Evaluating the Benefits of Team-Based Learning in a Systems Programming Class

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***Abstract*—In this Research-to-Practice Full Paper, we present the results of adopting Team-Based Learning (TBL) for teaching a Sophomore-level Systems Programming course. The goal of TBL is to "provide opportunities for students to apply their knowledge in the classroom to solve problems rather than just covering content." Based on the performance of the students in the course taught with TBL, we found that TBL had a statistically significant impact on student performance in 2 of the 5 programming assignments. Additionally, the end-of-semester student survey indicated that 88% of the students said that the team-based learning activities helped them understand the material better. Students mentioned that they felt like they belonged in Computer Science (fostering a sense of community in large classrooms) and frequently studied with some of their team members for the course assignments. Compared to a previous offering of the course that was purely lecture-based, the class as a whole received higher final grades and performed better on all of the programming assignments.**

***Index Terms*—active learning, team-based learning, flipped classrooms, student engagement**

I. Introduction

In industry, professional software developers invariably work in teams to identify an optimal solution. Being a "good" team player is considered an extremely important quality in any software developer, yet few undergraduate computer science programming courses enforce working together in teams. Working on a team for a term project in junior/senior-level classes is the closest that students get to getting a taste of working effectively in teams. These term projects do not simulate the "real world experience" since most students are taking multiple classes that results in significant difficulties with respect to finding times to work together. Additionally, these experiences do not provide avenues for students to learn about team dynamics and about their own strengths and weaknesses as team players. In the real world, all the employees on a team are fully dedicated to working on a project and are accessible throughout the work day for discussion and decision-making.

On the other hand due to the accessibility and inclusive efforts at the K-12 level for Computer Science [6], [14], [23], more students at the high school level are exposed to Computer Science. This has led to record enrollments [28] in class-sizes in Computer Science departments. As we address the wave of ever-increasing class sizes, it is increasingly difficult to provide sustained engagement in the class material through traditional lecture-style teaching. The amount of personalized attention and opportunities for interactive discussions too is limited due to the large size of the class. As class sizes grow, it impacts the attrition [3] and underrepresented groups in Computer Science. Female computer science students [22] as well as under-represented minorities [12], [25] may not have a sense of community and end up struggling to get help or, in some cases, even leaving the major. From the instructor's point of view, large classes also lead to a loss of quality of instruction with fewer opportunities for discussions in the classroom and even fewer opportunities for one-on-one interaction with students.

To deal with large class sizes and to provide students an opportunity to be engaged in the classroom, Larry Michaelsen developed Team-based learning (TBL) [19]. TBL provides structures to facilitate small group interaction in the form of teams to apply their knowledge in the classroom to solve problems. According to Michaelsen and Sweet [21], "The primary learning objective in TBL is to go beyond simply covering content and focus on ensuring that students have the opportunity to practice using course concepts to solve problems." TBL creates an environment where students can discuss problems and solutions to those problems with their peers.

In this paper, we present our experience with switching to TBL in an Introduction to Systems Programming course (CS 253) at Boise State University that was traditionally being taught as a lecture-based course. The research questions we wanted to answer were as follows:

- Would TBL be applicable for a programming intensive Computer Science class that has traditionally been taught in the lecture format?
- Do students perform better, on individual programming assignments as well as their overall grades, when taught using the TBL approach?
- What is the overall impression of students when asked about the efficacy of TBL in the classroom?
- Would TBL result in any noticeable improvement in student engagement and in-class participation?

Based on our analysis of individual programming assignments, final grades received by the students, and the student feedback, we have found that TBL fosters engaged learning [10] and allows students to *learn how to work in*

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teams and to appreciate varied perspectives. In-class activities allow students to apply their knowledge and gain a better understanding of the concepts.

II. Related work

Team-based learning [19], [20] is one of the many widely used *active learning* techniques [4], [18]. Team-based learning has been used in a variety of fields to effectively teach *large* classes with increased engagement [5], [13], [15], [24], [26].

