Improving Student Motivation through Competitive Active Learning

Manika Kapoor[1], Shuai Hua[1] and David C. Anastasiu[1,2]

***Abstract*— This Research Work in Progress paper introduces the Competitive Learning Platform (CLP), an online tool that provides automatic partial performance feedback to students or groups of students on individual or collaborative assignments. CLP motivates students to think *outside-the-box* and come up with novel solutions that can lead to improved assignment results before the assignment deadline. We developed the CLP system as an Active Learning tool for encouraging and motivating student engagement in a STEM course. In this paper, we describe the CLP system and present the results of a set of analyses aimed at gauging the impact of competitive Active Learning activities using the CLP system on student motivation, engagement, and performance. The analyses are based on CLP submission, student outcome, and student feedback data obtained from 5 STEM undergraduate and graduate course offerings over 3 semesters. Results indicate that competitive active learning is beneficial in this setting, leading to active student participation and improved motivation.**

I. Introduction

In the classic lecture-based educational environment, the professor introduces basic concepts during class and students complete homework assignments to strengthen knowledge acquired in class. In STEM classes, these assignments often expect students to just solve some problems once and achieve correct answers. While lecture-based education has been successful over the years, it does not greatly encourage creative thinking or stimulate enthusiasm in students. In our fast moving world, many problems require *continuous improvement* and innovative thinking to get the best results. Finding the best solution involves trying different approaches and the fortitude to stay motivated and engaged until the very end. In this work, we introduce the *Competitive Learning Platform* (CLP), an online tool that provides automatic partial performance feedback to students on continuous improvement problems/tasks, motivating them to think *outside-the-box* and develop novel solutions that can lead to further performance improvements. Student submissions are evaluated in real-time and anonymously shared with peers as a motivating factor for subsequent solution refinement.

TABLE I
Classes and Student Distribution

Class	Subject	Session	# Students	G/UG
CMPE-239	Data & Web Mining	Sp 2017	27	G
CMPE-139	Data & Web Mining	Fa 2017	23	UG
CMPE-255	Data Mining	Fa 2017	34	G
CMPE-255 (01)	Data Mining	Sp 2018	30	G
CMPE-255 (02)	Data Mining	Sp 2018	34	G

[1]Computer Engineering, Charles W. Davidson College of Engineering, San José State University, San José, CA 95192-0180, USA
[2]Corresponding Author, david.anastasiu at sjsu.edu

The CLP system has been in use as an Active Learning tool in several Engineering classes at San José State University, a major U.S. public university, over the past three semesters. In this paper, we describe the CLP system and present the results of a set of analyses aimed at gauging its impact on student motivation, engagement, and performance. For each course that used the CLP system, Table I provides information about the session the course was conducted in, the number of students in the course, and their classification.

As a means to understanding the usefulness of a competitive active learning approach, we are interested in answering the following research questions.

- Do students feel comfortable and have a positive attitude towards a competitive active learning approach?
- Through competitive active learning, are students encouraged to innovative and try different solutions?
- Does competitive active learning have a significant impact on student performance?
- Does student performance depend on how engaged/active they are in the class?

To answer these research questions, we conducted a survey and obtained student feedback on the CLP system. In order to reduce bias, the survey consisted of both negative and positive questions. The survey contained ten closed-ended questions and four open-ended questions, reproduced in Table II. Table III shows aggregate results for the closed-ended questions, where positive questions are scored 1–5 and negative ones 5–1, i.e., 5 is best for all questions in the table. The data from the survey, combined with student grades and CLP submission data, were used to analyze the impact of competitive learning on student performance, motivation and engagement.

