Effectiveness of modified team-based learning in the introductory biology classroom of a two-year, open access college

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Team-based learning (TBL) is a type of collaborative learning that utilizes permanent teams, consistent structure, a flipped classroom and elements of just-in-time teaching. It can be effective not just in selective institutions of higher education, but also in open access, two-year colleges. A retrospective study comparing introductory biology classes before and after modified TBL introduction was conducted to determine if there was an effect on retention and/or final grades. A survey was also conducted to determine student attitudes towards TBL. The setup of each module was as described by Michaelsen, but modified in the application exercises. Specifically, while applications followed the same problem, same time, and specific choice aspects of TBL, frequently answers were not reported simultaneously. Implementation of the modified TBL format led to a decrease in student withdrawals from the course, a 14 percentage point increase in students passing the course (D or above) and a modest (6 percentage point) increase in students earning a C or higher. Additionally, there was a small, but statistically significant, increase in overall average exam scores (t-test, p<0.05). A survey given to students at the end of the semester of a modified TBL format class agreed with statements regarding learning gains and disagreed with statements on lecture being more effective than problem solving. This is similar to the results of a study in large, introductory biology classroom at a four-year college, where TBL implementation led to an increase in exam scores and students' self-reported problem-solving capabilities. It also supports work showing that increased structure in introductory biology courses can lead to better performance, particularly among subpopulations that typically struggle. This is the first study to demonstrate the effectiveness of TBL in an introductory biology course at a two-year, open access college.

Retention and performance in introductory biology classes are a challenge for many institutions, particularly for disadvantaged subpopulations (Rath et al. 2007, Haak et al. 2011). Active learning, practice, peer-led workshops, and structure have all been shown to increase performance in these classes. A meta-analysis by Freeman *et al.* (2014) showed that science and engineering courses that incorporate active learning increase exam scores and the chance of passing the course. Specifically, Armbruster *et al*. (2009) showed an increase in exam score and student engagement in introductory biology courses that incorporate active learning The Carnegie Hall hypothesis (Haak et al. 2011) states that intense practice via active learning benefits capable, but underprepared students. This is of special interest at an open access college that attracts many of these types of students, and particularly in a biology course, where the achievement gap is the largest (Haak et al. 2011). In an introductory course, "prescribed active learning", a structured form of learning, leads to increased learning, particularly for at-risk students (Freeman et al., 2007). Specifically, a highly structured course design, that uses preparation outside of class, clickers or random call in class to answer questions, as well as active learning and practice exams, led to a 45% drop in the achievement gap between the most prepared and least prepared students (Haak et al., 2011). When repeated at a different R1 institution, a moderately structured course design decreased the achievement gap between black and white students and between first and multi-generational students (Eddy & Hogan, 2014). In addition, peer-led workshops increase student learning and engagement in introductory biology courses when combined with active learning (Preszler, 2009).

Team-based learning (TBL), as described by Michaelsen (2004), is a teaching method that combines all of the above, along with some “just in time teaching” (Michaelsen & Sweet, 2008). TBL, as its name implies, relies on teamwork. Teams are formed at the beginning of the semester and remain intact for its entirety. Teammates are held accountable through peer feedback that occurs mid- semester and at the end of the semester. Each TBL module requires that students first gain knowledge outside of class through readings, videos, etc., then come to class prepared to take a quiz or “readiness assessment test” (RAT) on the material. The students first take the RAT individually then the same RAT as a team. The team RAT is taken using a scratch off that will reveal the correct answer. Students then have the correct answers and can learn from each other. In addition, the instructor is aware of what concepts the class is struggling with and can give a mini lecture covering just those areas. Once the class is ready, they move on to application exercises. Michaelsen (2004) prescribes these exercises as: (1) simultaneous, where each team is working on the problem at the same time; (2) same problem, where each team is working on the same problem; (3) specific choice, where students must think critically to choose an answer and usually justify it; and (4) significant problem, where the exercise has relevance to real life (figure 1).

