Impact of High-Performing Teams on Student Learning

Dr. Molly A. McVey, University of Kansas

Dr. Molly A. McVey is a post-doctoral teaching fellow at the University of Kansas School of Engineering where she works with faculty to incorporate evidence-based and student-centered teaching methods, and to research the impacts of changes made to teaching on student learning and success. Dr. McVey earned her Ph.D in Mechanical Engineering from the University of Kansas in 2012.

Dr. Carl W. Luchies, University of Kansas
Adrian Joseph Villicana, University of Kansas

I am a graduate student in the Social Psychology PhD program at the University of Kansas. As of August 2017, I will be an Assistant Professor in Psychology at the University of Puget Sound. My research interests, broadly, are in stereotyping and prejudice, in which I apply an intersectional lens. As for teaching, I incorporate aspects of intersectionality and action teaching in increase students critical thinking and awareness of social justice issues.

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Introduction

The authors are experimenting with the incorporation of team-based learning (TBL) principles in a required undergraduate dynamics course and the effect on student learning. This course typically has 59-120 sophomore and junior level mechanical engineering students enrolled and has been taught in a flipped format, using the SCALE-UP model (Beichner, 2008), for several semesters. By design, the course relies heavily on peer-to-peer instruction through cooperative learning, and beginning in the semester of Spring 2016, the instructor aimed to move from cooperative groups to high performing teams using principles of team-based learning (L. K. Michaelsen, Knight, & Fink, 2002). Three primary research questions were examined: 1) what effect does the implementation of TBL have on *individua*l student learning, compared to an offering of the course prior to implementation; 2) what effect does the implementation of TBL have on *team performance*, compared to an offering of the course prior to implementation, and 3) what effect does being a member of a high-performing team have on individual student learning in the course?

Background

Team-based learning (TBL) takes cooperative learning to the next level by increasing the time teams spend together and the expectations of team integration and performance. TBL differs from cooperative learning in that particular attention is payed to team formation, peer assessment, prompt feedback on individual and group performance, and group work (L. K. Michaelsen et al., 2002). Teams should be made up of 5-7 people and stay together for the entire semester, group work should account for a significant portion of the course grade, immediate feedback should be given so teams can discuss outcomes, misunderstandings, and problems while content is fresh in their minds, and peer assessment should factor into the course grade.

TBL has been shown to improve student learning and course satisfaction in a variety of disciplines (Anwar, Shaikh, Dash, & Khurshid, 2012; Dana, 2007; Macke & Tapp, 2012; Mott & Peuker), particularly for low-performers (Conway, Johnson, & Ripley, 2010; Haidet, Kubitz, & McCormack, 2014). In addition, TBL is relevant to the development of the interpersonal, communication, and leadership skills that are in high demand in the engineering industry (Kumar & Hsiao, 2007). Therefore, we hypothesized that shifting to TBL, compared to cooperative groups, would 1) improve individual learning, 2) improve team performance, and 3) would most benefit individual members within teams performing at a high level. To explore these hypotheses we compared student performance across two semesters, one that utilized cooperative groups and the second that utilized TBL.

Methods

This research was approved by the University of Kansas Human Research Protection Program.

In Fall 2014, 59 students enrolled in the course which was taught in a flipped format (Beichner, 2008) in an active-learning classroom and utilized cooperative groups. Each class meeting consisted of: 1) a reading quiz, 2) lecture highlights, 3) example problem(s), and 4) group work. The instructional team consisted of the professor, two graduate teaching assistants (GTAs), and one graduate student grader. The instructor and GTAs walked around during the group work time to assist groups and/or individuals with questions.

The instructor formed the first set of cooperative groups by placing one student from the top, middle, and bottom third of the class's GPA distribution into 19 three-person groups and 1 two-person group. After the first exam, groups were re-assigned using the same process except that it was based on the first exam performance. After the second exam, the process was repeated based on the average of the first and second exam performance. Two groups of three students were assigned to sit at each semi-circular table in the classroom, with a nametag placed in front of each student.

Students were required to prepare for class by reading the textbook, watching lecture videos, or reviewing PowerPoint lecture slides prior to attending class. To encourage preparation, each class began with a two-stage reading quiz consisting of two multiple-choice clicker questions. The students answered the questions individually during the first stage, discussed their answers with their group members before answering the same questions individually during the second stage. Next, the instructor briefly highlighted the most important lecture points and concepts that students typically struggle with and ended with a brief discussion on one or two example problems designed to demonstrate the new concepts.

