–10%) improvement on mean exam scores between the 2012 and 2011 cohorts.

**DISCUSSION**

This report aimed to quantitatively assess the impact of a changed teaching approach on student performance in first-year, first-semester physiology. A number of teaching strategies were adopted in 2012, including team-based guided inquiry and collaborative testing. Since 50% of the subject grade came from team-based assessment, simply seeing significant improvements in the final results could, potentially, be written off as grade inflation due to the team-based assessment. Stated another way, poorly motivated students, it could be argued,

![](http://advan.physiology.org/)

**Fig. 3.** Relationship between the final result and ATAR for 2011 and 2012 cohorts. The *x*-y scatterplot of ATAR versus the final mark in first-year physiology is shown. As can be seen at any particular ATAR, students in 2012 outperformed students in 2011. As mentioned in the text, this may be accounted for by simply boosting the final mark as a result of team-based assessment. Contrary to this argument, it is noteworthy that there was a group of students who entered into their degrees with ATARs below 60 that achieved 80%). Grades greater than “C” (60–70%) require that students demonstrate a degree of individual success, being discussed in this report (Tables 4 and 5).

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![Figure 3](http://advan.physiology.org/)

### Table 4. Parameter estimates and related statistics for ANCOVA for the *week 13* assessment score

<table>
<thead>
<tr>
<th>Parameter</th>
<th>B</th>
<th>SE</th>
<th>t</th>
<th>Significance</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>16.174</td>
<td>2.617</td>
<td>6.180</td>
<td>0.000</td>
<td>11.036 – 21.313</td>
</tr>
<tr>
<td>ATAR</td>
<td>0.561</td>
<td>0.036</td>
<td>15.430</td>
<td>0.000</td>
<td>0.490 – 0.632</td>
</tr>
<tr>
<td>Year = 2011</td>
<td>−11.897</td>
<td>1.058</td>
<td>−11.240</td>
<td>0.000</td>
<td>−13.976 – −9.819</td>
</tr>
<tr>
<td>Year = 2012</td>
<td>0*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The B coefficients for year serve to alter the ANCOVA model constant so that 2012 and 2011 models can be compared. Since 2012 is the base year, its B coefficient is necessarily zero.
have succeeded in the subject by freeloading on the team success. The quantitative data presented here clearly demonstrate that on an individual assessment task, students taught in the redesigned subject outperformed similarly credentialed students studying the same material in a more traditional subject design. Perhaps more importantly, structural modeling of the student results provides evidence that the quality of the team that a student works with overcomes educational disadvantages of individual students.

Here and elsewhere (12, 18, 30), it has been well demonstrated that student tertiary entrance rank is directly correlated with achievement in human physiology. Modeling of the 2011 student outcomes suggest that a minimum ATAR of 60 was required to pass first-year human physiology. Criticism of human bioscience teaching that follows didactic teaching approaches is that they fail to address the inequalities of student preparation and background. Thus, while it has long been possible to predict the likelihood of any particular student passing human physiology based on their entrance rank and subject history achievement (2, 8, 12, 18, 27, 30), the criticism is that the teaching in the subject provides no structure to overcome these inequalities. While the data presented here demonstrate that results in human physiology are not uncoupled from ATAR, the influence of tertiary entrance rank is subordinate (or secondary) to the impact of the team performance on influencing individual learning.

Students in both 2011 and 2012 were expected to achieve individual mastery in the same set of learning objectives. In 2011, all learning objective were covered “in class,” students were taught all material in lectures, and these concepts were reinforced in (noncompulsory) tutorial classes. The week 13 assessment was a summative assessment of all material (learning objectives) taught between weeks 6 and 12 of the semester, and the final exam was summative of the entire subject. In 2012, intended learning objectives were divided into “core” and “extension” (26). Core objectives were taught in lectures, and these concepts were then learned as part of team-based guided inquiry activities in workshops. The week 13 assessment (collaborative test) assessed understanding and recall of these objectives. Extension concepts were not taught in the classroom, although online content in various forms was delivered via the university’s learning management system. The final exam then assessed student learning of the extension learning objectives. Thus, differences in assessment items mean that the assessments are not strictly speaking comparable between years. Notwithstanding these differences, the week 13 assessment in both years covered material from the same topics, albeit less some of the more difficult concepts that were included on the 2011 version of the test. On the other hand, the final exam in 2012 only assessed the most difficult concepts from the subject, where students’ performance is historically weakest. Further complicating this assessment, the material was entirely self-directed learning. As has been demonstrated, the improved student outcomes on the week 13 assessment in 2012 were related to having a strong team. Student success in the final exam was then built on the foundation of their success in the “core” learning objectives.

As the subject was designed, concerted effort was made to discourage freeloading. Built into the subject assessment model were a range of incentives and motivators to encourage individual student learning. The success of the individual students, on individual assessments, is likely due to the appropriate balance of these motivators. Historically, students at the low educational achievement end of the spectrum have become very quickly disillusioned (anxious) about their ability to pass human physiology (personal observations and Ref. 8). Failing early assessments in the subject demotivated student engagement. In the 2012 iteration of the subject, success (passing) always seemed achievable. The incentive for student engagement came from the need to prepare for workshops (via the weekly online quizzes). The team parts of the collaborative tests provided students with instant feedback on their understanding of the tested material. Students were able to see 1) the connection between the taught content and assessment items; 2) that individual success

Table 5. Parameter estimates and related statistics for ANCOVA for the final exam result

<table>
<thead>
<tr>
<th>Parameter</th>
<th>B</th>
<th>SE</th>
<th>t</th>
<th>Significance</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>10.720</td>
<td>2.588</td>
<td>4.142</td>
<td>0.000</td>
<td>5.638 to 15.801</td>
</tr>
<tr>
<td>ATAR</td>
<td>0.665</td>
<td>0.036</td>
<td>18.510</td>
<td>0.000</td>
<td>0.595 to 0.736</td>
</tr>
<tr>
<td>Year = 2011</td>
<td>−8.121</td>
<td>1.046</td>
<td>−7.765</td>
<td>0.000</td>
<td>−10.174 to −6.068</td>
</tr>
<tr>
<td>Year = 2012</td>
<td>0*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*The B coefficients for year serve to alter the ANCOVA model constant so that 2012 and 2011 models can be compared. Since 2012 is the base year, its B coefficient is necessarily zero.