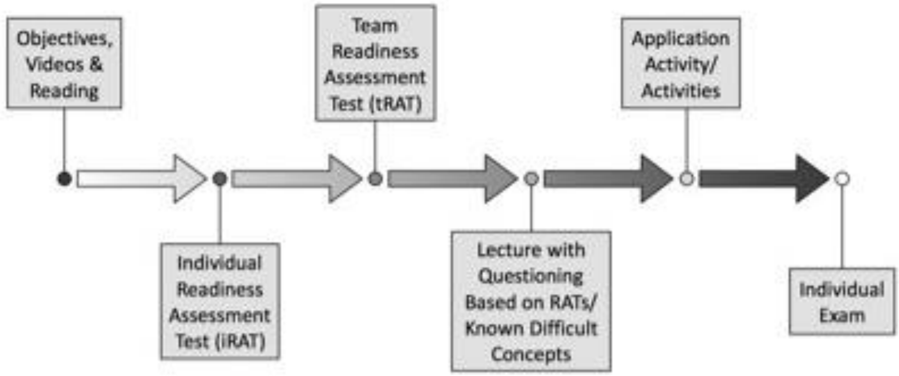

Figure 1. Modified team-based learning module design. Course activities were varied in type. All teams received the same problem at the same time and had to make a specific choice; however, reporting out of answers was not always simultaneous.

Results from biology and health science courses at four year, undergraduate institutions indicate that the TBL format can be effective (Carmichael, 2009; Jafari, 2014). In a large, introductory biology classroom, at a four-year school, Carmichael found an increase in exam scores, except the final, was observed, as well as an increased ability to interpret results and draw conclusions (Carmichael, 2009). TBL, as compared to lecture in a neurology course, also showed an increase in scores (Jafari, 2014). However, this is the first study to demonstrate the effectiveness of TBL in an introductory biology course at a two-year, open access college.

Methods

Course

The course evaluated in this study was an introductory biology course with mixed majors ranging from pre-nursing to business to art majors. Classes did not exceed 34 students. The concepts covered include basic chemistry, cell structure and function, energy transfer, genetics, and evolution.

Pedagogy

2012-2013

The course was set up in four sections covering chemistry and cell structure-function, energy transformations, the flow of information, and evolution. Students were encouraged to read before class by including the pages to be covered before each lecture on the learning management system (LMS), but there were no in class, reading quizzes given. Class time was spent on lecturing combined with questioning of the entire class. Students answered questions individually either by raising hands or using a freeware clicker system called Socrative. At the end of class each student submitted an exit question via the clicker; these were answered at the beginning of the next class. Three case studies were also included covering the scientific method, Mendelian genetics, and speciation. Students were expected to complete a publisher provided review online, outside of class, before each exam. Students were assessed informally when clickers were used and formally via four multiple choice and short essay exams. There were four exams. Final grades were calculated based on exams, online homework, and in class participation scores.

2013-2014

TBL, as outlined in Michaelsen et al. (2004), was implemented, combined with various lecture lengths and knowledge application types. Teams were formed at the beginning of the semester and remained set for the entire semester. In the first semester of implementation, teams were formed by the instructor; however, in the second semester, they were formed using CATME. This website allowed for collection and analysis of student feedback, as well as the distribution of peer evaluations to team members. Each module was setup as follows (figure 1): Sections of the text to be read, as well as outlines for each section, were placed on the learning management system. Students were required to read and complete a basic quiz online before coming to class. At the beginning of each module, readiness assessment tests (RATs) were given. RATs were taken first individually (iRAT) then as a team (tRAT). iRATs were evaluated by scanning answers while students were completing the tRAT using Immediate Feedback Assessment Technique (IF-AT) sheets. This feedback, combined with walking around during the tRATs, listening to team discussions, allowed the instructor to gauge areas of confusion and adjust the lecture to focus on difficult topics. After lecture, various types of knowledge applications were implemented, including case studies, problem sets, and discussion/acting. Four case studies were used during the semester. A case study on energy transfer was added to the three cases used in the previous year. Problem sets were used for cell structure and function, transport, genetics, and flow of information. Problem sets and case study answers were assessed informally by moving throughout the classroom and more formally by reviewing teamwork placed in folders and assigning a grade. Applications followed Michaelsen's recommendations in that all teams received the same problem at the same time and had to make a specific choice. However, reporting of results was not always simultaneous. Four exams were given during each semester. Final grades were calculated based on exams, iRAT, tRAT, online homework, and in class teamwork scores.

