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Manoj THULASIDAS
Singapore Management University, manojt@smu.edu.sg

Aldy GUNAWAN
Singapore Management University, aldygunawan@smu.edu.sg

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Manoj Thulasidas
School of Computing and Information Systems
Singapore Management University, Singapore
ORCID: 0000-0002-0508-5782

Aldy Gunawan
School of Computing and Information Systems
Singapore Management University, Singapore
ORCID: 0000-0003-0697-8619

***Abstract*—The question whether cold calls increase student engagement in the classroom has not been conclusively answered in the literature. This study describes the automated system to implement unbiased, randomized cold calling by posing a question, allowing all students to think first and then calling on a particular student to respond. Since we already have a measure of the level of student engagement as the self-reported class-participation entries from the students, its correlation to cold calling is also further studied. The results show that there is a statistically significant increase in the class participation reported, and therefore in student engagement, in the course for which the cold-calling system was implemented. Finally, along with the conclusions, the future plans and the limitations of this study are explained.**

***Keywords*—student engagement, class participation, cold calls**

I. Introduction

In modern classrooms, the traditional, lecture-only mode of content delivery has lost its relevance, in favor of interactive formats such as seminar-style discourses, group discussions and project activities. Central to all such activities is a need to ensure student engagement, and perhaps a need to assess the level of class participation. One way to enhance the engagement and participation is believed to be cold calling, which is the process of selecting a student at random to answer a question or share their thoughts. In this study, this belief is tested. A system to randomize cold calls, record their timing and assess their effect on the level of class participation is implemented. Along with the results and conclusions, the challenges faced in the implementation of the system and the mitigation techniques employed are also described.

The cold-calling system promotes active thinking and learning during whole-class questioning [1]. We first pose questions in the class and then call upon the students to respond and participate in the class activities. The importance of randomization becomes critical if class participation is an assessment component (as it was, in the course where this study was conducted) and is rewarded as part of the final grade. Without computerized randomization, unconscious biases may turn into the cold-calling sequence, despite the best intentions of the instructor. For instance, the names that are familiar to the instructor may get remembered and called more often than the rest. In multi-cultural, multi-racial classrooms, this unintentional bias may even come across as deliberate ethnic preferences. With computerized randomization, other challenges, such as the need for seamless integration and appearance of non-randomness, will need to be addressed. Therefore, the mitigation efforts are also described in this paper.

The remainder of the paper is organized as follows. Section II provides other work related to this study. Section III presents the proposed cold-calling system and methodology. Section IV provides the details of the implementation of the system. Section V summarizes the data used in this study and the steps in the analysis, followed by a discussion of the results in Section VI. Finally, Section VII summarizes the paper's contribution and future research directions.

II. Related Work

The benefits of class participation, ranging from enduring life skills [2], [3] to deeper understanding of the course content [4] and increased motivation to apply oneself, are well-established in the literature. From the student's perspective, it is also linked to improvements in learning as measured by course grades [5]. In a careful study on the effect of voluntary vs. called-on participation on class discussion [6], the authors found no significant difference between the two. However, the impact of class participation, when measured as the improvement in the student grade, was significant.

Another article [7] about the motivation behind student engagement lists the limitations of cold calling. It highlights the need to balance the time allocated to each student and to ensure coverage to all students lest they should gamble on the frequency with which they are cold-called. In addition, it notes that record keeping of the cold calls and the responses may be prohibitively time-consuming.

In a comprehensive literature review [8], the author summarizes and synthesizes the available information on the effect of student participation in college classrooms. As a recommendation to increase engagement, this study suggests using the class participation as an assessment component. Moreover, logistical variables such as the class size and the seating arrangement in the class can impact the level of participation. One concrete recommendation from this review was *not* to use cold-calling as a tool to improving the student engagement, due to its perceived intimidation effects. [9] calibrated a General Diagnostic Model and used a set of sample questions

from the question bank to ask the newcomer. The questions will be different to every newcomer, which is interesting for security purposes and allows us to calibrate various questions from the bank. [10] introduced the quasi-experiment tests by using the wheel of discussion. Results suggest that the use of a randomized name generator may be one way to improve engagement of students.

On the flip side, evidence of the efficacy of random name generation for classroom engagement and for grade improvement [10] has been recently published. The efficacy of non-voluntary class participation is highlighted in a different study [11] as well, where the results suggest that students did not feel uncomfortable, negating the wide-spread concerns about cold calling. A later investigation by the same authors on the same topic [12] re-establishes their findings. They further expanded on their theme [13], looking into the positive effects of cold-calling on nullifying the gender-equality issues in classrooms.