In Computer Science Education, Whittington [27] explored the use of Team-Based Learning in a senior programming languages class. They report that students performed particularly well and enjoyed working in teams. Lasserre et al. [16], [17] have implemented TBL in a freshman computer science class. They found that over the years, on average students have performed a *letter grade better* and the course drop rate has gone down from 30% to 6.4%. This evidence is very encouraging and led us to believe that not only will the students learn from team-based learning strategies but will also gain an increased confidence in their abilities to be successful in their class.

Recently, there have been hybrid approaches that combine lectures and TBL that allow instructors to introduce TBL concepts to the students. Elnagar and Ali [7], [8] found that "(LTBL) Lectures and Team-Based Learning" affected student success rates as well as helped them achieve their learning outcomes. With the proliferation of online pedagogy, Ghadiri et al. [11] have found TBL to significantly improve the "passage rate" to 91% from 59% for a traditional lecture class.

III. Overview of Team-Based Learning (TBL)

Team-based learning (TBL) was developed with the aim of increasing student engagement in large classrooms [19]. Michaelsen [20] started employing various active learning strategies in the classroom to increase student engagement, but when he had to teach a class of 400, he needed better strategies to interact with his students. Team-based learning fosters teamwork in the classroom through in-class activities that require students to work together as a team. It reinforces student learning by immediately applying concepts learned in the classroom.

Figure 1 provides an overview of the entire Team-Based Learning Sequence. The course is divided into 5-7 instructional units by the instructor before the course begins. For each instructional unit, the instructor assigns reading (a chapter from a textbook, a collection of research papers, relevant news articles, and so on.)

A key aspect of team-based learning is the Readiness Assurance Test (RAT) [1], [2]. The quiz is conducted at the beginning of every instructional unit. Students first take the **individual quiz** (iRAT) (Figure 2a) n the assigned reading and requires students to come prepared to class. Even though the individual quiz is multiple choice, the student gets to allot his/her 4 points per question however s/he pleases. If the student is confident that option A is the right answer then s/he can put down 4 points for A, whereas if she is unsure about option A or option B, s/he can put down 2 points for option A and 2 points for option B.

The individual quiz is immediately followed by a **team quiz** (tRAT) where the **same** quiz is taken by the entire team using scratch off sheets (Figure 2b). The lottery ticket-style scratch-off sheets provide instant feedback (in the form of a star under in the box for the correct answer). If the team gets the correct answer on the first scratch-off they get 4 points for that question. If the team gets the answer wrong on the first attempt, they then discuss the rest of the answers and pick a new answer to scratch off on the sheet. If they get the correct answer on their second attempt, then they get 3 points. The number of points a team can get per question decreases as the number of attempts/scratches increases. The team whose scratch-off sheet is shown in Figure 2b received the maximum points for the quiz since they got the correct answer for each question on their first attempt.

The benefits of a team quiz right after the individual quiz are that the team quiz helps students resolve any misconceptions about the assigned reading. Since the *team* can choose only one answer at a time and loses one point for every incorrect scratch-off per answer, they discuss the answers of each questions *thoroughly*. Another interesting side effect of the team quiz is that it balances the *team dynamics* where aggressive students are subdued, by being repeatedly wrong, and quiet students in a team, who may be frequently correct, are encouraged to participate more in the team quiz and related discussions.

At this point, a team could submit a *written appeal* if they all agree that one of the incorrect answers could have been correct based on the wording of the question. The instructor considers the appeal and awards the points to the team if their answer is correct. The process of submitting a written appeal further requires students to elucidate why their answer is correct by applying concepts from the reading. At this point, the students in the class are engaged with the material, a majority of their misconceptions have been clarified, and they are ready to apply their knowledge to solving problems using the concepts of that unit.