Assessment & Data Analysis

Retention and average exam scores in introductory biology courses taught by the same instructor were compared between the 2012-2013 (pre-modified TBL) and 2013-2014 (modified TBL) academic years. Two sections of introductory biology were taught in the fall of 2012 and three sections in the spring of 2013, for a total of 170 in the 2012-2013 academic year. One section of introductory biology was taught in each semester of the 2013-2014 academic year, for a total of 42 students.

Retention was calculated as the percent of students who did not withdraw during the course of the semester. Students dropping in the first week, without record, were not included.

Final course grades were tabulated, not including students who dropped in the first week (without record). Final grades were converted to a numerical scale (A=4.0, B=3.0, C=2.0, D=1.0, F=0.0) and compared between the two years. The proportion of students earning each letter grade was also calculated and compared. Average scores for each exam and combined exam scores were calculated; zeros were removed. Average exam scores from each academic year were compared using an unpaired, two-tailed, t-test. Differences were considered significant when $p < 0.05$.

Survey

A survey consisting of nine Likert Scale questions on student attitudes towards TBL was administered to introductory biology students at the end of the spring 2016. There was also space for comments. 24 students responded to the survey. Agree and strongly agree responses were combined as were disagree and strongly disagree.

Results

Retention

Implementation of the TBL format led to a decrease, from 14% to 4.4%, in student withdrawals from the course (figure 2).

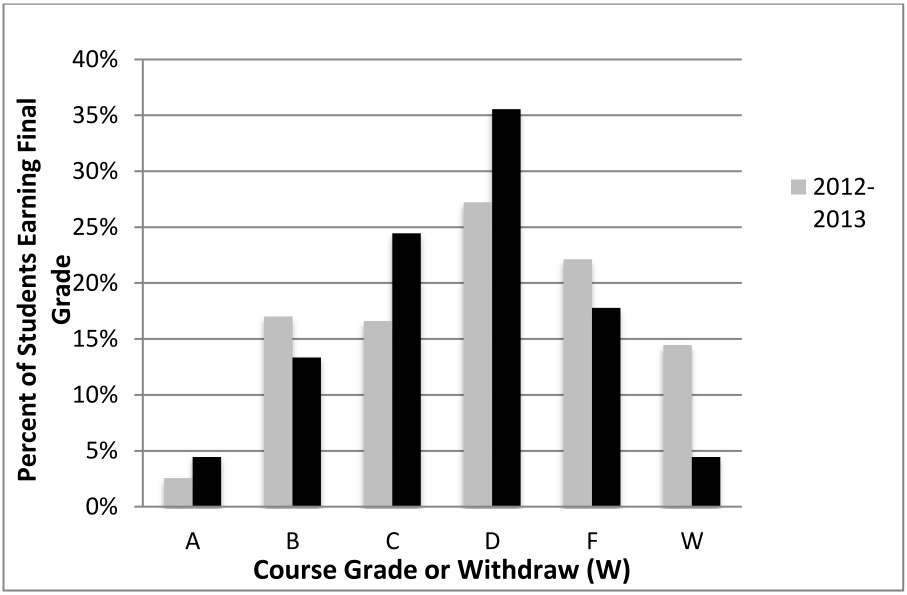

Figure 2. Perccent of students earning final grades before (2012-2013) and after (2013-2014) implementation of TBL.