Another study [14], conducted on the students of Masters in Public Policy at Harvard, finds that the time the students devote to class preparations increased in a statistically and practically significant fashion when cold calling was used in conjunction with web postings. In an exploration into the relationship between active-learning practices and student anxiety in the classroom [15], three different active learning practices, namely clicker questions, group work, and cold call, are investigated. It is concluded that the specific aspects of these practices can actually negatively impact the student anxiety levels; therefore, creating more inclusive active learning classrooms through other means may be necessary.

In light of the established advantages of student engagement through class participation, and the dubious role of cold calling to enhance it, it seems timely to conduct a quantitative study to measure the effect of cold calling on class participation. In this paper, we report such a study to directly verify the conflicting recommendations.

III. Methodology

In the course where cold calling was implemented for this study, there is a component, the so-called class participation (CP) with a weight of 7.5% of the final grade. The CP points are counted against the students' self-reported entries, which comprise three aspects: (1) Asking a question, (2) Answering a question, and (3) Helping a classmate.

All these three aspects carry the same weightage in the CP points. These self-reported numbers provide the data points to quantify the student engagement in the classroom, which can be considered the dependent variable in the analysis. This data is available on a per-student, per-session basis. Students were called upon (at random using an automated system, described later) to answer the short questions posed by the instructor, or share their views on solution steps during hands-on exercises.

A. Contextual Information

This study was carried out on undergraduate students of a course on spreadsheet modeling and analytics. The classes were conducted in an in-person, seminar style setting, where the instructor goes through the concepts for about an hour and 30 minutes, followed by hands-on exercises. The typical class size is about 40 students, comprising mainly Singaporean students with roughly 50% male-to-female ratio.

B. Research Questions

In this study, the following research questions are defined:

1) Does cold calling enhance student engagement in the class activities (as reported in all three of the aspects listed above) on an average? ($RQ1$)
2) Does cold calling enhance student engagement on a weekly basis or on a per-session basis? ($RQ2$)
3) Does cold calling improve student engagement on a per-student basis? ($RQ3$)

C. Potential Bias and Issues with Self-Reporting

Since CP is a graded component for the course, there is a potential for students to inflate their self-reported counts. This bias can be handled in the analysis stage, by looking at the increase in CP points when cold-called from their baseline, as described in the Analysis section later. In addition to this bias, recent studies [16] have indicated that although self-reporting could result in lack of accuracy in special situations, it is widely used. In the current study, it is assumed that the students report their engagement levels accurately enough for reliable results.

IV. Implementation Details

A. Initial Implementation

In the first implementation, a simple script to randomly pick a student name from the class list was deployed, and flash it on the main display in front of the students, overlaying it on the slides. The shell script extracted a random name from the class list, which is fed into appropriate system calls to display on the screen shown to the students, but it was hard to maintain an accurate log of who was cold-called and when.

B. Birthday Paradox

While the simple shell script above does randomly select a name, it was observed that names may be repeated: a student may be called with what might seem like an undue bias. This effect is similar to the famous birthday paradox [17], in which an unexpectedly high probability of sharing birthdays is observed among a set of n randomly chosen people.

We, therefore, needed a means to ensure that all students are called before any one name is repeated in order to mitigate this challenge.

C. Timing Logs

In order to use the statistics of the cold calls for further analysis, the timings of the calls, along with the student name were recorded. From this information, the effect of cold calling on the students' self-reported class participation points was deduced, on a per-student basis.

