Micro-Classes: A Structure for Improving Student Experience in Large Classes

Christine Alvarado, Mia Minnes, and Leo Porter
Department of Computer Science and Engineering
University of California, San Diego
{cjalvarado,minnes,leporter}@ucsd.edu

ABSTRACT

As class-sizes grow in computer science, the personal attention received by students tends to diminish. This work aims to replicate small-class community effects within a large class by creating “micro-classes”—small groups within the large class. These micro-classes consist of 20–30 students led by graduate teaching assistants and undergraduate tutors who are specifically trained in small-classroom instructional techniques. This paper studies the outcomes of the micro-classes framework in an upper-division data structures course and compares them to outcomes from the same class taught in a large lecture, active-learning format. Students report increased satisfaction and a higher perception of community in the micro-classes section, though there was no discernible difference in student academic performance.

Keywords

Classroom Community; Large Classes; Data Structures; Active Learning; Gender

1. INTRODUCTION

Computer Science (CS) education is growing at a massive scale. Millions of students have flocked to courses, both online and in the classroom [4, 15]. In short, there are more students than ever before who want to learn CS [9].

The opportunities for education in CS vary widely, from Massive Open Online Courses (MOOCs) to small private colleges. At one extreme, MOOCs provide content delivery for a relatively low cost on a very large scale, but lack rich interactions between instructors and among students. On the other hand, small private colleges provide a high-touch, tight learning community, at a very high cost.

Large public universities are left somewhere in the middle, educating the majority of young people in our country. Transforming CS education on a large scale requires addressing what happens at these large, physical institutions. In pursuit of this goal, we designed and piloted a novel structure for large-format, on-campus classes designed to deliver the

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benefits of a small college classroom (personal connections with instructors and students, opportunities for assistance, etc.) at a large scale, respecting the limited resources available at a large institution. This structure divides students in a large (200+) class into small 25–30 person “micro-classes,” each led by a graduate student teaching assistant (TA) assisted by 2–3 undergraduate tutors. All 200 students attend lecture together, but they sit and interact with their micro-class during class.

The pilot offering of the micro-class structure was held in an upper-division advanced data structures course. The results from this pilot demonstrate that this new structure increased the sense of community felt by students, increased many aspects of their satisfaction with the course, and potentially was more attractive to women students than our traditional active-learning class format.

2. RELATED WORK

The micro-classes design was intended to foster classroom community and to increase student interaction with the instructional team within large classes. Building on constructivist theories of learning, a sense of community and its social context increasingly is seen as playing an important role in learning [13]. Most directly, an increased sense of community can improve the chances that a student will engage in collaborative learning strategies that have been found to lead to student success across STEM disciplines [6, 19]. As such, programs for women and ethnic minority students have focused on building community-centered learning groups [1, 2]. More recently, work has explored using supplementary learning communities to increase student retention and success in CS [7, 16]. Our study builds on this work by studying the benefit of the micro-class design for building community in a large class in the context of high CS enrollments.

Current trends in scaling CS education to larger enrollments look to online or hybrid classes. Recent work has looked at community effects in such courses. In online classes in education and leadership, one study finds a stronger sense of community can be beneficial for retaining students [14]. However, a higher sense of community was found not to be correlated to success in either a flipped or an online offering of a CS1 class [3].

Classroom community can encompass the instructional team, including TAs and undergraduate tutors. Student connections with TAs and instructors have been found to impact students’ persistence in higher education in general, and in STEM specifically [8]. One study found that TAs may influence students’ decisions to stay in the sciences by

influencing lab culture, student grades and student knowledge of science careers [10].

Additional support from staff and a tighter community with which to work on in-class exercises may increase the benefits of an active learning framework. Studies of Peer Instruction (PI) provide evidence that PI contributes to improved retention of majors in introductory classes [12] and to higher student self-reports of engagement with other students in class [18]. Yet, to date, there have been no studies in CS which use assessments of community in PI classrooms. Our work both provides a baseline for community in a PI classroom, and examines the relative difference in community that the micro-classes structure provides.