Grades

Final grades, as calculated above, increased from 1.2 to 1.4 after implementation. Specifically, there was an increase in students passing the course (D or above) from 63% to 77%. There was also a modest increase of six percentage points, from 36% to 42%, in students earning a C or higher (figure 2). Finally, there was a small, but statistically significant ($p < 0.05$) increase in the overall average exam score (figure 3). However, this was not significant for individual exams (t-test, $p < 0.05$).

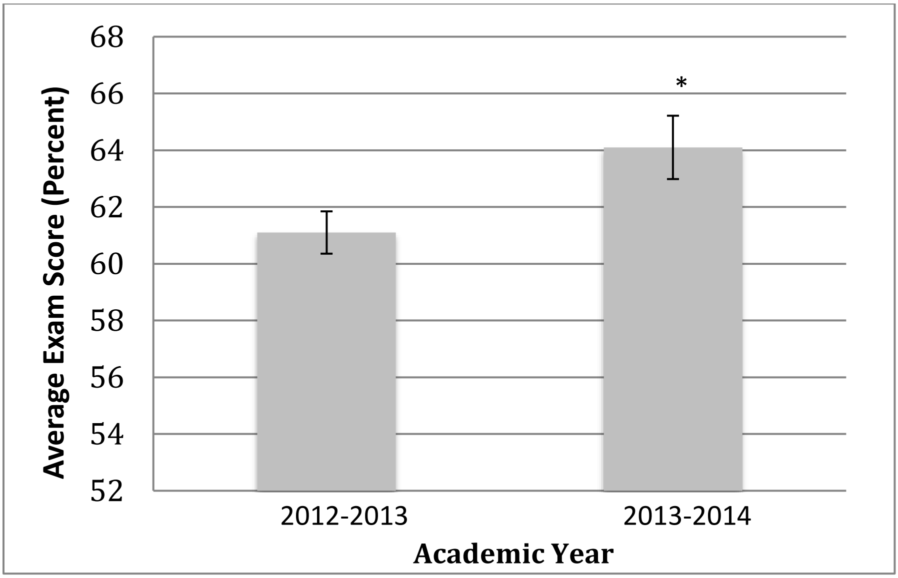

Figure 3. Average exam scores before (2012-2013) and after (2013-2014) implementation of TBL. For the 2012-2013 year n=157 and for the 2013=2014 year n=490. The asterisk indicates a significant difference in overall exam score (t-test, $p<0.05$) after implementation.

Survey

The overall response to team-based learning was positive. Regarding self-perceived learning gains from TBL, 79% of students agreed or strongly agreed that they learned from solving problems with their team, and 71% agreed or strongly agreed that working and discussing material with a team helped them think through problems. Sixty-seven percent agreed or strongly agreed that TBL helped them learn the material;

conversely, only 21% agreed or strongly agreed that that they preferred lecture to working on problems or activities.

Regarding overall learning gains, 88% agreed or strongly agreed that this class helped to apply concepts to the real world and 96% agreed or strongly agreed that they learned a lot from the class. Finally, 71% agreed or strongly agreed that the course design helped them become a more self-directed learner.

Fifteen out of 24 students commented on the survey. Three of these comments were explicitly negative towards team-work, while eight positively mentioned either team/group work or the course setup/teaching style. One comment was neutral and three were unrelated to the setup of the course.

Conclusions

This study demonstrates that a modified TBL course setup can lead to an increase in retention, higher final grades and sometimes higher exam scores in an introductory biology course at a two-year, open access college. This work supports other work in introductory biology classrooms, particularly a study by Carmichael (2009) on the use of TBL in the introductory biology classroom at a four-year university. The author also observed an increase in exam scores (except the final) in a modified TBL formatted class, compared to a lecture course. Carmichael found that individual's scores increased from 64% to 78%, while in this study averages were approximately ten percentage points lower. This could be due to the difference in reading assignments (online multiple choice vs. essay response), student populations, questions asked in the survey, or frequency of RATs (about every two weeks vs. every week). In a neurology course, Jafari *et al.* (2014) compared conventional lecture to TBL in an undergraduate neurology course and found that TBL increased exam scores as well. There is also evidence that TBL increased exam scores in a second-year medical school student population (Koles et al. 2010).

