AC 2007-1216: EMPHASIZING TEAMWORK AND COMMUNICATION SKILLS IN INTRODUCTORY CALCULUS COURSES

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Emphasizing Teamwork and Communication Skills in Introductory Calculus Courses

Abstract

It is widely recognized that teamwork and communication skills are important outcomes in undergraduate engineering curricula. At our institution, the program goals in the mathematics department, which apply to our pre-engineering majors, also reflect the necessity of these skills. Student course exit surveys analyzed by the department indicated that communication skills, both written and oral, were not integrated into the introductory courses. In an effort to achieve our program goals, we have implemented team-based as well as individual activities that foster communication skills in our introductory calculus courses. In addition, these activities encourage the students to become active learners and to assume greater responsibility for their learning of mathematics.

We have created both in-class and out-of-class activities to encourage the development of mathematical speaking and writing. Examples of team activities include group problem solving and assessment, assigning groups by related content so that determining the members of the group is itself a team activity, and team take-home exams with oral presentations. These activities promote students' ability to contribute meaningfully to the functionality of a team. Further, team-based activities serve to deepen mathematical understanding. Individual activities such as differentiation/integration *bees*, one-minute papers, journals and essays are also utilized in class. The journal and essay topics cultivate student understanding of major content concepts and alert the instructors when student understanding is lacking.

In this paper, we describe in detail the team-based and individual activities used. We will discuss class time-management, student attitudes, motivation challenges, and initial observations of student responses to these activities. We will also include preliminary assessment and reporting of the improvement in students' mathematical communication skills and teamwork. Finally, we will outline our plans for further investigation of questions raised as a result of teaching with innovative activities designed to encourage teamwork and communication skills while allowing students to take a more active role in the learning of calculus.

Introduction

Teamwork and communication skills are recognized as important outcomes in undergraduate engineering curricula. Accordingly, Criterion 3 of the ABET guidelines states that a student must have an "ability to apply knowledge of mathematics," an "ability to function on multi-disciplinary teams," and an "ability to communicate effectively."[1] In addition, the Committee on the Undergraduate Program in Mathematics (CUPM) of the Mathematical Association of America 2004 Curriculum Guide calls for an ability to "read and communicate mathematics with clarity," "write and speak mathematically," "contribute effectively to group efforts," and "communicate mathematics clearly in ways appropriate to career goals."[2]

At our institution, Georgia College & State University (GCSU), we have about 90 mathematics majors. Roughly half of our math majors are pre-engineering majors. While we do not have a formal engineering major, we offer a transfer program in conjunction with the Georgia Institute of Technology. Calculus courses at GCSU are four credit hours, and a semester consists of fifteen weeks. Four credit hour courses meet for a total of 225 minutes per week. This time can be divided into three or four class periods depending on length. There are no formal recitation classes, and the instructor leads all class periods.

Recently, our department participated in the NSF supported Mathematical Association of America project: Supporting Assessment in Undergraduate Mathematics (SAUM). A team from our department participated in workshops over a two-year period. As a result of participation in this project, the department wrote new outcomes tied to the above guidelines and new assessment instruments to measure these outcomes. The newly developed student course exit surveys and faculty course emphasis surveys analyzed by the department indicated that communication skills, both written and oral, are not integrated into the introductory calculus courses.

Communication skills are a key component of functioning effectively in a team environment. Research also supports that collaborative mathematics activities are beneficial to student learning.[3,4] Cooperative learning helps students understand concepts as well as learn how to function on a team. As a way of addressing the needs of the department, the desired outcomes of the professions and the above learning styles supported by research, the authors have designed and implemented activities so that students may accomplish three goals: the mastery of the calculus content, the ability to communicate that content, and the ability to contribute meaningfully as a member of a successful team.

Since many of our activities involve the students working in small teams, we will first discuss how we assign teams using activities with related mathematical content from the course. We then will describe and give examples of some of the in-class as well as out-of-class team activities that we use. Besides promoting teamwork, these activities encourage mathematical speaking. These activities include find-the-error problems, calculus bees, and team take-home oral exams. We will also describe individual writing activities that help strengthen the student's communication skills, which will, in turn, help the student become a better contributing member of a team. These writing activities include one-minute essays, essays, and journals. As we discuss both the team and individual activities, we will describe our experiences using them and our observations of student reactions. Finally, we will conclude with our plans for a study in which we will further investigate questions raised as a result of teaching with innovative activities designed to promote teamwork and communication skills in introductory calculus classes.