3. MICRO-CLASSES SETUP

This study aims to measure the effect of the micro-classes structure on students' performance, persistence, and sense of classroom community. Our main research questions are:

RQ1: Will students in the micro-classes section report a stronger sense of classroom community?

RQ2: Will students in the micro-classes section achieve better academic performance, specifically higher student retention and better performance on assessments?

3.1 Course and Study Design

We studied these research questions in the context of a sophomore/junior-level advanced data structures class at a large public research-focused university that enrolls a mix of residential and commuter students. This course is often stressful for students, being the first upper-division course in the curriculum and a significant gateway into further upper division work. During the 2015–16 academic year, we implemented the micro-classes design in a single section (the micro-classes section), and we compared it to two other sections of the same class taught by the same instructor (the first author): one taught in the same term as the micro-classes section (the primary control) and the other taught in the prior term (the secondary control). The micro-classes and the primary control each had about 200 students enrolled while the secondary control had 276 students enrolled. All sections met for three 50-minute class sessions per week led by the faculty instructor and one weekly 50-minute discussion section led by graduate student TAs. The overview of the experimental setup is given in Figure 1.

The micro-classes section was structured as seven parallel small classes. The 200 enrolled students were divided into these groups of 25–30 students based on their availability to attend a weekly discussion section at different times on Tuesdays. All 200 students in the micro-classes section attended a single class session at 9am on Mondays, Wednesday and Fridays, led by the course instructor. During this class, students were seated with their micro-class groups, with empty rows separating the micro-classes from each other. Each micro-class was assigned a single graduate student TA who was responsible for leading the in-class activities as well as the weekly discussion section for their micro-class. This TA worked with two or three undergraduate tutors who supported the in-class and discussion activities and graded students' assignments, providing rich individualized feedback.

The two control sections were structured as standard large-format classes. The instructor-led class sessions for the primary control were on Mondays, Wednesdays and Fridays at 8am, immediately preceding the micro-classes section. For

Figure 1: Micro-classes structure

the secondary control, the instructor-led class sessions were Mondays, Wednesdays and Fridays at 10am, immediately following a section of the same class taught by the same instructor at 9am (not included in this study). Scheduling similarities between the micro-classes section and the secondary control were the main reason we included this second control section. We were concerned that the early hour of the primary control and the fact that it was taught before the micro-classes section (meaning the instructor might be better-prepared for the micro-classes section) might negatively affect student experience in the primary control section.

Students in the micro-classes were assigned to a discussion section, while students in the control sections could choose to attend one of a small set of discussion sections. In the primary control, the TAs who led the discussion sections were two of the TAs who were also leading their own micro-classes discussion sections, and the content of these sections was similar to the micro-classes sections.

Other than the course structure, the micro-classes and primary control were identical, including topics covered, in-class activities, exams and assignments. In class, the instructor used active learning, combining lecture with peer instruction [5] and worksheet exercises; in each class session, students spent at least 10 of the 50 minutes of the class (often more) working on exercises either individually, with a partner, or in small groups. Both sections completed the same in-class exercises. Students received 5% of their grade for class participation (measured using clickers). Before each class, students did a reading assignment and took a reading quiz that together accounted for 5% of their grade. Students in both sections did the same programming assignments, where they were allowed to pair-program with a partner (within their micro-class or section) if they desired. Students also took the same weekly review quizzes, the same two midterm exams and the same final.

The secondary control was similar in content, but because it was taught in a previous term it could not be exactly the same. It also used active learning, gave points for reading quizzes and class participation, and students completed the same number of exams, quizzes and programming assignments.

However, these assignments and exams (and the rubrics used to grade them) were not identical to those in the micro-classes and primary control sections.