II. Related Works

Many research studies have focused on utilizing active learning techniques to enhance student success. Regueras et al. have used competitive and collaborative active learning approaches to motivate students by creating an environment where students work within their group to submit questions to their classmates and compete by answering questions posed by other groups [1]. Offutt et al. have used a self-paced learning approach promoting learning by collaboration [2]. Boutell and Fisher designed a course structure where the students were allowed to work on self-selected projects that add value for others [3]. Kao et al. built an Internet-based learning environment to encourage students to engage in competitive and active learning [4]. To promote the attractiveness of the European Higher Education Area

TABLE II

SURVEY QUESTIONS

No.	Question	+/-
	Closed-ended Questions	
1	I would prefer to use a competitive learning platform for my homework assignments.	+
2	I found that the leader board function in the CLP discouraged me from trying to improve.	-
3	I thought the CLP system was easy to use.	+
4	I hope I never have to compete in a homework assignment again.	-
5	The CLP leaderboard function motivated me to try my best.	+
6	I found the CLP system unnecessarily complex.	-
7	I would imagine that most people would learn to use the submission system in the CLP quickly.	+
8	I found the information provided by the CLP was insufficient.	-
9	The personal submissions table and graph summary were helpful to gauge my progress.	+
10	I found the personal submissions graph for a given assignment unhelpful.	-
	Open-ended Questions	
1	What were the most useful features of the CLP? Why?	+
2	What were the downsides of using the CLP systems? Why?	-
3	How, if at all, did you approach solving a CLP homework assignment in a different way than you would have approached a normal homework assignment?	+/-
4	Did you choose to display leaderboards before submission deadlines? If you could go back to the beginning of the semester and change you choice, would you? Why or why not?	+/-

(EHEA), Regueras et al. used active e-learning methodologies to force students to compete among themselves and analyzed the relationship between motivation and competition [5]. To teach Internal Control effectively, Gainor et al. designed an in-class competition to enhance student engagement and showed that such a competitive learning approach demonstrated educational benefits to the students by significantly increasing student engagement [6]. Guthrie and Carlin used a Personal Response System (PRS) to ask different types of questions and graphically-displayed student responses in real time [7]. Martin and Klein combined gamification and the application of makerspace concepts to develop several competitive active learning activities with a purpose to improve student motivation and attitude [8]. Abdool et al. used role-playing games (RPGs) and pop-culture references to stimulate student interest in analysis and problem-solving [9].

III. COMPETITIVE LEARNING PLATFORM

We developed a Competitive Learning Platform (CLP) system, similar to Kaggle Competitions[1], that engages students in active learning through peer contests. CLP was developed with the aim to motivate students and promote student engagement in a course, and, unlike Kaggle, is not limited to solving Machine Learning problems. Students are assigned a (homework) problem they must solve to the best of their ability. Figure 1 shows an example of a homework assignment in which the students are given a dataset of product reviews and are asked to classify them as either positive or negative. The students submit their assignment results in the CLP on-line portal and, in real time, are given an evaluation score on part of the test data. For instance, in

[1]https://www.kaggle.com/competitions

Detailed Description:
A practical application in e-commerce applications is to infer sentiment (or polarity) from free form review text submitted for a range of products. For this assignment, you have to implement a k-Nearest Neighbor Classifier to predict the sentiment for 25000 movie reviews provided in the test file (test.dat). *Positive sentiment* is represented by a review rating of +1 and *negative sentiment* is represented by a review rating of -1. In test.dat you are only provided the reviews but no ground truth rating. These data will be used for comparing your predictions. Training data consists of 25000 reviews as well.

Fig. 1. An Example Assignment

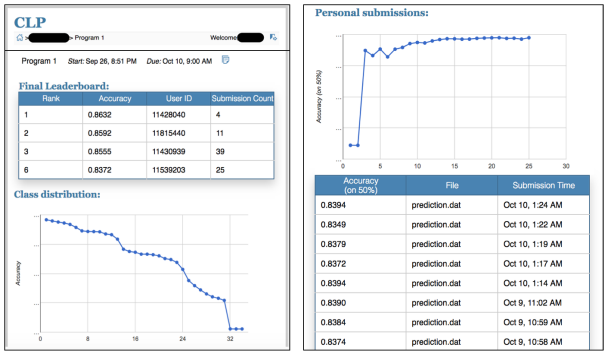

Fig. 2. Competition Leaderboard and Class Score Distribution

the sample assignment in Figure 1, the evaluation refers to checking classification accuracy on a random 50% subset of the test data. This is done to prevent students from creating models that only work well on the current test data and do not generalize to other similar datasets. After the assignment deadline, the final accuracy is computed using the entire test data.

