

INCREASING ENGAGEMENT IN A PROBABILITY COURSE THROUGH NOVEL TECHNICALLY-ENHANCED COMMUNICATION

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Mathematics Classroom Collaborator (MC²) (<http://mc2.trentu.ca>) is an online, real-time communication tool developed to make the communication of mathematical expressions easy and intuitive, thereby addressing many of the issues related to student engagement and inclusion in large mathematical science classes. It includes the option for anonymity, and works on a variety of platforms, including smartphones, tablets, and notebook computers. In this paper, we analyze the experience of employing MC² in an introductory probability course, and we discuss how this approach may be extended to develop new communication models for the technologically-enhanced class — models that may help overcome social barriers to create a more inclusive, student-centred environment.

INTRODUCTION

Many recent studies of face-to-face classroom experiences extol the virtues of new interactive pedagogical models, including peer-based learning (Mazur, 2009). Other research has shown that out-of-class student-teacher interactions (e.g., office-hour attendance) lead to improvements in key academic measures, including student performance, retention, and satisfaction (Nadler & Nadler, 2000). And students themselves overwhelmingly show an interest in greater online communication with their professor (Helvie-Mason, 2012). With these results in mind, perhaps, many instructors have adopted new teaching methods and tools, such as “flipped classrooms” and immediate feedback systems (i.e. “clickers”).

Within a given discipline, however, the benefits of increased interactions may not be distributed equally across students groups. For STEM disciplines in particular, classrooms may not be “democratic” in that participation rates may differ systematically across students. For example, women, relative to their male peers, are less likely to engage in both in- and out-of-class discussions (Eddy et al., 2015) and, in math courses, are less likely to pose questions (Krupnick, 1985). Anecdotal reports further suggest that international students may be shy about asking questions in what is their non-native language. Sankar et al (2015) have found that, in computer science, female undergraduate students ask 37 percent fewer questions than their male peers. Jong (2013) has shown that an anonymous discussion tool can improve participation and learning outcomes. Finally, Sankar et al (2015) found that, with the online bulletin board tool Piazza, female STEM students were more likely to use the anonymity feature than their male counterparts.

In this paper, we test a real-time, Mathematics-enabled chatroom that allows for anonymous in-class interactions. We first describe the features and interface design of this new communication tool: Mathematics Classroom Collaborator (MC²). We then present some results of using MC² in a large introductory Probability course — a calculus-based course that can be one of the least-engaged courses on campus, with students rarely asking questions even during tutorials. Our semi-inverted format allowed students to easily and anonymously ask and answer questions, while collaborating in small groups to solve worksheets in class. We present results on various aspects of student engagement and outcomes that highlight the characteristics, as well as the advantages and challenges, of our approach.

MC²: MATHEMATICS CLASSROOM COLLABORATOR

In developing MC², our aim was to create a mathematics communication and collaboration environment to allow even novice (i.e., non-TeX) users to interact with mathematics electronically. A requirement was that the software work on a variety of different hardware platforms — tablets,

smartphones, and laptop computers — running on a variety of different operating systems, including Windows, MacOS, iOS, and Android. To ensure that students would have easy access to the software without having to pre-install anything, a browser-based architecture was appropriate. Input methods include keyboard, mouse, stylus, touch screen, and camera.

One important difference between MC² and messaging applications is that the latter typically must be installed on the smartphone, while the former has been designed as a Web-application. This makes it easier for MC² to support a wide variety of platforms — including notebooks (PC, MacOS), tablets, and smartphones (Android, iOS) — and it avoids the associated application stores. Our software may be seamlessly incorporated into learning management systems. A Web-based application may also both lower the entry barrier for first-time users and ease privacy concerns regarding what data the application can gather from the phone. The client-side of MC² is written in JavaScript and utilizes SVG and MathJax, while the server-side is JavaScript and utilizes node.js, making it easy to install, as it contains an integrated Web server. MC² is composed of two panels — a chat panel and a math editor panel. On notebooks and tablets, these two panels present in one screen, while on phones the user can switch back and forth between the panels. On its face, MC² presents itself as a familiar texting application, with the addition of mathematical capabilities. We highlighted its functions by the annotated numbers from (1) to (6) in the Figure 1.