The rest of the class time during the week is then used for clarifying/mini-lectures and application activities such as problem-based learning, think-group discussion-share (share with your team and subsequently the classroom), solving programming problems and discuss approaches as a team and so on. The mini-lectures are to highlight critical concepts and common mistakes that students may have made due to misconceptions.

At Boise State University, our course (CS 253 - Introduction to System Programming) consisted of 76 sophomore students in the Team-Based Learning course. This course is pivotal as it is a required prerequisite for the following courses: Operating Systems, Distributed Systems, Computer Networks, Cybersecurity, Parallel Computing, and the Introduction to Artificial Intelligence.

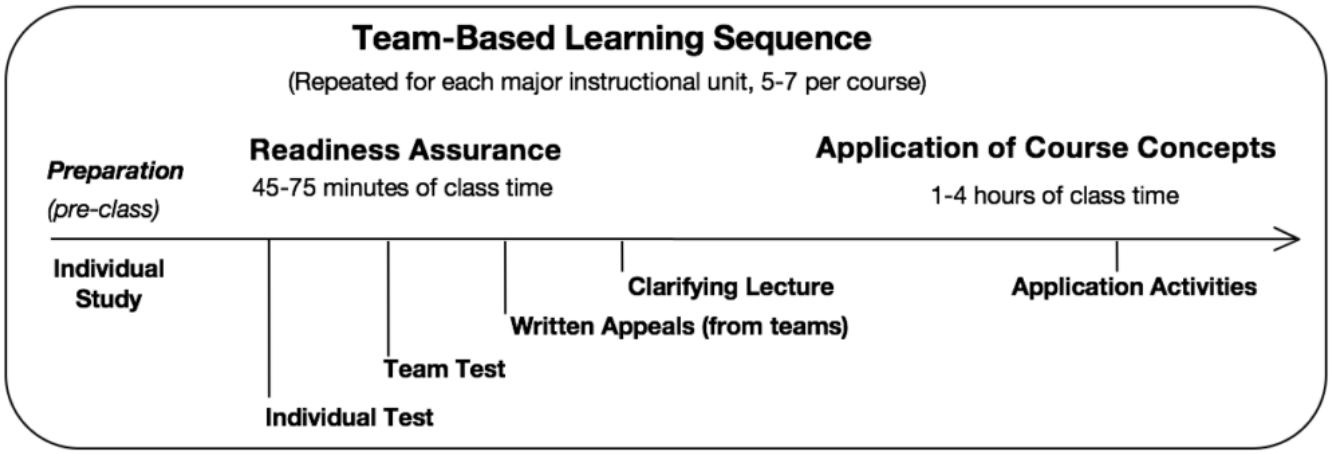
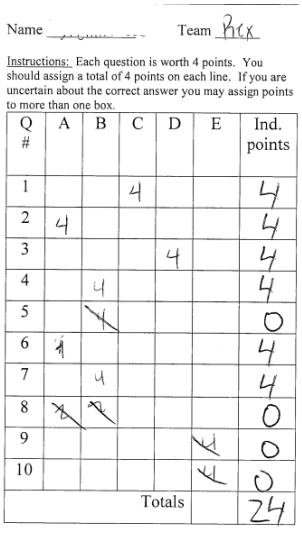


Fig. 1: This figure describes the learning sequence that includes the individual and team quizzes, following by mini-lectures, followed by in-class activities that are focused on applying concepts. Figure based on Michaelsen and Sweet [21].

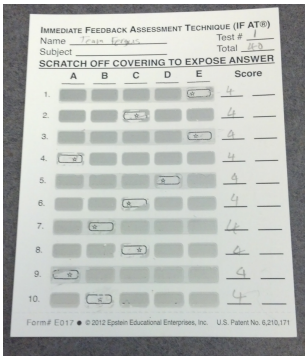


Name _____ Team Rick

Instructions: Each question is worth 4 points. You should assign a total of 4 points on each line. If you are uncertain about the correct answer you may assign points to more than one box.