Identifying Team Members

We use in-class cooperative learning activities in which students work in teams to solve fundamental problems in calculus. When we first experimented with group work, we resorted to the "get with a neighbor" method where students are allowed to form their own groups. This approach can lead to the same set of friends working together every time. In addition, there was no grade motivation for the students to do the assigned problems because the students were not required to turn in any of the solutions. In an attempt to make group work in class more productive, we opted to select the student teams ourselves, and the students would receive a class participation grade based primarily on attendance and their contribution to the in-class team activities and work. Teams were selected using a mathematical exercise that required the students to apply the current topic being taught. This method of team selection allows students to take an even more active approach in the learning process. Teams typically consist of two, three, or four members, and team composition is usually changed every two or three weeks. Below we describe some of the team-forming activities that we have created and implemented in our calculus courses.

- **Limit Definition of Derivative:** After introducing the limit definition of the derivative of a function, each student drew a card which contained either a function along with a point, a limit that represented the definition of the derivative of a function at a point, or the limit that represented the equivalent form of the definition of the derivative at a point. Each student's task was to find the other two students in the classroom who had the cards related to his or her card, and these three students formed a team. In the event that the number of students present was not a multiple of three, we removed the appropriate number and type of cards so that some teams of two students could be formed. Once the students had found their group members, each team evaluated the limits on their cards to find the derivative of the function at the specified point. After evaluating the limit, each team wrote their function and an equation involving their derivative as well as the corresponding derivation on the board, and then the class as a whole discussed these examples. Not only did this team-forming activity reinforce the definition of the derivative and evaluation of limits, but it also allowed for the students to discover some of the differentiation rules since we had selected functions accordingly.
- **Antiderivatives:** We introduced the concept of antiderivatives by using a team-forming activity. In this activity, each student in the class drew a slip of transparency paper which contained a different function. The task of each student, as quietly as possible, was to find the person whose function was either the derivative of the student's function or the student's function was the derivative of the other person's function. In our instructions, we were careful not to use the term antiderivative. After the students were paired, we introduced the term antiderivative and the indefinite integral. After this initial discussion, we continued with the team-forming activity by having each of the student pairs demonstrate the relationship between their two functions on the overhead projector; that is, they formed a differentiation statement and then a corresponding integration statement relating their two functions.
- **Volumes of Solids of Revolution:** As a follow-up to the initial lecture on volumes of solids of revolution, we have created a team-forming activity that allows students to implement calculus techniques on calculating volumes of solids. We designed this activity for students to work in teams of three (and if necessary, some teams of two). Each student drew a slip of paper that contained one of the following attributes:
  - a region that is to be revolved about an axis (such as $y = x^2, x = 1, y = 0$; about x-axis or $y = \frac{1}{x}, x = 1, x = 2, y = 0$; about x-axis)

- an integral that represents a volume of the solid formed by revolving the region about the axis (for example, $\pi \int_0^1 x^4\, dx$ or $\pi \int_1^2 \frac{1}{x^2}\, dx$)
- the numerical value of a volume (for example, $\frac{\pi}{5}$ or $\frac{\pi}{2}$)

The task of each student was to find the other two students in the class who had drawn the related pieces. If the number of students present was not divisible by three, then some groups of two were used by removing an appropriate number and type of the related pieces from the initial set of cards. For this activity, we allowed the class a few minutes to discuss a strategy for finding their group members as quickly as possible. In one class of 18 students the class took 6 minutes for the teams to be formed, but in another class of 18 students the class took 16 minutes. Once the teams were formed, each team worked on an assignment which allowed the students to discuss and apply problem solving techniques to calculating the volumes of solids of revolution.

Our calculus students have responded favorably to these team-forming activities and have worked well in their groups. The class participation grade, which accounted for 5% of the total grade, motivated the students to participate in the group activities. For the team-forming activities, each participating member received a *plus* toward the class participation grade. In addition, each team turned in one set of solutions for the corresponding collaborative learning assignment. For each correct solution, each team member received an additional *plus*. The *plusses* acted as extra credit towards the class participation grade. Even though the *plusses* did not add very much to the overall grade, the students were motivated to work for the *plusses*; that is, for a little extra credit.

Typically, we allow an entire class period for these activities including both the activity of forming the teams and the follow-up collaborative activity. Because these activities require an entire class period, we usually incorporate an activity every one to two weeks. For classroom time-management, the instructor can shorten the length of the lecture by not working as many examples. This approach has allowed our students to take an active role in solving calculus problems rather than a passive role of observing the instructor work multiple examples. Not only have team-forming activities encouraged mathematical communication and teamwork among the students, but we have used these activities to create an active learning environment. The activities can help introduce new calculus topics, reinforce calculus skills, encourage problem solving, and promote the discovery of new calculus concepts.