Name	1	2	3	4	5	6	10
[redacted]	34.0%	34.0%	57.0%	67.0%	57.0%	67.0%	90.0%
	34.0%	57.0%	34.0%	34.0%	34.0%	34.0%	34.0%
	34.0%	34.0%	1.0%	34.0%	1.0%	1.0%	34.0%
	24.0%	34.0%	24.0%	57.0%	34.0%	57.0%	67.0%
	37.0%	67.0%	57.0%	57.0%	70.0%	67.0%	100.0%
	34.0%	67.0%	34.0%	34.0%	0.0%	57.0%	67.0%
	34.0%	34.0%	57.0%	34.0%	34.0%	34.0%	70.0%
	57.0%	57.0%	90.0%	34.0%	34.0%	67.0%	24.0%
	57.0%	57.0%	57.0%	57.0%	57.0%	57.0%	57.0%
	57.0%	34.0%	47.0%	57.0%	90.0%	34.0%	1.0%
	90.0%	57.0%	100.0%	90.0%	90.0%	90.0%	100.0%
	50.0%	47.0%	80.0%	67.0%	90.0%	0.0%	47.0%
	47.0%	80.0%	57.0%	47.0%	70.0%	57.0%	47.0%
	67.0%	67.0%	57.0%	34.0%	57.0%	57.0%	57.0%
	1.0%	1.0%	1.0%	1.0%	14.0%	1.0%	1.0%
	34.0%	80.0%	57.0%	70.0%	57.0%	57.0%	57.0%
	24.0%	34.0%	14.0%	14.0%	1.0%	1.0%	14.0%
	60.0%	57.0%	37.0%	0.0%	24.0%	24.0%	57.0%
	67.0%	47.0%	57.0%	57.0%	67.0%	1.0%	100.0%
	34.0%	57.0%	57.0%	57.0%	34.0%	0.0%	57.0%
	47.0%	90.0%	44.0%	57.0%	90.0%	87.0%	90.0%
	100.0%	90.0%	90.0%	90.0%	90.0%	57.0%	90.0%
	47.0%	80.0%	90.0%	50.0%	90.0%	90.0%	60.0%

Fig. 1. The self-reported class participation points, as a measure of student engagement

V. Data Collected and Analysis

A sample of the student class participation data is shown in Fig 1. The numbers are self-reported by the 114 students listed in the "Name" column. Out of the 13 contact weeks of the term, the CP data is available for seven of them: Weeks 1 through 6 and 10. The other weeks are excluded because of course activities such as project work, mock exam or recess holidays, where the cold-calling sequences were significantly different from the normal weekly sessions.

After pre-processing the cold-calling log files, there is a parallel table of when the students were called upon to respond to the instructor, as shown in Fig 2. Because of the safeguards against repeated calls (unless all students in a section are called at least once), no student was called twice on the same day.

A. Summary of the Data

- Number of Students: 114, in three different sections.
- Number of Classroom Sessions: 21 (over seven weeks).
- Total Number of Cold Calls Recorded: 107.

B. Analysis Steps

In order to see whether cold calling makes a difference in the student engagement level, as measured by the self-reported CP numbers, the null hypothesis is that the difference seen in the data, if any, is a statistical fluctuation. The data is aggregated at the appropriate level of granularity depending on the research question (RQ) and see whether the null hypothesis is rejected with a certain level of significance (e.g. 5%).

Name	1	2	3	4	5	6	10
[redacted]	1	0	0	0	0	1	0
	0	0	0	0	0	1	0
	0	1	0	0	1	0	0
	0	0	0	0	1	0	0
	0	1	0	0	0	0	0
	0	1	0	0	0	0	0
	0	0	1	0	0	0	1
	0	0	0	0	1	0	0
	1	0	0	0	0	0	0
	0	1	0	0	0	0	0
	0	1	0	0	0	0	0
	0	0	0	0	1	0	0
	1	0	0	0	0	0	1
	0	0	0	0	0	1	0
	0	0	0	0	1	0	0
	0	0	0	0	0	1	0
	0	0	0	0	0	0	0
	0	0	1	0	0	0	0
	0	0	0	0	1	0	0
	0	0	0	0	0	0	0
	0	0	1	0	0	0	0
	0	0	0	0	0	0	0
	0	0	0	0	0	0	1

Fig. 2. The number of times each student is cold-called in each week

1) RQ1: The top-line number, based on the entirety of the data, tells us whether cold calling has a statistically significant effect on the student engagement. For this purpose, we calculate the average CP numbers (from the table shown in Fig 1) when the students were cold-called (that is, in the 107 instances in Fig 2 when the indicator is one) and subtract from it the average of $114 \times 7 - 107$ numbers when the students were not called. These entities are denoted by the symbols μ_1 and μ_0 respectively.

We then compute the standard errors on the averages (denoted by σ_{μ_1} and σ_{μ_0}) as the standard deviation of the averages as the respective standard deviations divided by the square root of number of observations in each. Since the difference $\Delta\mu$ of two averages is taken, the resultant standard error is given by:

$$\sigma_{\Delta\mu} = \sqrt{\sigma_{\mu_1}^2 + \sigma_{\mu_0}^2}$$

With the difference in the averages $\Delta\mu$ and its standard error $\sigma_{\Delta\mu}$, we proceed to calculate the p-value of rejecting the null hypothesis using the standard t-test, which is used to determine if two population means are equal.