Q #	A	B	C	D	E	Ind. points
1			4			4
2	4					4
3				4		4
4		4				4
5		4				0
6	4					4
7		4				4
8	2	2				0
9					4	0
10					4	0
					Totals	24

(a) Answer sheet for an individual quiz (iRAT).



(b) A scratch-off sheet from a completed team quiz (tRAT)

Fig. 2: For the individual quiz, students can get partial credit by splitting the available 4 points per answer. For the team quizzes, an asterisk/star can be seen in the box for the correct answer.

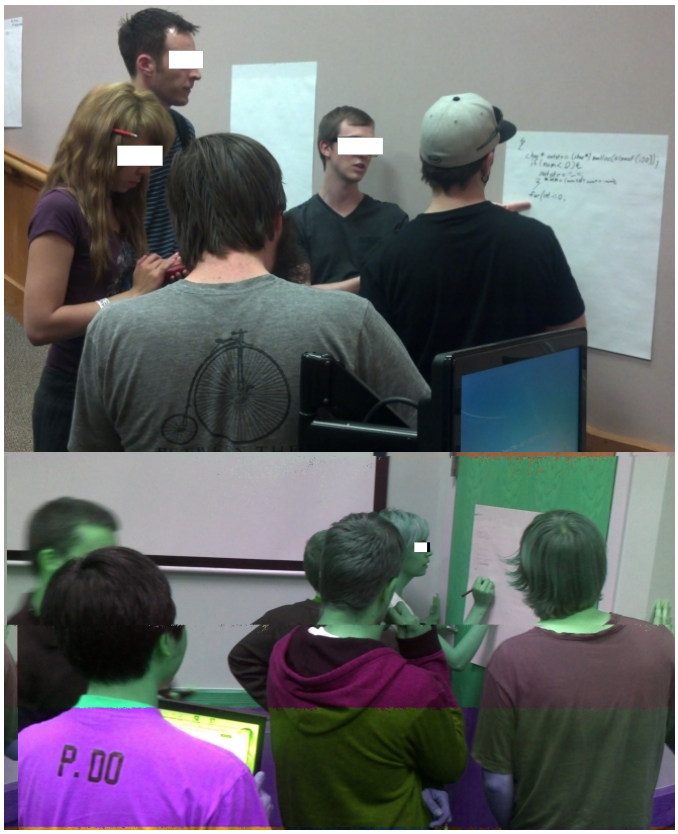


Fig. 3: Teams working on solving real interview questions on their Post-it Self-Stick Sheet.

A. *In-class activities*

Based on our experience, the weekly quizzes (iRATs and tRATs) led the students to be more prepared to apply their knowledge in class than when the course was taught in a traditional lecture style. The in-class activities frequently included active learning strategies such as peer survey [18], writing a snippet of code, or writing pseudo-code on a Post-it Self-Stick Sheet (See Figure 3) and sticking it up on a wall for the rest of the class to see. After the team has written their solution, they walk around the classroom, examine the solutions of other teams, and provide feedback to the solution/approach listed by a team on their big post-it.

These activities were greatly appreciated by students (in the end-of-semester survey) as they were able to see a different approach to the same problem in a short period of time. Figure 3 shows two separate teams working on actual interview questions that they may face when they go for job interviews

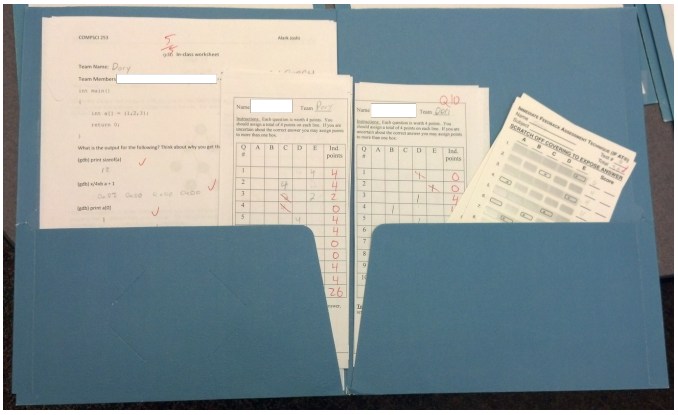


Fig. 4: A sample team folder that includes in-class worksheets, graded iRAT's and tRAT's.

at a software company. This activity helps students gain the ability to think through problems as a team and to identify optimal solutions that work.