Outside of class, the micro-classes and the primary control section had a shared student support framework. TA and instructor office hours and tutor lab hours were open to students from either section, and both sections shared a discussion board (Piazza). Support for the students in the secondary control was similar.

Before the term started, students registered for the micro-classes and primary control sections without knowing about the micro-classes pilot. However, after the first day of class when the experiment was explained, students were permitted to move between sections as their schedules and the course enrollment limits allowed, per standard registration procedures at our university. Students in the secondary control were unaware of the upcoming micro-classes pilot.

3.2 TA and Tutor Training

All TAs and tutors at our university participate in a training course covering basic TA/tutor mechanics and pedagogy during the first term they tutor or TA. Since micro-classes TAs and tutors had additional leadership and instructional roles, TAs and tutors for the micro-classes section participated in extra training and professional development sessions. This training followed recommendations by Patitsas for improving the effectiveness of TAs [11].

The term before the micro-classes experiment was run, all micro-classes TAs and tutors attended all of the classes in the advanced data structures course. They also attended two weekly training sessions: one focused on leadership and community development, and one that allowed the TAs and tutors to practice leading mock class sessions. The interactive activities developed for these mock classes were iterated and refined for use in the micro-classes the following term. In addition, each micro-class team (one TA and three tutors) met independently on a weekly basis to prepare for the upcoming pilot.

3.3 Data Collected

To measure the impact of the micro-classes design on performance, we collected performance data including attendance, grades on each assessment, and overall course grades. We also tracked students who withdrew from the course during the last six weeks of the term (who receive a W on their transcript). We used student end-of-term evaluations to determine student satisfaction and perceived learning.

To measure students' sense of community we used the Classroom Community Scale (CCS) instrument [13]. This self-report survey comprises 20 questions, each with a statement about the student's impressions of class community followed by a 5-point Likert scale. The questions factor into two sub-scales: Connectedness (e.g., "I feel that this course is like a family", "I trust others in this course") and Learning Community (e.g., "I feel that I am encouraged to ask questions", "I feel uneasy exposing gaps in my understanding"). Half of the questions belong to each of these sub-scales. In addition, half of the questions are positively worded and half are negatively worded. Points are assigned from 0–4 for each question so that scores lie in the range 0 to 80, and higher scores reflect a stronger sense of classroom community. In the micro-classes and primary control section we administered the survey twice: once at the beginning of the term,

where we modified it slightly to ask about students' previous experiences in their CS courses, and once at the end of the term, where we asked about their experience in the current course. In the secondary control section we administered the survey once at the end of the term.

In all, 150 students in the primary control section, 233 students in the secondary control section, and 176 students in the micro-classes section consented to include their data in our analysis. Of these, 13% of the students in the primary control, 15% in the secondary control, and 24% of the students in the micro-classes section were women (more on this difference below). These numbers are within one percentage point of the actual percentage of women in each section.

To inform our interpretation of the quantitative results, a small number of interviews were held with students, tutors, and TAs from both the primary control and the micro-classes sections of the course.

4. RESULTS

We first examined whether the micro-classes and control sections had comparable groups of students. On most aspects, we found no significant difference between the primary control and the micro-classes section, but there were differences between the secondary control and the other two sections. The average GPA coming into the class was 3.17 for the primary control section and 3.16 for the micro-classes section, but for the secondary control it was 3.36. An ANOVA with a Tukey HSD post-hoc analysis revealed that the secondary control GPA was significantly different from the other two sections ($p < 0.001$), but that the primary control and the micro-classes section did not differ from each other. The balance between CS majors (micro-classes: 48%, primary control: 40%), math majors (micro-classes: 34%, primary control: 37%) and other majors (micro-classes: 18%, primary control: 23%) was also similar between the primary control and the micro-classes section ($\chi^2 = 2.53, p = 0.28$), but the secondary control had a significantly higher proportion of CS majors (76%, with 13% math and 11% other, overall $\chi^2 = 62.33, p < 0.001$).