2) RQ2: For the second research question, the analysis is identical to the one described for RQ1, except that the aggregation is performed for each week, segmenting the data into seven parts. In principle, the data could be further subdivided, on a per-section, per-week basis. However, it was seen that the dataset then became too fragmented for meaningful analysis.

3) RQ3: On a per-student basis, using pair-wise analysis, the data yields some more interesting insights. We tested whether any difference on the student engagement across 1) all sessions and 2) all students. For the former, we use the two independent sample t-test and for the latter, we use the paired sample t-test (or the dependent sample t-test), which quantifies the significance of the mean difference between two sets of observations (e.g. with and without cold calling).

VI. Results and Discussion

A. Improvements in Student Engagement

When analyzing in its totality, the data shows statistically significant results at 95% confidence level, as shown in Table I. The probability of the null hypothesis (that there is no improvement in student engagement due to cold calling) being true is only 2.6%, and can therefore be rejected. In other words, it is concluded that cold calling does improve student engagement in the classroom and the answer to the first research question is in the affirmative.

The second research question, however, cannot be answered adequately with the statistics available. As shown in Table II, the probability of the null hypothesis is significant for most of the weeks.

For the third research question, we first explored the validity of the hypothesis that there is a difference across different sessions among the students who received cold calls and who

TABLE I. RESULTS FOR RQ1

	Average	Standard Error
CP from cold-called students	$\mu_1 = 55.8\%$	$\sigma_{\mu_1} = 2.4\%$
CP from other students	$\mu_0 = 51.1\%$	$\sigma_{\mu_0} = 1.1\%$
Difference	$\Delta\mu = 4.6\%$	$\sigma_{\Delta\mu} = 2.6\%$

TABLE II. RESULTS FOR RQ2

Week	1	2	3	4	5	6	10
$\mu_1(\%)$	49.7	58.4	54.5	54.5	56.0	61.8	53.7
$\sigma_{\mu_1}(\%)$	5.4	5.7	4.9	13.3	5.6	6.9	7.9
$\mu_0(\%)$	46.1	54.5	60.8	44.0	51.3	46.3	56.7
$\sigma_{\mu_0}(\%)$	2.4	2.6	2.7	2.6	3.0	3.0	2.8
$\Delta\mu(\%)$	3.6	3.9	-6.3	10.5	4.7	15.5	-3.0
$\sigma_{\Delta\mu}(\%)$	5.9	6.3	5.6	13.6	6.4	7.5	8.4
p-value	0.269	0.266	0.868	0.221	0.229	0.020	0.639

did not receive it. In order to investigate this difference, we refer to the values of μ_1 and μ_0 in Table II and conduct the two independent t-tests. The statistical result of the two independent t-tests (shown below) gives us a p-value (17.34%), from which it is concluded that there is no statistically significant difference across different sessions among the students who were cold-called and the ones who were not. We attribute this lack of significance to the relatively low number of students who were cold-called in each session.

Each student may get a cold call in different sessions. For this reason, we would like to examine the following hypothesis: supposing the student is cold-called in a certain session, they should have a higher class participation number compared with those sessions where they were not called. This is the focus of the second part of RQ3. We use the paired sample t-test in order to verify this hypothesis. The statistical result is shown below. Since the p-value is 1.38% (well below the significance level of 5%), we conclude that on average, cold calling actually improves the CP numbers in all students.

B. Limitations and Future Plans

Since the study was only conducted on one course with three sections and one instructor, we cannot be certain that the improvement thanks to cold calling seen in the data will generalize to other courses and instructors. Further fine-tuning may be necessary. The dependence of the improvement on factors such as the types of the questions, student gender, cultural differences etc. may be worth exploring. For future work, we will consider implementing the same system for other courses and other instructors. Some adjustments or generalizations of the system may be required, such as topics to be asked, etc. Comparisons with other methods, such as clicker questions and group work, could also be interesting to explore or study.

VII. CONCLUSION

The cold-calling system to ensure randomized prompting of class participation is implemented. It was integrated with the classroom workflow and eliminated inadvertent biases on the part of the instructor, as well as the potential appearance of a bias. Using the logging facilities afforded by the system, and in conjunction with the self-reported class participation entries from the students, we measured the level of student engagement.

The basic research question, whether cold calling improves student engagement, is answered in the affirmative, although more data collection is needed to fully confirm it. Out results indicate that cold calling does improve student engagement in the classroom. Students tend to show statistically improvements in their class participation numbers after receiving cold calls. The system is described in this article in some detail so as to enable other instructors to implement it, should they choose to. The code is also freely available from the authors.

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