B. Team composition

Feichtner and Davis [9] found that "Students are more likely to have positive experiences in classes where groups are either formed by the instructor or by a combination of methods (e.g., one instructor collected data on students' research interests and then grouped those with similar preferences). By nearly a 2 to 1 margin, if students formed their own groups they were likely to list the group experience as being a 'worst' group experience." Based on their findings, we decided to assign students to teams at the beginning of the semester rather than let them self select. Michaelsen et al. [19] suggest that *group diversity* is an essential component to team success. We balanced team compositions based on gender, major/minor, their cumulative GPA, and C programming skills. Balancing the team based on the GPA turned out to be significantly better than we had expected and ensured that the groups had a good mix of motivated students as well as students who benefited from being in a proactive group. To provide a sustained feeling of community, the teams assignments are permanent for the entire duration of the course.

TBL provides all the benefits of peer-to-peer instruction without the shortcomings of working on large team projects that are worth a large proportion of their grade. Students truly benefit from learning from each other and do not have to worry about the logistics of trying to meet outside the classroom for any course-related work.

Since TBL was developed to deal with large classrooms, collecting completed quizzes, handing out graded material and in-class worksheets would be fairly time consuming. To alleviate problems associated with this, Michaelsen et al. [19] suggest using team folders. The team folders worked (see Figure 4) perfectly for quick dissemination and collection of material.

IV. Methodology

To compare the effectiveness of the TBL offering as compared to the lecture-based offering, we used the same textbook, the same notes (slides from the class were provided to the students in the TBL course for reference), and we assigned the same assignments to the students. In addition to analyzing the performance of the students on each programming assignment, we also conducted end-of-semester surveys that included specific questions on the overall perception of TBL in the classroom and whether it was considered an asset or a hindrance to the learning process of the students. We could not compare the weekly individual quiz and team quiz scores, as there was no equivalent in the lecture-based offering.

A. Data Analysis

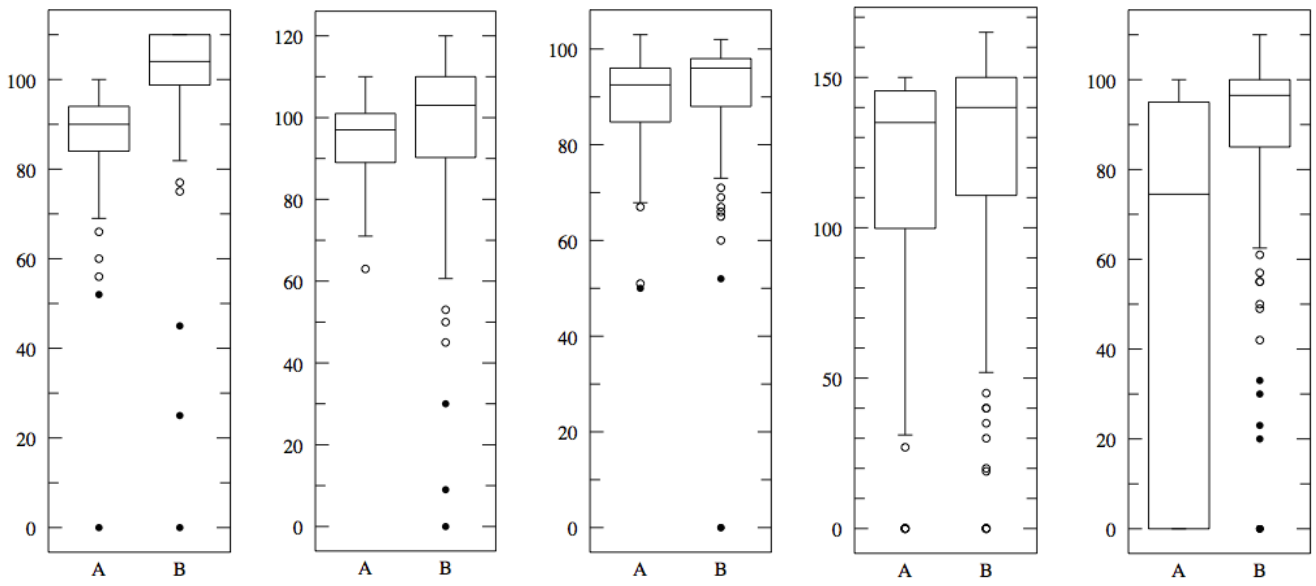
The performance of the students on the *individual* programming assignments was consistently better when the TBL strategy was used in the classroom. The individual scores were analyzed using the student's t-test and the p-values were significant ($p<0.05$) for programming assignments 1 and 5 (refer Table I). Figure 5 shows the overall data spread over the five programming assignments (P1 to P5 from left to right). The figure shows that the overall student performance for the early warm-up assignments (P1 and P2) was close and the median performance was higher on all assignments. The TBL students performed better and the statistical analysis validates its significance particularly for programming assignment 1 and 5 (P1 and P5) (refer Table I).