The majority of class time was spent working both conceptual multiple-choice problems and a more in-depth open-ended problem(s). The groups worked through the problems together, although each group member was required to record their own solution and answer for each problem, which was graded. During group work, clickers were used for anonymous polling of students' answers on each multiple-choice question, results were presented to the class, and concepts were discussed as necessary. Groups were polled regarding their final answer(s) for the in-depth problem(s), and the concepts and solution method required to solve this problem were discussed as necessary. This process provided each group with immediate feedback regarding their performance on each problem and provided them the opportunity to discuss and solidify their understanding of the concepts by correcting their solution for each problem. All group work was graded, with credit given for the correct approach and solution for each problem, not for the

correct answer. Group members were instructed not to leave the classroom until all group members completed the group work.

Three two-stage exams were given during the semester, each consisting of four multiple-choice questions. Each question was designed to assess the outcome of a learning objective. Student performance on each question, for both stage one and two, was recorded and tracked for all three exams. During the first stage (55 minutes, 50% exam credit, closed book, equation sheet allowed), each student developed their solution and final answer individually for each question. At the end of stage one, each student kept their solutions but handed in the completed answer sheet, and each question was scored as right or wrong, with no partial credit given. During the second stage (20 minutes, 50% exam credit, open book, equation sheet allowed), the teams discussed and compared their solution and worked together to determine the correct solution and answer on the same four questions. Stage two of the exam was scored using scratch cards (Smith, 2013), where groups had multiple chances to get the correct answer, but the point value earned went down with each attempt (10, 5, 2, 1, 0 points). Teams in which all members scored at or above the exam mean were rewarded with extra credit points on the exam.

Throughout the semester the instructor observed that at some tables, the two 3-person groups merged into a single group and worked together as a group of six, which he neither promoted nor prohibited during group work, but did not allow during the exams. Furthermore, he observed that the six member groups performed better in class compared to the three member groups. He noticed this occurrence even after groups were shuffled. Therefore, the instructor was motivated to move toward a TBL philosophy. To that end, in Spring 2016 the instructor used CATME (Layton, Loughry, Ohland, & Ricco, 2010) to form teams of 5 that were kept together for the entire semester, implemented team-building into each lecture period, and implemented a more thorough peer review process.

Implementation of TBL

In Spring 2016, 73 students enrolled in the course which was again taught in a flipped format (Beichner, 2008) in an active-learning classroom but this time implemented TBL. Each class meeting consisted of: 1) reading quiz, 2) team development, 3) lecture highlights, 4) example problem(s), and 5) group work. The instructional team consisted of the professor, two graduate teaching assistants, and two undergraduate teaching fellows (UGTFs). Undergraduate teaching fellows were undergraduates who had succeeded in the course and were hired specifically to serve as peer mentors during active-learning activities. The instructor, GTAs, and UGTFs walked around during the group work time to assist groups and/or individuals with questions.

Students were placed into 13 five-person teams and 2 four-person teams using CATME (Layton et al., 2010). Surveys were sent to students asking about gender, racial/ethnic identity, overall GPA, grade in the pre-requisite course, schedule, English skills, writing skills, commitment level

to the course, preferred leadership role, preferred team leadership structure, and a question about being detail-oriented versus a big picture thinker. The CATME software assigned students to teams, grouping like students in terms of schedule, gender and racial/ethnic identity, and distributing students in terms of all other categories. One team of 4-5 students was assigned to sit at each semi-circular table within the classroom, with a name tag placed in front of each student.

Each class began with the same two-stage reading quiz as was done in Fall 2014 semester (described above). The second activity, team development, required approximately five minutes and consisted of two questions for team discussion. The first question was an icebreaker, designed to be easy to answer and help the teams engage in conversation. The second question was designed to focus on team function and cause reflection on attributes of a team. A sample of questions used for each question type is provided in Table 1. After approximately four minutes of team discussion, the instructor asked a subset of the teams to quickly report to the class a representative answer to each question, and occasionally followed up with a brief discussion on the importance of team development and performance. Next, the instructor provided the 3) lecture highlights, 4) example problem(s), and 5) group work as done in the Fall 2014 semester (described above). Three two-stage exams were also utilized as was done in the Fall 2014 semester.