Team Activities

As described above, team composition can be determined by using a mathematical exercise; however, sometimes we assign teams with a less time-consuming method (such as counting off or drawing playing cards). In this section, we describe some of the collaborative learning activity assignments.

Find the Error: One skill that is critical for engineering and mathematics majors to master is the ability to evaluate the correctness of solutions. Throughout the semester, we assess this skill by presenting the students with a "solution" written by fictitious calculus students. Students evaluate the “solution,” and if the solution is not correct (which is usually the case), they are to state the error and provide a correct solution. For example, we used the following problem:

- Jim encounters the following problem on his Calculus II test:
  Does $\int_1^{\infty} \left(-\frac{1}{x}\right) dx$ *converge or diverge?*
  His solution is given below. Assign a grade of A (correct), C (partially correct), or F (failure) to his solution. For assignments of grades other than A, explain what Jim did wrong and provide a correct solution.
  Jim's solution: Consider $f(x) = \frac{1}{x^2}$ and $g(x) = -\frac{1}{x}$. For all $x \geq 1$, $f(x) \geq g(x)$ since $f(x)$ is positive and $g(x)$ is negative when $x \geq 1$. We showed in class that $\int_1^{\infty} \frac{1}{x^2}\, dx = \frac{1}{2}$; hence, $\int_1^{\infty} f(x)\, dx$ converges. Now since $f(x) \geq g(x)$ and since $\int_1^{\infty} f(x)\, dx$ converges, by the Comparison Theorem for Improper Integrals, we can conclude that $\int_1^{\infty} \left(-\frac{1}{x}\right) dx$ also converges.

In this example, observe that two errors have been included: a computational error as well as a conceptual error. In the first class that we used this problem, the majority of the teams detected the smaller computational error, corrected this error, and stated that the solution was now correct. Since the teams were not detecting the conceptual error, we suggested that there was something else wrong with the solution, and then three of the five groups did detect the conceptual error. For the second class, we modified the problem by removing the computational error. Without having to prompt the groups that there was an error, four of the six groups detected the conceptual error. Another possible modification is to include both errors but ask the students to find *all* the errors.

In addition to including find-the-error problems on team collaborative assignments, we have used these problems as class examples to introduce new calculus concepts. When used in this manner, the students work together as an entire class. For example, we assigned the following modified problem[5] to introduce logarithmic differentiation.

- On a calculus test, students are asked to find the derivative of $f(x) = x^x$. Below are two student solutions. Assign a grade of **A** (correct), **C** (partially correct), or **F** (failure) to the solutions. **Justify** assignments of grades other than A and tell what the student is thinking.

  1. Jim says that the derivative of $f(x) = x^x$ is given by $f'(x) = x(x^{x-1})$.
  2. Janet says that the derivative of $f(x) = x^x$ is given by $f'(x) = (\ln x)x^x$.

Usually we poll the students on what grade they would assign to each solution, and then we ask for volunteers to explain their reasoning. Through the classroom discussion, this particular problem provides an avenue to emphasize the difference between a power function and an exponential function and to discuss why the corresponding differentiation rules do not apply. It also allows the students to see that a new differentiation technique is needed to handle this type of problem. Engaging the students in this manner promotes their oral communication and understanding of mathematics.

We have also used find-the-error problems to emphasize that the hypotheses of a given theorem must be satisfied in order to use that theorem. For example, the following problem can be used to promote classroom discussion after introducing the limit laws.

- Some first-year calculus students claim that they have a proof that zero equals one. Their argument follows below. Do you believe the students (in other words do you accept that zero equals one)? If you doubt the students' claim, there must be an error in their reasoning. Find the error.

  The students claim that by looking at the graph of $y = \tan x \cot x$ it is easily observed that

  $$1 = \lim_{x \to 0} \tan x \cot x$$

  and using limit laws and properties of the real number 0 we have:

  $$\begin{aligned} \lim_{x \to 0} \tan x \cot x &= \lim_{x \to 0} \tan x \lim_{x \to 0} \cot x \\ &= 0 \cdot \lim_{x \to 0} \cot x \\ &= 0 \end{aligned}$$

  Therefore, $1 = 0$. What is wrong with the students' argument?