P5 is significantly more difficult than the previous assignments in the semester since it requires students to manage memory dynamically. Students also need to build a test harness for their data structure and perform robust testing on the same. The student performance on this assignment is statistically significant ($p<0.001$) as compared to the previous offering which points to the fact that the in-class learning is helping student gain a deeper understanding of the material. This improved level of understanding seems to lead them to apply their knowledge better for the individual programming assignments.

In addition to the programming assignments, we wanted to measure the overall student success in the course and to this effect, we analyzed the number of students who received an A, B, C, and so on. Table II and Figure 6 show a frequency distribution of the final grade obtained by the students who took the lecture-based class as well as the TBL-based offering. Figure 6 shows a graphical representation that shows a clear shift towards higher grades and a noticeably higher percentage of students in the TBL offering get an "A" grade (90-100+) in the course.

Table III shows the detailed results of the frequency distribution analysis conducted on the final grades of the students in both offerings. On comparing the two offerings of the lecture-based teaching and the TBL-offering, we see that the median for TBL is higher than the median for the lecture-based class.

To fairly compare the two frequency distributions, we used the Chi-squared test which allows comparisons of distributions



(a) P1 (b) P2 (c) P3 (d) P4 (e) P5

Fig. 5: These graphs show the student performance on the programming assignments P1—P5 (left to right). Points received on the assignments are represented on the y-axis. The **A label** refers to the **lecture-based** offering and the **B label** refers to the **TBL-based** offering. Statistical significance was observed for P1 and P5 with a $p<0.001$.

	P1		P2		P3		P4		P5	
	Lec	TBL	Lec	TBL	Lec	TBL	Lec	TBL	Lec	TBL
p-values	**p<0.001**		p<0.16		p<0.66		p<0.16		**p<0.001**	
Mean	85.7	101	94.4	97.7	88.9	90.0	111.0	122.0	59.7	83.3
Stddev	17.1	15.5	10.5	21.4	11.3	16.1	50.7	44.5	39.8	27.6
High	100.0	110.0	110.0	120.0	103.0	102.0	150.0	165.0	100.0	110.0
Low	0.00	0.00	63.0	0.0	50.0	0.0	0.0	0.0	0.0	0.0
Median	90.0	104.0	97.0	103.0	92.5	96.0	135.0	140.0	74.5	96.5
AvgAbsDev from Median	9.30	8.22	7.85	13.8	6.95	8.59	32.9	29.4	33.0	16.1