The micro-classes section had a significantly higher proportion of women (23.9%) compared to the two controls, which were similar to each other at 13.3% and 15.5% ($\chi^2 = 7.4074, p < 0.05$). We do not have a snapshot of student enrollments from the first day of class (before students learned about the micro-classes experiment), so we cannot know whether or not this difference was caused by women and men self-selecting into or out of the micro-classes section intentionally. However, considering the secondary control section, it appears that the proportion of women in the primary control is in line with the proportion of women typically enrolled in this course.

4.1 RQ1 — Community and Satisfaction

Table 1 provides the results from the classroom community survey before and after the term in each section. At the beginning of the term there was no statistical difference between the senses of community of students in the micro-classes section as compared to the primary control section. At the end of the term the total community score in the micro-classes section was significantly higher than the scores in both control sections (using ANOVA with a Tukey HSD

Table 1: Mean CCS scores for the micro-classes section and controls (Ctl1=primary, Ctl2=secondary)

	Micro	Ctl1	Ctl2	p-value
CCS Before				
Total community	44.4	45.5	N/A	0.31
Learning	23.1	23.2	N/A	0.90
Connectedness	21.3	22.3	N/A	0.13
CCS After				
Total community	50.6	47.0	46.8	<0.001
Learning	27.2	24.5	24.2	<0.001
Connectedness	23.4	22.5	22.6	0.31

post-hoc analysis). Calculating the two different sub-scales of the CCS suggests that the difference in overall score can be explained primarily by the increase in students' sense of Learning Community in the micro-classes section.

When we examined CCS scores by gender, we found that the difference between micro-classes and control CCS scores for women were very small and non-significant. Most of the differences in Table 1 are due to men's scores.

Student evaluation data complements the CCS data. We found that students in the micro-classes section were generally more satisfied with the class than those in the control sections (see Table 2). Response rates were high in all three sections (micro: 81%, primary: 85%, secondary: 83%). Based on ANOVA with a Tukey post-hoc analysis, we found that student responses in the micro-classes section were higher than both controls for eight of the 16 questions and higher than at least one of the controls for all but two questions. This pattern leads us to believe that at least some of the positivity in the micro-classes section is due to the micro-classes format. Furthermore it seems that students are simply more positive about the class as a whole in the micro-classes section, since several of the questions have seemingly nothing to do with the micro-classes format.

Finally, students' overall satisfaction for the course and the instructor was higher for the micro-classes section than the primary control (Table 3), but similar to overall satisfaction in the secondary control.

4.2 RQ2 — Course Outcomes

We compared several measures of course performance between the micro-classes and the primary control, but were unable to use the secondary control because of the difference in specific assessments and grading. On each measure we found that there was no significant difference in performance (see Table 4). Similarly, there was no difference in the drop rates (micro = 6.8%, control = 8.0%, $p = 0.68$) or the DWF rates (micro = 16.5%, control = 16.7%, $p = 0.96$).

We further analyzed the data looking for differences by gender, CS major status, and cumulative GPA prior to the course and we again found no significant patterns of performance differences. We found two significant differences between the sections at the $p < 0.05$ level (CS-majors in the control section had a slightly higher assignment average, and non-majors in the micro-classes section had a higher final exam average). However, we hesitate to draw conclusions from these results because we performed nearly 100 tests and at the 95% confidence level we would expect about five of these to have a p value less than 0.05 simply by chance.