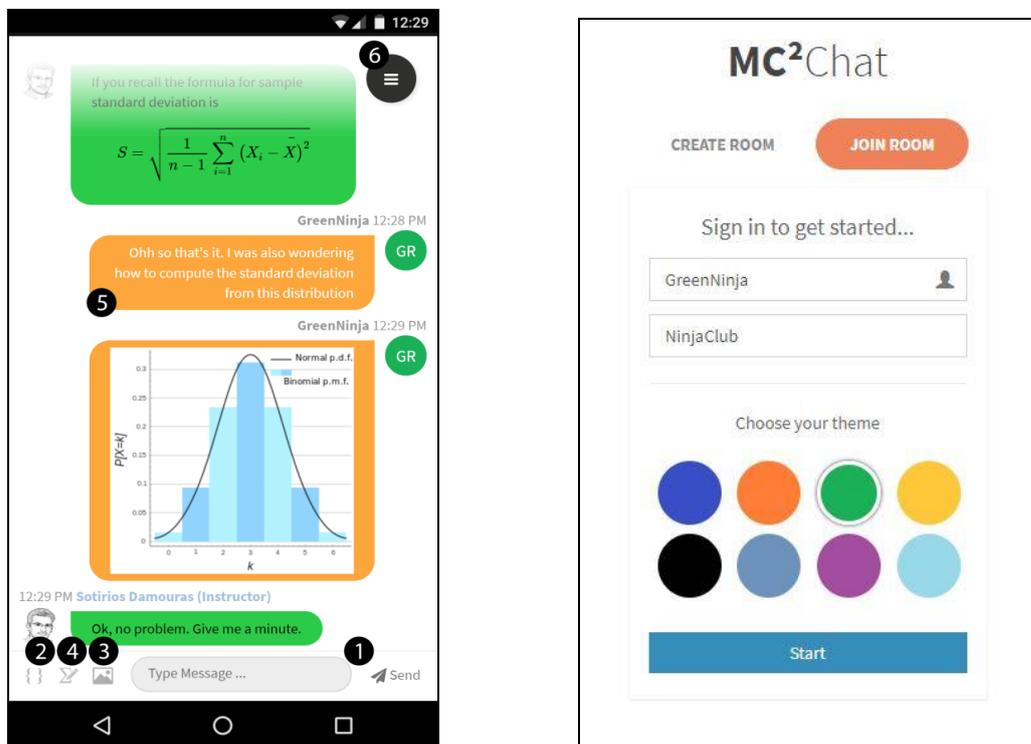


Figure 1: Left Panel: MC² Chat Screen (1) Text input field. (2) Insert TeX into text field (3) Input image from camera or gallery (4) Launch the mathematical expression editor. (5) Dialogue Pane: clicking on an image or mathematical expression launches the expression editor for annotating or modification. (6) Chat Option – tab to expand the options of Online Users button and Logout button. Right Panel: Initial Login Screen.

- ❶ Text Field: In addition to typing regular texts, the text field supports the insertion of TeX.
- ❷ TeX Editor: TeX input requires a number of symbols such as \$, \, {, }, _ , and ^ . On smartphone keyboards, these symbols are often difficult to access quickly. In MC², these symbols can be found under this button.
- ❸ Image/Camera: The image button allows a user to upload an image. A user can write mathematical expressions on a piece of paper, take a picture from the smart phone and upload it, which could be convenient for those accessing the chat from a smartphone. Students can upload screenshots of questions from homework or online lecture notes.