Table 1. Sample of team-building questions

Sample of Ice Breaker Questions
▪ What kind of place do you currently live (dorm, house, apartment, fraternity, sorority, etc.)? ▪ What is your favorite restaurant and why? ▪ What is the most beautiful place you have ever visited? ▪ Describe one volunteer experience in the last few years? ▪ What adventure did you do in the last year or plan to do in the next year? ▪ What is your #1 hobby? ▪ What book has influenced you greatly? How? ▪ What's the most important lesson you've learned in the last year? ▪ If you could solve one problem facing civilization today, which one would you solve? ▪ Based on your experience in preparing and taking Exam #1, provide one study technique that you plan to use to prepare for Exam #2.
Sample of Reflective Team Based Questions
▪ Provide one attribute of an effective team. ▪ Provide one attribute of an effective team member. ▪ Provide one attribute of your team that is working well. ▪ If you had a team member who participated very little during group work, what could the other team members do to encourage that team member to participate? ▪ If you had a team member who often dominated the group discussion, what could the other team members do to achieve a more balanced participation by all team members? ▪ If a member of your team seldom comes to class prepared, which hurts the entire team, what could the other team members do to encourage better preparation? ▪ Humor might not be an obvious factor in effectiveness of a team, but humor inspires trust and intimacy – which can lead to better team interactions, including effective communication, development of group goals, group productivity and management of emotions. On a scale of 1-5 (1=no team humor, 3=some team humor, 5=significant team humor), how much humor does your team utilize? ▪ In the context of dynamics group work, what is one strength and one weakness you bring to your team? ▪ What is one characteristic that you admire in a member within your team? No name is needed. ▪ If you were to start an engineering consulting company from scratch, what core values would you build it on?

Peer evaluation was done using CATME software (Loughry, Ohland, & Moore, 2007; Ohland et al., 2012) once at the end of the semester. The peer evaluation along with the instructional teams' evaluation of each team member during group activity accounted for 5% of the total course grade.

Therefore, the primary difference between the two semesters was related to the teams; Fall 2014: three person cooperative groups, formed based on GPA/test scores, shuffled every 4-5 weeks with no class time spent on team formation, compared to Spring 2016: five member teams, formed based on CATME surveys, maintained all semester, class time invested in team development, and structured peer evaluation.

Assessment Methods

Individual and Team Performance Fall 2014 Compared to Spring 2016

Learning objectives, provided by the textbook (Hibbeler, 2016), were linked to exam problems for the Fall 2014 and Spring 2016 offerings of the course. Each exam consisted of problems that tested the learning objectives (see Table 2 for the specific learning objectives that were compared across semesters). The specific problem testing each learning objective was not identical, but was of a similar level on Bloom's Taxonomy (Anderson, Krathwohl, & Bloom, 2001).

Table 2. Learning objectives and associated test questions for Fall 2014 and Spring 2016 (Ex= Exam, Q= question number).

Topics		Fall 2014	Spring 2016
CHAPTER 12: Kinetics of a Particle			
12.6 **LO 12.6**	**Projectile Motion** Analyze the free-flight motion of a projectile.	EX1 Q1	EX 1 Q1
12.9 **LO 12.9**	**Absolute Dependent Motion** Relate the positions, velocities, and accelerations of particles undergoing dependent motion.	EX 1 Q2	EX 1 Q4
CHAPTER 13: Kinetics of a Particle: Force and Acceleration			
13.4 **LO 13.4**	**EOM: Rectangular Coordinates** Apply Newton's second law to determine forces and accelerations for particles in rectilinear motion.	EX 1 Q3	EX 1 Q4
13.5 **LO 13.5**	**EOM: Normal & Tangential (n-t) Coordinates** Apply the equation of motion using normal and tangential coordinates.	EX 1 Q4	EX 1 Q3
CHAPTER 14: Kinetics of a Particle: Work and Energy			
14.6 **LO 14.6**	**Conservation of Energy** Apply the principle of conservation of energy.	EX 2 Q1	EX 2 Q2
CHAPTER 15: Kinetics of a Particle: Impulse and Momentum			
15.4 **LO 15.4b**	**Impact** Analyze the motion of bodies undergoing a collision, in both central and oblique cases of impact.	EX 2 Q4	EX 2 Q3
CHAPTER 16: Planar Kinematics of a Rigid Body			
16.1 **16.2** **16.3** **LO 16.1**	**Planar Rigid-Body Motion** **Translation** **Rotation about a Fixed Axis** **Analyze** the kinematics of a rigid body undergoing planar translation or rotation about a fixed axis.	EX 3 Q2	EX 3 Q1
16.7 **LO 16.7b**	**Relative-Motion Analysis: Acceleration** Determine the acceleration of a point on a body by using a relative acceleration analysis.	EX 3 Q3	EX 3 Q2
CHAPTER 18: Planar Kinetics of a Rigid Body: Work and Energy			
18.5 **LO 18.5a** **LO 18.5b**	**Conservation of Energy** Determine the potential energy of a conservative force. Apply the principle of conservation of energy.	EX 3 Q1	EX 3 Q4

Peer evaluations were conducted through the CATME (Comprehensive Assessment of Team Member Effectiveness) software. Students completed comprehensive peer evaluations at the end of the semester, and evaluated themselves and their peers on several measures of effective teams. The CATME peer review software measures 29 types of team member contributions, and the short-version clusters team member contributions into five broad categories (contributing to the team's work, interacting with teammates, keeping the team on track, expecting quality, and

having relevant knowledge, skills, and abilities) (Ohland et al., 2012). Students rate themselves and each teammate on questions on a 1-5 point scale.