For a particular student, a general CLP dashboard displays a leaderboard with the top three current scorers in the class plus their best score and rank, a graph displaying the class score distribution, a graph displaying the trend of personal submissions, and a table containing all the submissions of the student and corresponding scores. Figure 2 shows a sample competition leaderboard and class score distribution (left) and a sample the personal submission trend graph and submission history table in CLP (right). The submission history table (right) shows "Accuracy on 50%" as their submissions were evaluated on 50% of the test data before the deadline, while the competition leaderboard (left) shows the final accuracies computed on the entire test dataset.

To reduce the potential stress such a competitive environment can pose on some students, CLP provides an option to not display the competition leaderboard. Students are presented this option only the first time they access the CLP system for each class. Once a choice is made, it cannot be changed for that class. If a student chooses not to see the competitive leaderboard, they may then choose a traditional assignment setting, in which they submit only one solution to the problem, or can attempt to improve their own scores, without competing against their peers.

The CLP system remains open for submission for the duration of the assignment. Generally, students are allowed five submissions per day. The last submission is considered to be the final submission used for grading. To increase student participation, extra credit points are awarded to the students with the top three scores.

TABLE III
SUMMARY OF RESPONSE TO CLOSED-ENDED QUESTIONS

Question	5	4	3	2	1	Question	5	4	3	2	1
Q1	75	36	21	10	6	Q6	77	27	12	15	17
Q2	69	30	20	18	11	Q7	91	41	8	5	3
Q3	95	42	7	3	1	Q8	59	38	28	14	9
Q4	60	29	31	19	9	Q9	84	46	11	5	2
Q5	67	43	21	10	7	Q10	89	31	16	8	4

IV. ASSESSMENT DATA

To find answers for the posed research questions in Section I, data from various sources were used, including data collected from student surveys, submission data from the CLP system, and grades information for the competitive assignments. The responses to the open-ended questions are used to perform sentiment analysis. For numerical analysis, we use the submission data collected from CLP, which contains the history of each submission, including the student ID, time of submission, and the performance result corresponding to the submission.

V. EXPERIMENTAL RESULTS

To answer the research questions we posed, we conducted sentiment analysis on the textual data as well as numerical analysis on the numerical data. As there was not enough data to build our own sentiment analysis model, we used the Google Natural Language API[2], an open-source model for sentiment analysis, to gauge the polarity of survey question responses. For each processed textual input, the API provides in response a numerical value between -1 and 1, which represents negative sentiment if the value is less than 0, and positive sentiment if the value is greater or equal to 0. In the following sub-sections, we will present analysis results supporting our answers to each of the research questions.

A. Do students feel comfortable and have a positive attitude towards a competitive active learning approach, or do they feel that it is demotivating?

To understand the sentiment of the students towards competitive active learning, sentiment-analysis is performed on the textual data for every student. Question 2 in Table II Open-ended Questions is not included in this analysis as it is a critical question asking the downsides of CLP and thus, will have negative sentiment only. The mean sentiment for each student and question is calculated and used for different types of analysis. To get the sentiments of the students per class, this experiment is performed on each class separately and to get the overall sentiment, it is performed on all the classes together. Figure 3 shows the mean sentiment distribution for one course from each session and also all the courses together.

As can be seen from the "All courses" (top-left) graph in Figure 3, the mean sentiment of most students is positive. It can also be observed that, among all the courses whown in Figure 3, CMPE-139 has the most students with negative sentiments. This particular course offering was an undergraduate course but followed the majority of the content of the equivalent graduate course. Students found the course requirements too demanding, which likely contributed to the negative sentiment associated with CLP, which was part of that load.