- 4 Mathematical Editor: Complex mathematical expressions can be entered by accessing the mathematical editor (see Figure 2), where equations can be input using a diagrammatic equation editor for non-TeX users. The symbols can be selected, moved, and resized based on the diagram editor UI principals. Diagrams can be drawn and be recognized using a baseline structured approach (Zanibbi et al., 2002 and Pollanen et al., 2007) and converted to TeX which can be displayed by the messenger.
- 5 Dialogue Pane: The dialogue pane is where the conversation is displayed in a chronological order. It is nearly identical to the panes found in text message apps. Instructors can delete posted messages and users can copy messages and paste them into the TeX editor.
- 6 Chat Option: click to expand the options of chat. There are two options: Online user button and logout button. Online user button provides the user names that are currently at the chat.

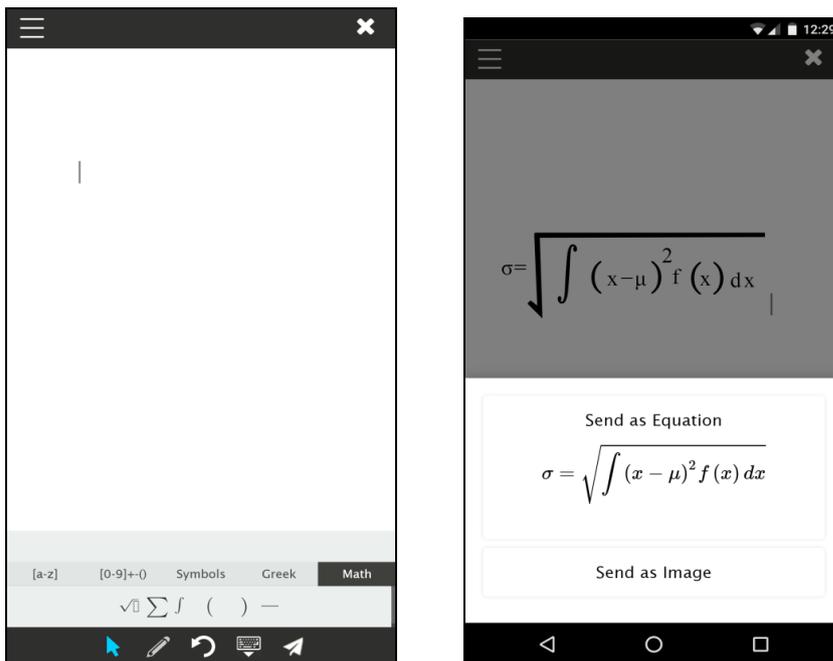


Figure 2: MC² Mathematical Editor – non-TeX users can click on math symbols or Greek letters from the menu and make a diagrammatic equation that can be either converted to TeX expressions and sent to a text file, or sent directly to the dialogue pane as an image file.

METHOD

In the Fall of 2017, undergraduate students enrolled in Introduction to Probability (STAB52) in the Department of Computer and Mathematical Sciences at the University of Toronto Scarborough were invited to participate in this study. MC² was used in weekly in-class group work sessions (2 hours) and in online office hours (2 hours) conducted by a teaching assistant. There were three sections in STAB52 with a single instructor, and we randomly choose one section per week to use of MC² during a group work session. With anonymity, a key and purposeful design feature of MC², no “sign-up” stage was required: there were no passwords to remember and students were free to use any username. To identify students for the purposes of our research, we did send a personalized invitation email to access MC² for each session. The invitation email contains an encrypted link providing the encrypted identification of each student. This method provided easy access to MC² for students, and also allowed us to identify each student in an indirect way. A total of 368 students completed the course. There were 103 female students (about 30% of our sample), of whom 73 (30) were international (domestic). Overall, 139 of the students were international.

MC² Survey Results

To measure the satisfaction levels of MC², and to receive additional comments, we sent a

brief survey to students during the last week of the course, the results of which indicated that, of the 85 respondents, 67 used MC² at least one time. The main reasons for not using MC² included a stated preference for face-to-face interaction with Teaching Assistants during a group work session, and indications that the time pressure of having to submit a worksheet discouraged MC² use. Table 1 summarizes the results. Students responded particularly positively to the software’s anonymity and upload features.