Table 2: Mean responses on student evaluations by section. Students rate each question on a 1 (strongly disagree)–5 (strongly agree) scale. Asterisks next to control means indicate that the micro-classes mean was significantly higher at the $p < 0.05$ level (*) or $p < 0.01$ level ().**

Question	Micro	Ctl1	Ctl2
Q1: Instructor displays a proficient command of the material.	4.65	4.31**	4.38**
Q2: Instructor is well prepared for classes.	4.7	4.43**	4.43**
Q3: Instructor's speech is clear and audible.	4.7	4.48*	4.47**
Q4: Instructor explains the course material well.	4.6	4.29**	4.31**
Q5: Lectures hold your attention.	4.32	4.11	4.09
Q6: Instructor's lecture style facilitates note-taking.	4.12	3.87	3.9
Q7: Instructor shows concern for students' learning.	4.59	4.32**	4.39*
Q8: Instructor promotes appropriate questions/discussion.	4.59	4.34**	4.43
Q9: Instructor is accessible outside of class.	4.48	4.11**	4.23*
Q10: Instructor starts and finishes class on time.	4.67	4.35**	4.43**
Q11: Instructor is effective in promoting academic integrity.	4.59	4.37*	4.42
Q12: The course material is intellectually stimulating.	4.53	4.3*	4.34*
Q13: Assignments promote learning.	4.54	4.3*	4.41
Q14: Required reading is useful.	4.02	3.62**	3.86
Q15: This course is difficult relative to others.	4.23	3.98*	4.03
Q16: Exams are representative of the course material.	4.28	4.13	4.01*
Q17: I learned a great deal from this course.	4.46	4.21*	4.31

5. DISCUSSION

5.1 Community

The course chosen for both the control and the micro-classes sections is a gateway course between the lower division and upper division CS classes at our university. Most of the students in the course have already taken several CS courses at the university and entered their class with learning groups and support networks already in place. During the debriefing interviews, students in both the control and the micro-classes section mentioned the contributions from these previously existing groups to their sense of community. However, the interviews also brought to light differences between the sense of community experienced within the TA-led discussions themselves. For example, a student in the control section praised the TA's clear exposition of the material while describing the experience as like a movie theater, where there is interaction between the TA and the student but not among the students. On the other hand, multiple students in the

Table 3: Percent by section who answer “Yes” to each statement. Asterisks next to control means indicate that the micro-classes mean was significantly higher at the $p < 0.05$ level (*) or $p < 0.01$ level ().**

Question	Micro	Ctl1	Ctl2
Do you recommend this course overall? (Yes/No)	97%	92%*	96%
Do you recommend this professor overall? (Yes/No)	97%	87%**	95%

Table 4: Mean performance of the primary control and micro-classes section on graded assessments.

	Micro	Ctl1	p-value
Programming Assignments	82.3	83.9	0.39
Midterms	77.9	76.7	0.41
Quizzes	86.9	87.9	0.64
Final	81.1	81.0	0.94
Overall	82.5	82.5	0.96

micro-classes sections mentioned how the TAs and tutors in their micro-class knew all the students’ names and that the micro-class as a whole had opportunities to bond. Follow-up work on whether micro-classes are effective on earlier classes may see more pronounced differences in performance and perhaps long-term effects.

We had anticipated a stronger impact on women from the increased community because, as a minority group, they are at a higher risk for social isolation. As such, we were surprised to find the micro-classes had no measurable impact on women as a subgroup. The only impact we observed for women was with regard to the percentage of women in the micro-class section. We have weak evidence that this difference might be due to student self-selection. Of the students in our sample who switched sections after the first day of class, 13 men and 2 women switched out of the micro-classes section, while 1 man and 1 woman switched in. Although this difference is not statistically significant, it appears that more women (or fewer men) were interested in participating in the micro-classes, perhaps out of desire for an improved sense of community.

5.2 Active Learning Baseline

Similar to findings in CS1 [3], despite the increase in community, student performance did not improve. One key factor in the results was the high-quality of the control section. The course instructor has received multiple teaching awards and receives consistently high evaluations for the course. In addition, the instructor has already adopted pedagogical practices for which there is evidence of positive impact on student performance [12, 18]. Moreover, there was no discernible difference in participation, as measured by in-class and discussion attendance as well as pre-class reading quiz performance, between the control and the micro-classes sections. So although students in the control section did not feel as strong a sense of community, they were sufficiently motivated (either by earning credit or by valuing the activities) to participate at the same levels as the micro-classes.