[2]https://cloud.google.com/natural-language/

TABLE IV
LEADERBOARD DISPLAY STATUS FOR CLP STUDENTS

Class	Session	Opted In	Change	Opted Out	Change
CMPE-139	Fa 2017	20	0	3	1
CMPE-255	Fa 2017	33	1	1	1
CMPE-255 (01)	Sp 2018	27	0	1	0
CMPE-255 (02)	Sp 2018	27	1	2	0

To gain an even better idea of how well CLP is accepted, we studied results of the sentiment analysis for Question 4 in Table II, which ascertains whether students would choose to or not to display the CLP leaderboard. In this analysis, CMPE-239 is not represented as this question was not included in the survey at that time. Table IV shows the number of students who opted in/out for seeing the leaderboard in the CLP system and how many among them wished to change their decision if given the chance. Of the students who responded to this question, 107 students opted for the CLP leaderboard and only 2 of them wished to change their decision. Additionally, only 7 students opted out of seeing the leaderboard in CLP and 2 of them wished they would have made a different decision. The "Q4 Open-ended" graph in Figure 3 further shows the overwhelmingly positive sentiment of students towards the competitive leaderboard feature of the CLP system.

B. Through competitive active learning, are students encouraged to innovative and try different solutions?

One of the major purposes of a competitive active learning platform such as CLP is to encourage students to think outside-the-box. As the homework assignments did not have a specific answer, we hypothesized that, by comparing their performance with their peers, the students would come up with better approaches to solve the problem and improve their result. To support our hypothesis that CLP promotes innovative thinking, we study the sentiment of students in response to Question 3, which focuses on student attitude towards solving a competitive assignment in lieu of an ordinary homework assignment.

The result of this analysis shows that CLP motivates students to think outside-the-box and try different approaches. The "Q3 Open-ended" graph in Figure 3 shows that the majority of students saw competitive assignments as a positive addition to the course curriculum.

C. Does competitive active learning have a significant impact on student performance?

The CLP system is expected to aid student performance by encouraging them to engage more in learning activities. Our hypothesis is that, as a student engages more, they will perform better. We can verify this hypothesis by analyzing numerical data from 3 different classes with similar homework assignments. There are no single correct answers for