Table 6. Predicted outcomes for two students who entered into the subject with the same ATAR but who worked with teams of different strength

<table>
<thead>
<tr>
<th>ATAR</th>
<th>Team Grade (total: 100)</th>
<th>Predicted Week 13 Assessment Score (total: 100)</th>
<th>Predicted Final Exam Score (total: 100)</th>
<th>Contribution to Final Grade (total: 61)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Student A&lt;br&gt;50</td>
<td>80</td>
<td>43</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td>Student B&lt;br&gt;50</td>
<td>65</td>
<td>30</td>
<td>33</td>
</tr>
</tbody>
</table>

The model predicted that student A, who worked with a stronger team, will outperform student B on individual assessments by as much as 12% for the week 13 assessment and 9% for the final exam, despite the fact that these students had identical entrance ranks. Note that these scores are out of 100 for each assessment and results do not reflect the relative weighting that each assessment contributes to the final grade. The contribution toward the final grade toward the total of these assessments is shown. This was calculated using the assessment weightings shown in Table 1.
was achievable, as other members of the team were able to demonstrate the relationship between the test items and course material; and 3) how the team could work together to improve any one individual student’s understanding of the content.

Another important motivator for individual success and accountability was the internal mark hurdle. Students were required to achieve a minimum mark on intrasemester assessments to pass the subject overall. Intrasemester assessments were worth 60% of the subject grade, of which students needed to earn at least 40%. It was only after achieving this hurdle that an aggregate grade for the intrasemester assessment and final exam was calculated.

Finally, success breeds success. Thinking passing is within their grasp motivated students to remain engaged in the subject, especially regarding the self-directed learning activities. Take away these motivators, or make the subject too easy to pass on the back of teamwork alone, and students (particularly students with low levels of internal motivation) will not learn for themselves.

Understanding the Structural Equation Model

The structural equation model attempts to produce a mathematical description of the impact of team-based guided inquiry learning on individual student performance on assessment. For this purpose, we assumed that the team score on collaborative tests reflects the combined team’s ability to work together researching and developing a shared understanding of the physiological concepts being learned. The predominant determinants on an individual student’s performance are their ATAR (scholastic background) and the strength and functioning of the team. Table 6 shows the model’s predictions for two students who have entered the subject with the same ATAR but who work in teams of different strength. What the model shows us is that the student who works with the stronger team will outperform a similarly credentialed student working in a weaker team on individual assessments. Thus, although ATAR does influence the students overall success in the subject, the dominant influences are who the student is learning with. The structural equation model’s explanatory power is limited to the 2012 iteration of the subject. Its usefulness is restricted to quantifying the impact of team learning and demonstrating that a team-based guided inquiry activity has the potential to overcome educational disadvantages.

In this study, we have provided evidence showing that the human bioscience problem can be resolved through team-based (peer-to-peer) guided inquiry active learning. It is interesting to note that while the literature surrounding tertiary education is evangelical about the benefits of active learning in one form or other, the quantitative evidence supporting this enthusiasm, at least in the biological sciences, is rather weak. The use of cooperative learning models has not been shown to substantially improve individual learning (as measured by individual assessments) (5, 6). Data from one study (6) suggested that students may actually underperform on individual assessment as a result of peer-led teaching, particularly academically weak students. These data contrast with observations by Cortright et al. (7), who found that when students were allowed time in lectures to solve problems on the material just learned, students who worked in small teams outperformed students who worked on their own solving these problems. Crucially, students who worked in teams were better able to transfer their learned material and correctly apply the knowledge to unfamiliar questions. This study, however, was performed with third/fourth-year students, whose better maturity and experience in tertiary education may have made them more receptive and better skilled for the team-based learning.

While the study conducted here shows significant improvement in student outcomes in individual student assessment items, a cautionary note should be raised. Improvement in performance seems correlated with the strength of the team that the student works with. Teams made up of students with similar abilities are, thus, less likely to benefit from this approach to teaching and learning than teams made up of both weak and strong students. The beneficiaries of the course design changes appear to be academically less prepared students who were teamed with and worked with more academically credentialed students. In our student body, we are lucky in that we have a strong mix of students. In other scenarios, where the student body is more homogenous, these outcomes may not be so obvious. Weaker students in a weak team may still be at a high risk of failing physiology.

Conclusions

This study attempted to demonstrate that team-based active learning can overcome disadvantages due to prior education among first-year allied health students studying physiology. Students who studied physiology with this pedagogy achieved better personal outcomes, and presumably better understanding of physiology, than students learning the same material in a more traditional didactic teaching model. Furthermore, we have demonstrated here the potential for teamwork to specifically benefit the least-prepared students in the classroom, provided the correct environment for learning is established.

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DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

AUTHOR CONTRIBUTIONS

Author contributions: J.A.R. conception and design of research; J.A.R. performed experiments; J.A.R. and G.B. analyzed data; J.A.R. and G.B. interpreted results of experiments; J.A.R. drafted manuscript; J.A.R. and G.B. edited and revised manuscript; J.A.R. and G.B. approved final version of manuscript; G.B. prepared figures.

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