#	Question (scale 1 – 5)	Mean	Median
1	MC ² supported my development as a student in the course.	3.08	3
2	MC ² fostered a learning community in the course.	3.18	3
3	MC ² had a positive contribution to my learning.	3.2	3
4	MC ² 's anonymity feature made me feel more comfortable asking questions.	3.8	4
5	MC ² 's online office hours were convenient.	3.3	3
6	MC ² 's mathematical input was easy and effective.	3.3	3
7	Attaching a document (taking a picture) provided a convenient way of communicating mathematics.	3.5	4

Table 1: MC² survey questions and summarized results

Question 8 asked about any additional features of MC² that a student found useful. Selected comments were as follows: the teacher directly helping with MC² during lectures was really helpful; easy access; naming; office hours; helpful and fast; multiple people could submit questions at the same time and it is easy to read and understand; you can input any languages. Students also mentioned that MC² was under-utilized during group work sessions because the available time was limited. Another comment was that “MC² was very helpful, in the future allowing TA's to answer some of the questions within the app could improve efficiency since students had only 30-40 minutes to finish the quiz”.

MC² with Piazza Data

Because of a technical problem, we could not retrieve all chat histories saved to the server, so the usable data included only 19 unique students who used MC², either in the group work session or for the online office hours. The course instructor did, however, use Piazza (<https://piazza.com/>), a free online Q&A discussion board. Although it lacks the real-time communication feature of MC², and although anonymity is left up to the student, we combined these richer data with MC². Doing so allowed us to create a variable, *Engage* = *Piazza participation* + *number of MC² messages*. The histogram in Figure 3 illustrates that *Engage* has an extremely right-skewed distribution, so we created a new dichotomous variable, *Y*, as follows: *Y* = 0 if *Engage* = 0; *Y* = 1, otherwise. A logistic regression was fitted to investigate which factors are statistically significant in terms of their impact on the engagement of students with either Piazza or MC².

$$\text{Logit}(\pi_i) = \beta_0 + \beta_1 (\text{LEG_STATUS}) + \beta_2 (\text{YEAR_OF_STUDY}) + \beta_3 (\text{GENDER})$$

Variable	Estimate	Std.Error	Z value	P-value
Intercept	-0.06653	0.55379	-0.120	0.90437
LEG_STATUS(International)	-0.70441	0.24679	-2.854	0.00431 **
YEAR_OF_STUDY	0.22416	0.19285	1.162	0.24508
GENDER (M)	0.09117	0.26389	0.345	0.72973

Table 2: R logistic regression output

We tested the goodness-of-fit of the logit model with the Hosmer-Lemeshow test, and the result was insignificant (p-value = 0.4253). After controlling for the student’s year of study and gender, the legal status was the only highly significant factor (p-value < 0.005) in our estimation of the probability of being engaged in online activities. The estimated odds ratio of domestic relative to international student engagement was $1/e^{(-0.70441)} = 2.022653$.