The general shift in grade distribution seen in this study is similar to other studies that utilized peer teaching or TBL (Preszler, 2009; Carmichael 2009). However, while Preszler and Carmichael saw an increase in As and Bs and decrease of Ds and Fs, in this study there was an increase in Cs and Ds, and a decrease in Fs and Ws. Additionally, there was a slight decrease in As and Bs. These discrepancies could be due, in part, to the iRAT scores, as students did not perform as well on these as in the Carmichael study. In addition, it could be attributed to different grading schema. Specific to withdrawal rates, Carmichael (2009) did not report a large difference between the lecture and modified TBL format classes (9% and 8% respectively), while in this study, the difference in withdrawal rates was larger (14% and 4.4% respectively). However, these withdrawal percentages are similar to those reported by Preszler (2009) after instituting peer led workshops in an introductory biology course (12% to 7%). The larger increase in retention may be due to differences between the student populations on both studies. As an open access college, there is a large proportion of Pell-eligible and first generation students, and there is data to show that structured course design benefits all students, but increases performance even more for first generation and black students (Stephens et al., 2012)

Not only is TBL effective at increasing retention and grades, but, based on their responses to the survey, students see the benefit in increased problem-solving skills, real life applications, and learning biological concepts. This was also found to be the case in first year pharmacy students, who self-reported gains in critical thinking, problem solving and exam preparation skills (Frame et al., 2015). The Carmichael study also reported that the majority of students agree or strongly agree that they have a better grasp of biological concepts (Carmichael, 2009). Not only do students self-report increased gains in problem solving skills, but they exhibit increased critical thinking skills, as evidenced by improved performance on questions that require higher order thinking skills. In addition, the majority of students report a preference for TBL. This preference for TBL over standard lecture has been documented in a TBL-based neurology course, and in medical education (Abdelkhalek et al., 2010; Chung et al., 2009; Jafari, 2014). However, in a study conducted in a principles of biology course, students did not have a positive attitude towards team work (Agogo, 2015).

Due to the number of changes that were made from year to year (team work, the addition of quizzes, and more in class active learning), it is difficult to pinpoint what exactly led to the increased retention rate in this study. TBL can be considered a type of moderately structured learning, as delineated in by Eddy and Hogan (2014). Reading quizzes require students to work on material before class and frees up time for more active learning in the classroom. Students who distribute their study time throughout the semester (instead of cramming before exams) tend to perform better, and students in structured learning environments spend overall more time (on average twice as much) engaging with the material outside of class (Eddy & Hogan, 2014). In addition, the community environment found in a structured course design where students are working together increases the feeling of community, which can lead to greater success in the classroom (Eddy & Hogan, 2014; Stephens et al., 2012).

All of the studies mentioned thus far have been conducted at four-year universities or colleges. Student populations differ significantly between four year and two year institutions and, although research shows that subpopulations typical of two-year schools benefit even more from structured learning, no previous work has been published to show its effectiveness in two-year colleges. This study provides evidence that a modified TBL format is not only possible at a two-year open access college, but it improves retention, overall course grade, and exam scores. However, there are limitations that should be addressed in future studies, particularly looking at grades and retention under different instructors. Future work should focus on what specific interventions led to an increase in scores, or whether it is the combination of extra practice and collaborative and active learning.