Recent work by Freeman et al. [6] calls for more education research on what they call “second generation” studies. Their

argument is that, given the extensive body of research demonstrating active learning to be more effective than traditional lecture, the community needs to raise the bar of success of new pedagogical practices by comparing against existing active learning classrooms, rather than traditional lecture classrooms. This study is one of these “second-generation” studies and its setup should temper expectations.

We also suspect enrollment pressure may affect DWF rates. Our CS classes are heavily enrolled with long wait lists. We suspect that the high demand for seats in these classes may cause students to be reluctant to drop classes for fear of not being able to enroll in subsequent terms. Once in the course, we suspect the active learning practices in both sections contributed to the lack of difference in the DWF rate.

The key finding of improved community in the micro-classes section is particularly interesting given the baseline course. Students commonly work together in small groups in a Peer Instruction course and value this active role [17]. The increase in community from the micro-classes then stemmed predominately from improved interactions with course staff and the smaller discussion sections. Future work may seek to disambiguate which of these factors was most significant.

5.3 Professional Development

One facet not yet addressed is the impact on TAs and tutor professional development. In interviews, TAs and tutors in the micro-classes reported valuing the content training where they developed new discussion section activities. They felt they gained confidence in the material and particularly valued opportunities when they played the role of TA with tutors acting as students. They also reported benefits from the community and small-classroom teacher training (but suggested that it could be reformatted into a long single session of best practices). In light of these observations, the micro-classes design may have benefits to the the course staff as well as for subsequent students of these better-trained staff, the effect of which remain unmeasured by this analysis.

5.4 Resource Costs versus Benefits

The micro-classes section was much more resource intensive, requiring a larger TA and tutor pool and a full term’s worth of training and professional development. The number of TAs and tutor for the micro-classes was roughly three times the number of TAs and tutors in the control. The TA and tutor training in the prior term required funding for the TAs and Tutors. This additional expense would be difficult to sustain given current campus funding and limited instructor resources to lead the training.

While we were pleased with the benefits to community from the micro-classes experiment, we recognize these benefits came at significant expense. As such, we recommend future work in this area focus on more lightweight interventions aimed at achieving similar gains to class community.

5.5 Threats to Validity

As discussed in Section 3, there were a number of careful controls in place to mitigate threats to validity. In particular, the micro-classes and primary control had the same in-class and discussion activities and content; all sections were taught by the same instructor who had taught the course many times prior; and we included a second control section to account for the effect that the 8am time slot might have had on our

primary control. However, as with any educational study, there remain threats to validity/replication:

Student Course Selection: As mentioned in Section 5.1, there was movement of students, predominantly males, between sections after learning about the class structure. In addition, students may have added (or dropped) with this class structure in mind. As a result, students may have selected into a section based on desire (or lack of desire) for community-oriented activities.

Instructor Background: The study was performed on a class taught by an instructor who is both active in education research and in research on community-building for diverse student groups. Replication by instructors with less experience would be valuable.

TA and Tutor Resources: There were significantly more TAs and tutors in the micro-classes section than in the control section. The effect of the higher instructional staff to student ratio may have contributed to the effect on sense of community. However, it was the micro-class structure which provided the framework for increased interaction between students and instructional staff.

6. CONCLUSION

This work explored the value of breaking a large active-learning classroom into micro-classes. Comparing the micro-classes section against a control section taught in the same term, we found no evidence that students performed better academically in the micro-class section. However, there was strong evidence that students in the micro-classes felt an increased sense of learning community. Students in the micro-classes section also reported higher overall satisfaction on student course evaluations. These are positive findings, particularly given that the control sections already included evidence-based instructional practices. These findings encourage further inquiry into creating community within large classrooms by subdividing the class into micro-classes.

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