TABLE I: This table shows the detailed results of comparing the programming assignments from the lecture-based offering with the TBL offering of the course. The results are statistically significant for P1 and P5. P5 is the most difficult programming assignment for the course and therefore that result is particularly significant.

of varied populations. The Chi-squared test informed us that the TBL offering was statistically significant at $p<0.0123$ as compared to the lecture-based offering (See Table IV for details about the Chi-squared test). Additionally, as per Michaelsen et al. [19], we also found that the performance of the students in the team quiz (tRAT) was consistently better than on the individual quiz (iRAT).

B. End of semester survey

In addition to examining the quiz scores, assignment scores, and the final exam, we also conducted an end-of-semester survey after the TBL offering of the course. Based on the survey, we found that for a question that asked whether "Team-based learning activities in class enhanced my learning experience in the course," the the average student score was **4.46** on a Likert scale of 1 (strongly disagree) to 5 (strongly agree). Overall, 88% of the students said that TBL activities such as individual quizzes, team quizzes, and in-class team activities benefited them and helped them understand the material better.

Total % of points received	Lecture	TBL
0-10	6.52%	0%
10-20	0%	0.93%
20-30	0%	0.93%
30-40	0%	0.93%
40-50	13.04%	0.93%
50-60	4.35%	1.85%
60-70	4.35%	2.78%
70-80	10.87%	12.04%
80-90	23.91%	24.07%
90-100	34.78%	48.15%
100-103	2.17%	7.41%

TABLE II: Frequency distribution of the final grade/% of points received in the class. As the number of students in both the offerings were different, we present the normalized distribution of the number of students in each group that received the overall grade in the course.

The students found the overall TBL-focused activities such as peer-to-peer discussion, group activities, and working with a team to be useful. Here are some quotes from the qualitative

	Lecture	TBL
Minimum grade	0.0	14.6786
25% Percentile	59.1	83.7475
Median	**86.1**	**91.4961**
75% Percentile	94.45	96.25
Maximum grade	100.0	102.466
Mean	75.1087	87.2154
Std. Deviation	26.2615	14.9868
Std. Error	3.87204	1.4421
Lower 95% CI of mean	67.3099	84.3566
Upper 95% CI of mean	82.9075	90.0742

TABLE III: This table shows the details of the frequency analysis conducted on the final grades received by the students in both the offerings. Since the number of students in both the offerings is different, the median offers a better comparison between the two groups. The median grade received in the TBL-offering is higher than the lecture-based offering.

Chi-squared test	df	22.62, 10
P-value	0.0123	
P-value summary	*	
One- or two-sided	NA	
Statistically significant? ($\alpha < 0.05$)	Yes	

TABLE IV: For the Chi-squared test, the number of rows analyzed were 11 and the number of columns were 2.

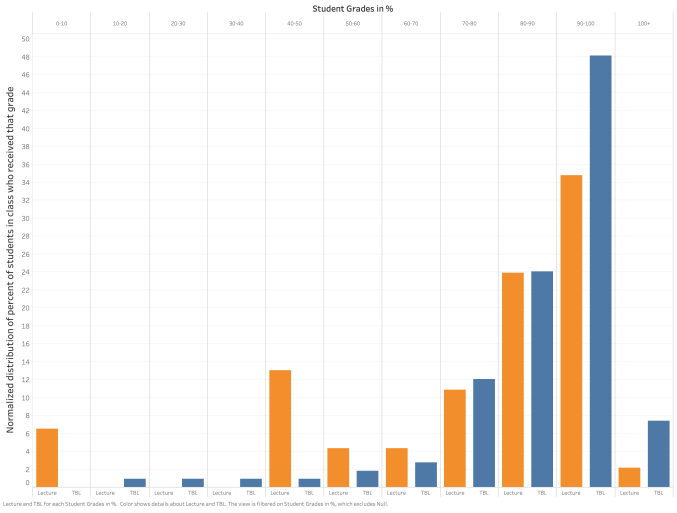


Fig. 6: This graph plots the frequency distribution of the final grade received by the students in both the offerings. Based on performing the Chi-squared test, the TBL offering (blue bars) was found to be statistically significant ($p<0.0123$) as compared to the lecture-based offering (orange bars). There were a few students who did all the extra credit for the assignments and got more than a 100% in both the offerings.