The first component of the peer review consisted of students ranking themselves and their teammates on their performance in four categories (contributing to the team's work, interacting with teammates, keeping the team on track, and expecting quality). Students made their rankings using a 1-5-point ranking. A description of each of the five rankings was presented for the students' reference. The next component was a series of questions on "Team Conflict," which were answered using a Likert scale (none, little or rarely, some, much or often, very much or very often). Examples of questions included, "How frequently do you have disagreements within your work group about the task of the project you are working on?" and "How much emotional conflict is there in your work group?" Next, three questions on "Team Satisfaction" were answered on a Likert scale (strongly agree, agree, neither agree nor disagree, disagree, strongly disagree). Questions included, "I am satisfied with my teammates", "I am pleased with the way my teammates and I work together," and "I am very satisfied with working in this team." Next, five questions on "Team Interdependence" were answered on a Likert scale. Questions in included, "My teammates and I have to obtain information and advice from one another in order to complete our work," and "I depend on my teammates for the completion of my work." Next, students answered questions on "Team Perspectives" that consisted of items such as "I'm unhappy with my team's level of commitment to the task," and "Being part of the team allows team members to do enjoyable work." Finally, students answered questions regarding "Team Transition Processes," such as Mission Analysis, Goal Specification, and Strategy formulation and planning.

Impact of being on a high-performing team on individual performance

To investigate the effect of being in a "high performing team" on individual exam performance, teams were grouped into "high performing," "average performing," and "low performing" teams. First, average team scores were calculated for two exams (the first exam was neglected because all but one team scored 100% on the team portion). Next, each team score was compared to the average team score for that exam. If the team scored 1 standard deviation above the average group score or higher, it was defined as a high score. If the team scored 1 standard deviation below the average team score or lower, it was defined as a low score. If the team score was within +/- 1 STD of the average team score, it was defined as an average score. Finally, if a team scored a high score on both exams, the team was labeled a "high performing" team. If a team scored a low score on both exams, it was labeled a "low performing" team, and if the team scored an average score on both exams, the team was labeled an "average performing" team. Two teams ended up in each low, average, and high performing category. The other teams did not fit the criteria and were not included in this analysis. To examine the impact of being in a high performing team on *individual* learning, scores on the *individual* section of the three exams were compared across the low, average, and high performing teams.

Statistical Analysis

A series of logistic regressions were conducted to determine the effect of semester (Fall 2014 or Spring 2016) on the percentage of students who answered the individual portion of each learning objective correctly. A series of one-way ANOVAs (essentially *t*-tests) were conducted to determine the effect of semester (Fall 2014 or Spring 2016) on group scores for each learning objective. Finally, ANOVA was used to determine the effect of being in a high performing team on individual overall exam scores for the three exams. Two contrasts were examined: high performing teams compared to low and average (combined) and low vs. average performing teams. A *p*-value < 0.05 was required for significance, although marginally significant results are also reported.

Results

Individual performance Fall 2014 versus Spring 2016

In three out of nine learning objective comparisons made, the logistic regression model revealed a significant improvement in performance in Spring 2016 compared to Fall 2014 (Figure 1). On learning objective 12.6, the logistic regression model was significant (χ^2 (1) = 27.37, $p < .001$) and students in the Spring 2016 course were 7.3 times more likely to correctly answer the question associated with LO 12.6 than students in the Fall 2014 course. On LO 14.6, the logistic regression model was significant (χ^2 (1) = 16.641, $p < .001$) and students in the Spring 2016 course were 4.4 times more likely to correctly answer the question associated with LO 14.6 than students in the Fall 2014 course. On LO 15.4b, the logistic regression model was significant ($\chi 2$ (1) = 21.359, $p < .001$) and students in the Spring 2016 course were 5.4 times more likely to correctly answer the question than students in the Fall 2014 course. In one learning objective, LO 13.5, the logistic regression model was only marginally significant (χ^2 (1) = 3.505, $p = .061$), and students were 2.0 times more likely to answer the question correctly in Spring 2016 compared to Fall 2014. On two learning objectives, LO 16.7b and 18.5b, the logistic regression model was significant but in the negative direction (students were more likely to answer the question correctly in Fall 2014 than Spring 2016) (LO 16.7b: χ^2 (1) = 9.518, $p = .002$; LO 18.5b: χ^2 (1) = 17.020, $p < .001$).