This particular problem seems to intrigue the students because at first they do not see anything wrong with the argument, but they also *know* that 1 cannot equal 0. In fact, as the students discussed this problem, they focused on the graphical interpretation as being what was wrong rather than the improper use of the limit product law.

The find-the-error problems are effective at promoting debate among the students, whether they are discussing it as an entire class or in smaller groups. We have discovered that it can take the students a long time (10 to 15 minutes) to find the error, but these problems are valuable since the students must apply their mathematical knowledge and reasoning to determine if a given solution is correct. In addition, these problems promote mathematical communication among the students.

Calculus Bees: Some other activities that we have implemented in our calculus classes are differentiation bees and integration bees which are similar to a spelling bee except the students are differentiating or integrating functions within a time limit. These bees get the students involved in working problems, and they emulate a testing environment since the students are timed. We have based our rules for the classroom bees on the more formal version described by Rubin.[6] The general format that we use in running the bees is:

- Team composition is usually three to four members.
- Participants are **not** allowed to use any books, notes, calculators, etc.

- Participants are given a blank sheet of paper so that they can take notes during the bee.
- To determine the order that the teams will proceed, each team draws a card with a number on it, and the teams line up accordingly.
- On a team's turn, the team comes to the board and has 1 minute and 30 seconds to collaboratively differentiate (integrate) the given function. The team is required to box-in or circle the final answer.
  - If the team's answer is correct, then the team survives the round and play passes to the next team.
  - If the team's answer is incorrect, then the team is "out" of the bee, and the next team comes to the board and has half the time to work the missed problem.
    - If the next team's answer is correct, then that team stays in the game, and play passes to another team.
    - If the next team's answer is incorrect, then that team is out, and we go over the problem that was missed on two attempts. The next team in line gets a new problem to differentiate (integrate) in the allotted time.
- If only two teams are remaining after a round, then both teams get the same problem and have the same amount of time to work the problem.

  Note: For more involved problems, the initial amount of time may be increased; for example, 2 minutes for a first attempt, and 1 minute for a second attempt.

We utilize the entire class period for a calculus bee. We usually conduct about two bees during a semester course, and frequently we use these bees as a review before a test. Occasionally, we use the calculus bee as an individual activity in which case, play is more like a traditional spelling bee. Not only do the bees get the students engaged in working mathematics problems, but we also use missed problems or mistakes as a teaching opportunity. If the problem is missed on the second attempt, then the problem is discussed. In addition, since the student's or team's work is on the board, even if the final answer is correct, we can use this opportunity to discuss with the class whether or not proper notation was utilized as well as logical reasoning applied. The students' reactions to the bees have been highly positive. We do not force the students to participate in a calculus bee. Students have the option of earning class participation *plusses*. As a result, all of our students have opted to participate. On student opinion surveys of the instructors' teaching, students have written: the integration bee was the best test preparation; it would be good to do a similar thing for other material; have more bees (for example, integral bee, differentiation bee, etc.); the differentiation bee was fun.

Team Take-Home Oral Exams: Not all team activities that we use take place in the classroom. In this section we describe team take-home oral exams which take place almost entirely outside the classroom. We were in the practice of incorporating many team activities in our calculus classes, when a student asked if we would give group exams. As a result, we began to research the idea of team exams. The next semester, we modified Annalisa Crannell's Collaborative Oral Take-Home Exam (COTHE) model[7] for our calculus classes.

The team take-home oral exams that we designed had four problems, and the students were divided into groups of four. The problems were distributed along with the grading rubric, and the students were given approximately a week and half to work the problems. The teams were responsible for signing up for a presentation time and showing up in the instructor's office at the agreed upon time to present their solutions. When the team arrived for their exam, we selected the exam problem as well as the student who would present the team's solution. Each student presented at least one problem. Their work was evaluated as it was being presented, and questions were asked of both the presenter and the rest of the team. Every member of the team earned the same grade. In total, each team's presentation and questioning took approximately 45 minutes. There were two exams of this type during the semester.

Initially, the students were excited about the idea of working together but somewhat anxious about presenting the solutions in the office. After the first exam, they knew the expectations; hence, their nervousness lessened. The students expressed concern throughout the semester about the final exam since they knew it would be an in-class, individual effort. These sentiments were expressed in the written comments at the end of the course (given before the final exam), as well as on feedback surveys which were administered after each team oral exam. There were some complaints about working in teams, mostly arising from students who felt they were "doing all the work." In one case, we did assign different grades to members of the same team due to an obvious deficit in the level of preparedness of some of the students.