survey:

- "The group activities and the discussion in the class were really useful and interesting"
- "Peer to Peer interaction worked well and also help to look outside of your own way of thinking."
- "Teamwork - my team really helped me learn"

Regarding the weekly iRATs and tRATs, students had the following feedback:

- "I really, really liked the way the professor incorporated teamwork into the class. Normally, with quizzes, you take them and that's it; done and over with. With retaking the same quiz with my team, I am not only able to see that I got an answer right or wrong, but am able to obtain a greater understanding of as to why through the discussion that occurs. I learned A LOT through this experience."
- "The quizzes each week were good for challenging what I had recently read in a chapter and helped me better understand the material that would be covered that week. The following group quizzes were also helpful for understanding others opinions on the questions asked and to challenge your own answer by supporting it with evidence to help answer each group question."
- "Group Assignments and Quizzes were extremely useful and helped me a lot."

V. Challenges Faced

We gained a lot of insight into what worked and what did not work in the semester. Conducting the weekly iRATs and tRATs took a maximum of 15 minutes in class. After students figure out the mechanics of the iRATs and tRATs, they come to class every week prepared to take a quiz and the process becomes very efficient. The weekly reading followed by the quizzes ensures that students take the assigned reading seriously. This promotes increased student responsibility and requires them to be prepared for class. In terms of preparation for each week, the instructor has to make the weekly quiz which could potentially be viewed as a time-consuming activity since it needs to be done every week (or at least once at the beginning of every instructional unit).

In terms of team composition and seating in the classroom, it is optimal to have 5 students in a team facing each other to facilitate discussion. Teams of 6 can work, but Teams of 7 resulted in disengagement. When dealing with a large number of teams, team folders are indispensable for collection and dissemination of quizzes, worksheets and in-class activities (Figure 4.)

One of the biggest problems with implementing TBL is that most classrooms are designed for lectures and a lecture hall does not facilitate interaction between students. We received a comment in our end-of-semester survey regarding this exact issue and were delighted to see that a student too had felt that it would have been better to be in a classroom with configurable seating - "I thought the class size was too big and it was hard to work with my group in the lecture hall. It would have been easier if we were in a class room where we could more easily face each other."

VI. Conclusions

Teaching the systems programming class with the team-based learning strategy was more effective and appreciated by the students as well. Team-based learning had a statistically

significant impact on student performance in 2 of the 5 programming assignments The end-of-semester student survey indicated that 88% of the students thought that the team-based learning activities such as individual quizzes, team quizzes and in-class team activities benefited them and helped them gain a deeper understanding.

To answer the questions we had when we decided to explore TBL in our classroom:

- TBL was implemented successfully to the content heavy Computer Science class that was previously taught in the lecture format.
- Students perform better on individual programming assignments and the overall final grade received was higher for the course taught using TBL.
- As per the end of semester survey, a large majority of the students seemed to have liked the TBL activities
- In terms of student engagement and participation, we found that the students were more prepared and engaged in the material and asked insightful questions.

In conclusion, we found that the semi-flipped nature of the course lead to improved performance as well as engaged discussions in class. Team-based activities in the classroom fostered engaged learning and provided an avenue for students to learn how to work in teams. The combination of student preparation before class, in-class discussions, and in-class activities resulted in a better understanding of the concepts (as evidenced by the overall improvement in grades) rather than being introduced to the material for the first time in the form of a lecture. The biggest challenge is the restrictive layout for big lecture halls.

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