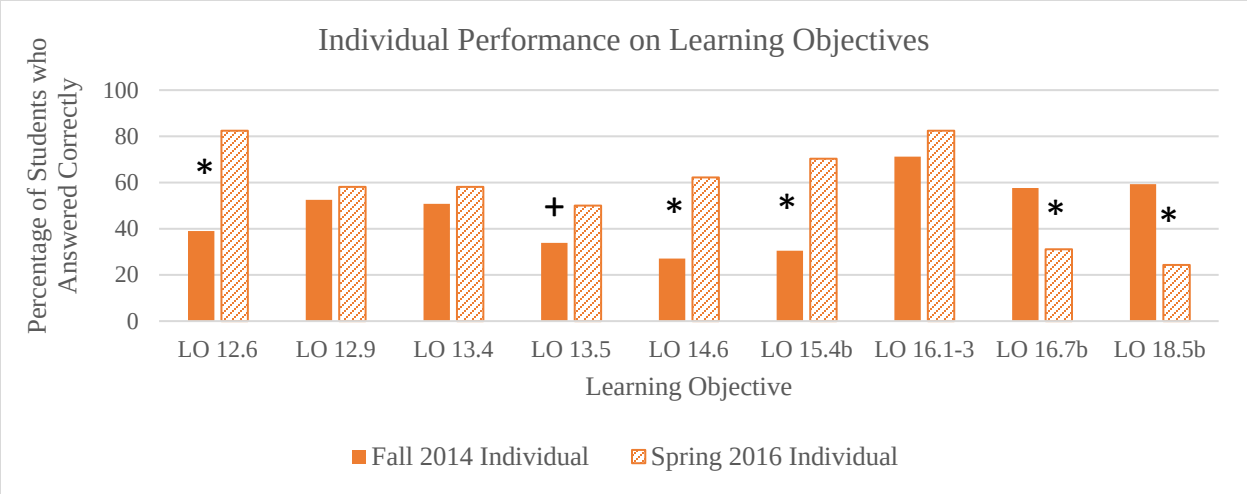

Figure 1. Individual performance on learning objectives in Fall 2014 and Spring 2016. * Indicates $p < 0.05$, + indicates $p = .06$. Solid bar= fall 2014, striped bar = Spring 2016.

Team Performance Fall 2014 versus Spring 2016

In three out of nine learning objective comparisons made, the t-test revealed a significant improvement in performance in Spring 2016 compared to Fall 2014 (LO 13.5: $p < .01$, LO 14.6: $p < .001$, and LO 15.4b: $p < .05$) (Figure 2). In one learning objective, LO 12.6, the improvement was marginally significant ($p = .075$). On two learning objectives, LO 16.7b and 18.5b, the t-test revealed a significant difference in the negative direction- groups performed worse in Spring 2016 than Fall 2014 (LO 16.7b: $p < .01$, LO 18.5: $p < .01$).

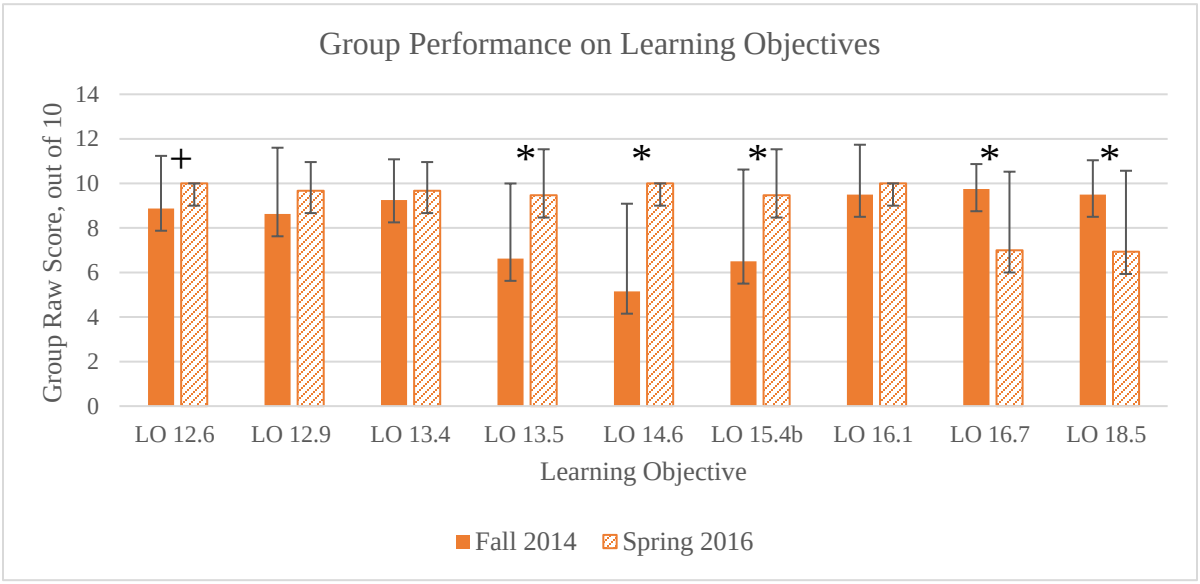

Figure 2. Group performance on learning objectives. * Indicates $p < .05$, + indicates $p = .075$. Solid bar= Fall 2014, striped bar= Spring 2016.