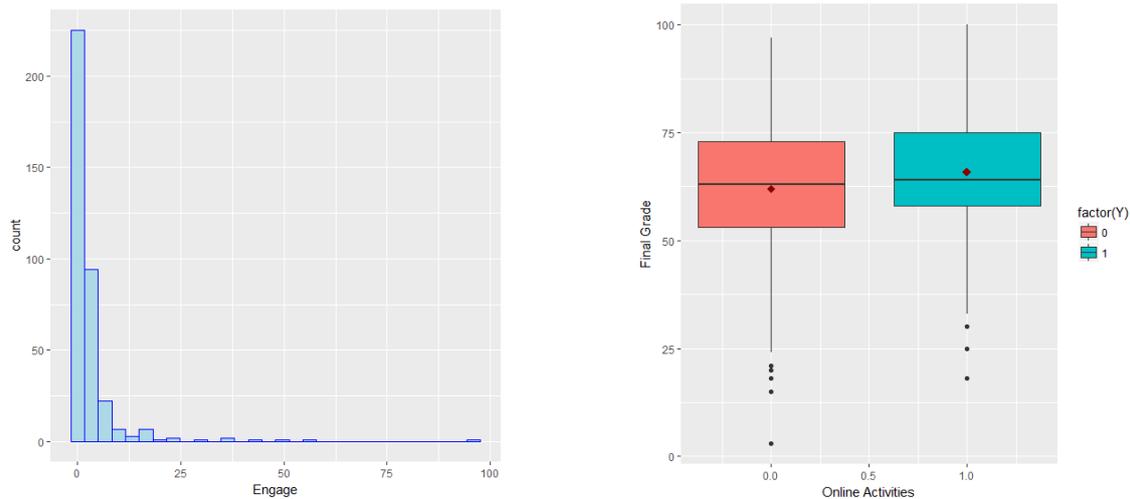


Figure 3: Histogram of Engage and side-by-side boxplot of final grades of students by dichotomized engagement of online activities.

Y=0 (No, online activities)		Y=1 (Yes, online activities)	
		Gender	Gender
		Female	Male
Legal Status	Domestic	9	75
	International	43	34

Table 3: Three-way frequency table with the response variable Y, Gender and Legal Status

As we see in Table 3, 30% of the domestic female students did not participate in the online activities, while 60% of international female students — the least engaged group overall — did not participate. Within the group of domestic students only, females had a slightly higher rate of participation compared to males (70% vs 63%) — a result consistent with Sankar et al (2015) — but the difference was not statistically significant.

Finally, we performed the *t*-test for the final grades of the course between two groups (Y=0 and 1). We found a significant difference in final grades — specifically, the engaged group had a higher mean than the non-engaged group. It is important to note, however, that, because our data are observational in nature, we cannot conclude that engagement in online activities is the only factor contributing to better performance in the course.

Group	n	Final Grade		t-test	P-value
		Mean	SD		
Y=0	161	62	16.8	t = -2.34 (df = 312.88)	0.01968 (*)
Y=1	207	66	14.2		

Table 4: Summarized R output from t-test result

We also compared student performance over two consecutive years, in Fall of 2016 and 2017. The instructor and overall format of the course were the same for both terms. But there was one noteworthy change: in 2017, worksheets counted for 10% of final marks, and students were allowed to work on them collaboratively, while in 2016, students were required to individually solve shorter (10 min) in-class quizzes for the same amount of credit (10%). The midterm average in the Fall of 2016 (2017) was **56.87** (**60.47**), while the final course average was **63.48** (**64.17**). These marks are consistent with a modest improvement, although the differences are not statistically significant. Of course, this comparison is not conclusive since it does not control for differences in the student population or the difficulty level of the exams. Nevertheless, we did witness an increase in student attendance and engagement, and we hope that the improvement in

grades reflects an actual improvement in student learning.

CONCLUSION

The literature has established that active learning — in particular, two-way communication — is an integral part of creating an optimal learning environment. In STEM subjects, however, there appear to be barriers to communication that prevent women from having an equal voice inside, and perhaps outside, the classroom. Particularly in the quantitative sciences, where communication may be more subdued due to math or statistics anxiety, these barriers may prevent women from achieving their full potential. One possibility for increasing communication is through the use of online technology and the anonymity that it provides. Mathematics communication, however, requires specialized user interfaces for input. To that end, we have developed a Web-based application, MC², that allows for easier entry and communication of mathematical expressions on all devices. MC² was employed in the large introductory probability course. Although we could not capture all aspects of MC² student engagement due to technical limitations, we combined our data with rich data from Piazza, and found a significant average course grade difference between students who engaged in online activities and those who did not. Females engaged at slightly higher rates than males in on-line activities within the domestic student group. International female students were still the least engaged group, suggesting that work remains to be done to improve the technically-enhanced classroom model and achieve a more democratic classroom. In closing, we note that research into the use of anonymity in mathematics and statistics courses is still in its infancy. The results presented here, however, suggest that the development of additional technologies to enable easy, anonymous communication and interaction in quantitative subjects is warranted.

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