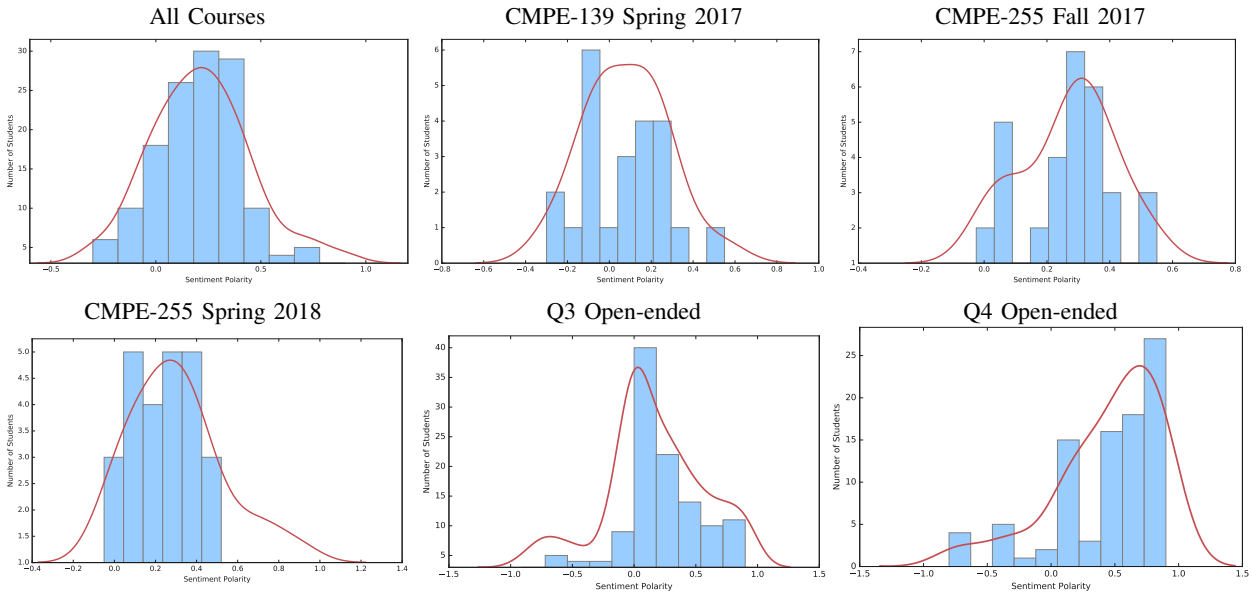

Fig. 3. Mean Sentiment Distribution

TABLE V
AVERAGE SUBMISSION CORRELATION FOR CMPE-255

Class	Best Score	Improvement	Grade
Homework-1	0.419347 (33)	0.627656 (33)	0.314100 (33)
Homework-2	0.321742 (38)	0.576598 (38)	0.274715 (38)
Homework-3	0.334773 (37)	0.578663 (37)	0.358696 (37)

all these assignments. Instead, the homeworks are designed to encourage students to attempt better results. Due to lack of space, we only show results for CMPE-255.

In order to better understand the relationship between performance and involvement, we computed the Pearson correlation coefficient between the average number of submissions and student best scores, score improvement, and grades. Table V provides a summary of this result for CMPE-255. The other two courses have similar results but are omitted due to lack of space. Results indicate that the number of submissions can significantly impact performance. Higher values of the coefficient indicate stronger correlation between the variables. In other words, the number of CLP submissions was a strong indicator of performance improvement over the life of the assignment, denoting strong student engagement in the course.

D. Does student performance depend on how engaged/active they are in the class?

A student could be considered to be actively engaged in class if he/she demonstrated a similar level of engagement every day. We quantify student engagement by computing a student's *engagement score*, which is defined as the ratio of the number of days they submit an assignment and the total number of days the assignment is open for submission. Figure 4 shows the engagement score distribution across 3 homework assignments in CMPE-255 (other results are similar). High engagement score values indicate continued student engagement. The results show a variety of student engagement levels in the course, with some students attempting performance improvements on a daily basis and only a minority submitting once or twice.

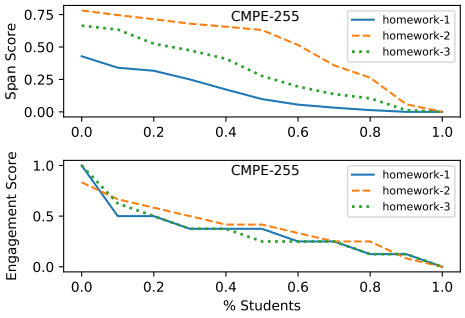

Fig. 4. Submission Span Score and Daily Engagement Distributions

Another way to analyze the impact of CLP on student performance is to consider the ratio between the number of days from the student's first and their last submission and the number of days the assignment was open, which we call the submission *span score*. Figure 4 shows the submission span score distribution for CMPE-255 (other results are similar). High submission span score values indicate higher improvement in score and thus increased performance.

VI. CONCLUSION

In this paper, we presented a Competitive Learning Platform (CLP) system designed to improve student motivation and course engagement for courses that can expose continuous-improvement assignments, which can be readily found both in and outside STEM fields. Numerical and textual data collected from five course offerings that employed the CLP system over three semesters were used to analyze the effects of CLP towards student motivation, engagement, and performance. Analysis results clearly show that a competitive active learning platform can play a key role to improving student engagement and performance.

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