Peer Review Results Spring 2016: Peer review feedback was overwhelmingly positive. Figure 3 shows the Likert-scale scores on each of the 9 categories of questions. Possible scores range

from 1-5, with 5 being the best. In 6/9 categories, average ratings were over 4.3. In the remaining 3 categories, ratings were over 3.6. There was also very little variation between teams. Even teams that were the lowest performing in the course ranked themselves relatively high and had positive comments to say about their group. Some of the most positive and most negative comments that were voluntarily shared are listed in Table 3.

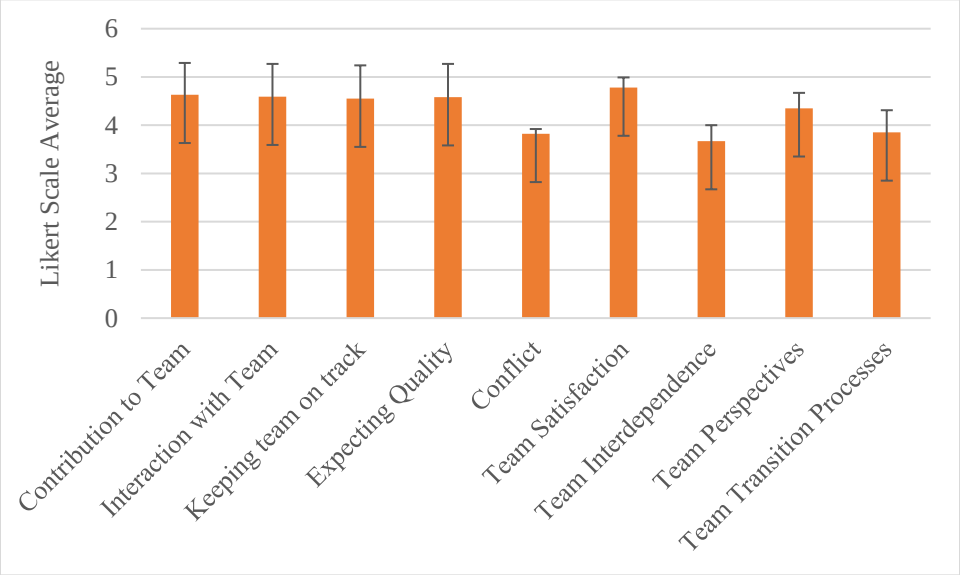

Figure 3. Likert scale team averages for peer review. Maximum score is 5.

Table 3. Voluntary open-ended responses from end of semester peer review.

Positive	"I believe our team worked very well together. We always stuck together no matter the task at hand. It was good to see how patient everyone could be during the exams and also during group work. Our group meshed perfectly together as we could all contribute to the task at hand fairly."
	"I thought this team worked very well together. Everyone in the group contributed evenly when they understood something that someone else didn't. Everybody was also trying to develop an understanding of what we were learning by asking our teammates questions when we were confused. I really like the structure of this class because of these teams. I honestly think i learned more by being able to work on problems with my team."
	"I loved working with my team this semester. They made coming to class and participating in class very enjoyable. We connected from the very beginning and were able to work well through out the semester. As we connected more and more during class (especially through team building exercises), we were able to learn more about each other. Most of us have similar classes so we were able to help each other in other classes as well as in dynamics. We all have pretty similar learning types so we were all able to learn the concepts and study for the tests together. I would 100% work with this group over and over again if I had the chance to!"
	"It can be a little difficult when assigned to a team which consists of people you have never worked with or maybe even talked to before. To be honest I never knew any of my teammates before this class, but I have grown very fond of each of them. They are all great people in their own ways and each bring something different to the team. Each works hard to learn the material and contribute to the team and I have truly enjoyed and appreciated working with them this semester and I could not have asked for a better group of people to work with."
	"Our team was perfectly diversified as far as understanding dynamics is concerned; there were some who did not really get it, some who kind of did, and some who knew it very well. Those that knew it very well were incredibly helpful for those who did not and made sure that everyone was on the same page when everything was said and done. Overall, this group worked very well together and we had much success."
	"Out of all the groups I've worked with since coming back to school, this has been the best by far. We get along great, and there is no conflict within the group. If one person is struggling to understand the material, others step in to help that person and make sure they understand. We all have shared interests, but also different interests that help us learn from each other, which has allowed us to be very successful."
	"This classroom was run extremely effectively. There was never a shortage of TA's to assist while doing the in-class assignment. The team building questions really brought our group together and I can not say we would be such good friends if that activity was not present. Excellent class."
Negative	"The group works well together, but teammate 1 misses class quite a bit so it's hard to count on him to be there to help when we need him"
	"I typically would just ask a GTA to come over because my team members didn't like asking questions. I feel that I am someone not satisfied with methods and I like to understand the concepts of my step processes. I don't like writing something down and thinking "We do it this way because it just works." I like being able to understand why, but I felt that my team members didn't care. As long as equations worked then they were satisfied. But generally, I regret that I did not speak up. It seemed like half my team really weren't intentional with asking questions during group work, and I knew that but didn't round everyone up together. I think my team got through fine though. There wasn't anything specifically that was bad, that hurt the team in ways I would be concerned, but I definitely feel like everyone in my team was smart and intelligent and could have utilized communication better! Overall, great team experience and I learned a lot."
	"Most of these questions don't really relate to the kind of group I saw us as. Our group was 5 people who worked together during class and got along well and occasionally talk and work on things together outside of class when it's convenient, but we never really had to sit down and make goals or really put our minds together for anything except tests. Everyone helps each other if they know something someone else doesn't."