References

Abdelkhalek, N., Hussein, A., Gibbs, T., & Hamdy, H. (2010). Using team-based learning to prepare medical students for future problem-based learning. *Medical Teacher, 32*(2), 123–129. https://doi.org/10.3109/01421590903548539

Agogo, A. (2015). Implementing Team-Based Learning in principles of biology to determine effects on students’ content knowledge, thinking skills, and attitudes about teamwork (M.S.). Texas Woman’s University, United States - Texas. Retrieved fromhttps://search.proquest.com/docview/1800291227/abstract/C82F78527644CF0PQ/1

Armbruster, P., Patel, M., Johnson, E., & Weiss, M. (2009). Active Learning and Student-centered Pedagogy Improve Student Attitudes and Performance in Introductory Biology. CBE-Life Sciences Education, 8(3), 203–213. https://doi.org/10.1187/cbe.09-03-0025

Carmichael, J. (2009). Team-Based Learning Enhances Performance in Introductory Biology. *Journal of College Science Teaching, 38*(4), 54–61.

Chung, E.-K., Rhee, J.-A., Baik, Y.-H., & A, O.-S. (2009). The effect of team-based learning in medical ethics education. *Medical Teacher, 31*(11), 1013–1017. https://doi.org/10.3109/01421590802590553

Eddy, S. L., & Hogan, K. A. (2014). Getting Under the Hood: How and for Whom Does Increasing Course Structure Work? *CBE-Life Sciences Education, 13*(3), 453–468. https://doi.org/10.1187/cbe.14-03-0050

Frame, T. R., Cailor, S. M., Gryka, R. J., Chen, A. M., Kiersma, M. E., & Sheppard, L. (2015). Student Perceptions of Team-based Learning vs Traditional Lecture-based Learning. American Journal of Pharmaceutical Education, 79(4), 1–11.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. Proceedings of the National Academy of Sciences of the United States of America, 111(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111

Freeman, S., O'Connor, E., Parks, J. W., Cunningham, M., Hurley, D., Haak, D., Dirks, C.Wenderoth, M. P. (2007). Prescribed Active Learning Increases Performance in Introductory Biology. CBE-Life Sciences Education, 6(2), 132–139. https://doi.org/10.1187/cbe.06-09-0194

Haak, D. C., HilleRisLambers, J., Pitre, E., & Freeman, S. (2011). Increased Structure and Active Learning Reduce the Achievement Gap in Introductory Biology. Science, 332(6034), 1213–1216. https://doi.org/10.1126/science.12134820

Jafari, Z. (2014). A comparison of conventional lecture and team-based learning methods in terms of student learning and teaching satisfaction. Medical Journal of the Islamic Republic of Iran, 28, 1–8.

Koles, P. G., Stolfi, A., Borges, N. J., Nelson, S., & Parmelee, D. X. (2010). The Impact of Team-

Based Learning on Medical Students' Academic Performance: Academic Medicine, 85(11), 1739–1745. https://doi.org/10.1097/ACM.0b013e3181f52bed

Michaelsen, L.K., Knight, A.B., Fink, L. D. (2004). Team-Based Learning: A Transformative Use of Small Groups in College Teaching (1st ed.). Sterling, VA: Stylus Publishing.

Michaelsen, L. K., & Sweet, M. (2008). The essential elements of team-based learning. New Directions for Teaching and Learning, 2008(116), 7–27. https://doi.org/10.1002/tl.330

Preszler, R. W. (2009). Replacing Lecture with Peer-led Workshops Improves Student Learning. CBE-Life Sciences Education, 8(3), 182–192. https://doi.org/10.1187/cbe.09-01-0002

Rath, K. A., Peterfreund, A. R., Xenos, S. P., Bayliss, F., & Carnal, N. (2007). Supplemental

Instruction in Introductory Biology I: Enhancing the Performance and Retention of

Underrepresented Minority Students. CBE Life Sciences Education, 6(3), 203–216. https://doi.org/10.1187/cbe.06-10-0198

Stephens, N. M., Fryberg, S. A., Markus, H. R., Johnson, C. S., & Covarrubias, R. (2012). Unseen disadvantage: How American universities' focus on independence undermines the academic performance of first-generation college students. Journal of Personality and Social Psychology, 102(6), 1178–1197. https://doi.org/10.1037/a0027143