Impact of being on a high performing team Spring 2016:
Exams 1, 2 and 3 were examined in terms of individual exam scores in three groups: high, average, and low performing teams (figure 4). No significant effects were found on exam 1 or exam 2. On Exam 3, a main effect of group emerged ($F(2, 26) = 4.428$, $p = .022$). Students in high performing groups had better exam 3 individual scores than students in low and average performing groups combined ($p = .013$). There was no significant difference between low and average performing groups ($p = .165$). Peer review comments were also compared between high and low performing teams (Table 4), and even low performing teams had positive things to say about their team.

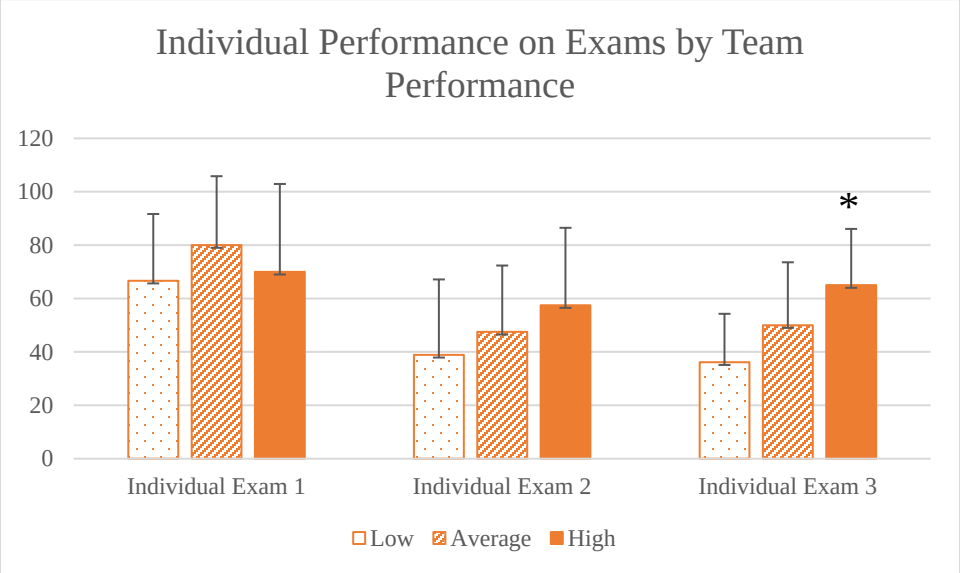

Figure 4. Individual performance on exams by group type. * indicates $p < .05$

Table 4. Comments on peer review from high and low performing teams.

High Performing Teams	"I thought our group worked together well. Student 1 and Student 2 both really went above and beyond during group work to make sure that we all were keeping up with the team and getting all the answers correct as well as making sure we understood how to get those answers. They were very helpful. Student 3 made the team fun to work in and he was also helpful during group work. Student 4 sometimes struggled during group work, and I am guilty of struggling too. But he always stayed positive and worked through the problem until he fully understood it, not just copying down the groups work to just turn it in. We met outside of class to work on the bonus problems before every class and I think that helped a lot. Students 1,2 and 4 were most consistent with this. I came to the out of class time more often than not. Student 3 talked to the group and decided that since we do all problems together, he would rather do those problems on his own to practice working through problems on his own as well. He didn't participate in the out of class work, but I don't want him to get penalized for that because it is something he took the time to talk to the group with before hand and I personally think is a valid reason."
	"I am very pleased with the group I ended up with. We met an hour before class Tuesdays and Thursdays to work out example problems, discuss homework, and work on extra credit- which was both fun and helpful. I would say that we enjoyed one another's presence, to the point where we would distract each other from the lecture with jokes or questions. One complaint I have was it was disappointing that we didn't get called to answer the "Team Building" questions nearly as often as the other tables, we had some really good replies!"
	"I really enjoy the team I was placed with. We have a strong group, and we have developed a good understanding of each other. Whatever formula or system you used to set up the teams, I am quite pleased with."
	"had a great time in this class. favorite class of the semester"
	"I really enjoyed working in the same group all semester."
Low Performing Teams	"I loved working with my team this semester. They made coming to class and participating in class very enjoyable. We connected from the very beginning and were able to work well through out the semester. As we connected more and more during class (especially through team building exercises), we were able to learn more about each other. Most of us have similar classes so we were able to help each other in other classes as well as in dynamics. We all have pretty similar learning types so we were all able to learn the concepts and study for the tests together. I would 100% work with this group over and over again if I had the chance to!"
	"I absolutely loved all my group members and thought we worked very well together!"
	"I think our team worked really well together. We always got our work done in a timely manner and worked hard to get it done. Each one of us had our bad days when we didn't understand a concept and had trouble with completing some problems, but the other members of the group would step in and make sure that the struggling member understood the concept and the problem. We would not move on until everyone understood what they previously did not. I believe we all contributed equally and deserve equally good grades."
	"I have no problems with my group, we all work very well together and have become friends due to the semester."
	"Team did a great job of respecting each other. We as a team often talked during the lecture, which we could improve on. Overall I really enjoyed the way the classroom works and getting to know my teammates."

Discussion

This research investigated the impact of implementing TBL by comparing student learning across two offerings of a Dynamics course. The primary difference between the semesters was the utilization of cooperative groups versus a structured implementation of TBL. TBL resulted in significant improvements on learning objective outcomes for both individuals and teams, a high level of team satisfaction as noted on peer evaluations, and improved individual performance for those on high-performing teams compared to lower performing teams. This is encouraging given the relative ease of making the change from cooperative groups and casual group work to a more structured TBL environment.

Michaelson (L. Michaelsen, 2002) suggests that the four essential principles of TBL are 1) groups must be properly formed and managed, 2) students must be made accountable, 3) team assignments must promote both learning and team development, and 4) students must receive frequent and immediate feedback. The authors found the implementation of these principles to be a significant factor in the positive outcomes observed.

Following the first essential principal and moving to five person teams formed using CATME, investing a small amount of class time on team development, and keeping the teams together for the entire semester proved to be important. Our data suggests that the benefit to individual performance of being a member of a high performing team does not become statistically significant until the end of the semester. Therefore, it is important to give each team enough time for full development (e.g. forming, storming, norming, and performing) so that the team can achieve the desired stage of being a high-performing team.

The remaining three essential principles were embedded into the increased course structure that provided multi-faceted and frequent opportunities for teams to work together on something that mattered, and immediate feedback. For example, in each class period the two-stage quiz, team building exercises, and teamwork on problems provided three different opportunities for the students to work as a team. The quizzes and exams provided immediate feedback. All teamwork was worth a significant amount of points, so individuals were motivated to improve the team performance. For example, the team portion of each exam was worth 50% of the total points, demonstrating the value placed on the teams performing at a high level. An individual could not do well in the class if their team did poorly. By the same token, if the entire team did better than the average on an exam, the team was rewarded with extra credit points.

Our data also suggest that it was not only the highest-performing teams who appreciated the TBL implementation. One of the major outcomes of this work was the overwhelming satisfaction the students had with their teams. The peer review numerical scores were all above a “satisfied” level, with little variability. Originally, the authors planned to use the peer review scores to

delineate “low,” “average,” and “high” performing teams, but this was not possible because of the lack of variability in the scores. Additionally, out of 73 students, only three students left negative feedback in the open-ended, voluntary section of the peer assessment. This is in line with what the instructional team qualitatively observed, which was that there was only one team out of 13 that seemed “dysfunctional.” Incidentally, the team that was noticed to be dysfunctional was one of the teams made up of only four (instead of five) students.

Limitations and Future Work

While these conclusions are encouraging, and consistent with TBL literature, there were several limitations to the study. We did not control for the potential impact of undergraduate teaching fellows, who were an additional resource added to the class for Spring 2016. The addition of this resource enabled the implementation of TBL by providing additional people to move around and interact with groups. We are currently investigating the impact and effectiveness of this program. Secondly, we do not have peer evaluations for Fall 2014, so we are unable to compare the perception of the cooperative groups compared to the teams of Spring 2016.

Future work for this course includes implementing Bloom’s Taxonomy to design test questions that cover a wider range of cognitive levels. Currently, most questions are at the “application” level. A wider range of questions will allow for more robust analysis of student learning. Additionally, a concept inventory has been implemented as an additional measure of student learning. The development of a measure for team performance, independent of exam performance would allow the authors to more closely examine the effect of being on a high-performing team on student learning. Finally, the authors are investigating the effect of TBL extended to individual performance in downstream courses.

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