As a result of talking with the students, reading their feedback and evaluating their oral exams, we believe these students had a deeper understanding of some calculus concepts. Their final exam was the same as one given in previous sections of calculus where team exams were not given. Their average performance on the final was similar to the other sections. The final exam, however, measured different skills from the team take-home oral exams. Given our impressions about the students who participated in the team exams, we would like to find or develop an instrument that would measure change in the depth of a student's understanding of calculus.

During the semesters that we use team exams, we still do a lot of group activities in class. We find that the students who participate in the team exams are better team players in class. Students also needed less encouragement to tackle more difficult tasks. The class seemed more bonded than classes where team exams were not used. The students had to deal with arranging times to meet each other outside of class. Since the students did not know who would present what question in the team take-home oral exam and since every member of the team earned the same grade, each team member was responsible not only as an individual contributing member but also for everyone else on the team.

Time management is a double-edged sword with this activity. On the one hand, class time normally reserved for tests is freed up. On the other hand, out of class time spent with the students is greatly increased. For example, during the semester in which there were 11 teams and two exams of this type administered, the instructor spent approximately one hour per team per exam for a total of 22 hours outside of class.

Since team take-home oral exams require a lot of out-of-class time with the students, we do not use this type of activity every semester. We have tried giving two team take-home oral exams in two different classes during one semester. A combination of team take-home oral exams and in-class exams might be better for the sanity of the professor and the students. The students feel more at ease taking a traditional final when they have had at least one other traditional exam, and the instructor still gets at least one in-depth assessment of each student. In short, the team take-home oral exams not only promote students' proficiency in oral communication of mathematics but can also provide the instructor with an assessment of the students' depth of understanding of calculus concepts.

Writing Activities

Effective communication and effective teamwork are inextricably linked. The above activities are designed to expose the students to the challenges of working in a group. Specifically, one of the challenges of working in a team environment is communication. Individual writing activities help strengthen the communication skills needed in the team environment, and likewise the team environment can enhance the students' communication skills. When a student is forced to write mathematical thoughts, the instructor has an opportunity to help the student clarify concepts.[8] Using writing in a mathematics class may seem contrary to the discipline; however, the opposite is true. Good mathematical writing is essential to understanding. To that end, the individual activities described below are designed to strengthen the students' written communication skills.

We outline three types of writing assignments below. The one-minute essays are short and take about five minutes of class time. The essays are more time-consuming and can be used both in class and as homework assignments. The journals are mostly an out-of-class activity.

One-Minute Essays: We used one-minute essays to assess the students' understanding of a topic without penalizing the student for a deficiency; that is, students did not receive a grade on these one-minute essays. Topics for the one-minute essays have included:

- Write down one key fact from today's lecture.
- Explain one key concept from today's lecture.
- What unanswered questions do you have from today's lecture?
- How did you participate in today's class meeting?
- Since the last class meeting, how much time did you spend preparing for today's class meeting?
- How did you prepare for this class meeting?

The one-minute essays are an effective way to introduce writing into the class since the students do not seem to mind writing a few sentences. The responses on the one-minute essays generally provide useful information on just how much the class understands a topic immediately after it has been introduced. For example, after doing a lesson on the squeeze theorem, the assigned one-minute essay question was to state in their own words the squeeze theorem. We noticed that several of the students did not have a solid grasp of the theorem's hypothesis and conclusion;

therefore, the next time the class met, we pointed out the differences and covered more examples. Thus, we were able to clear up students' misunderstandings.

Essays: Sometimes the one-minute essay responses indicated that more narrowly focused questions were needed to achieve a more in-depth response. Sometimes it is desirable to assess the students' depth of understanding without informing them ahead of time and without penalizing the student for a lack of understanding; that is, students would not be graded formally on the assignment. An in-class essay is one way of more deeply assessing both students' knowledge and their ability to communicate that knowledge. An example of an in-class essay assignment follows below:

- Write an essay on the calculus concepts of continuity and differentiability. Remember to use complete sentences. You might have a paragraph that discusses continuity such as definitions, conditions for a function to be continuous, types of discontinuities, left and right continuity, continuity on an interval, etc. You could have another paragraph that discusses differentiability such as the definition of derivative, the equivalent form of the derivative, where a function fails to be differentiable, interpretations of the derivative, etc. You could have a final paragraph that discusses the relationship between continuity and differentiability. In your explanations, you may want to give some examples. You have approximately 20 minutes to work on this assignment. (Write clearly and neatly, and remember to use correct English grammar.)

Despite the fact that students do not anticipate having to write an *essay* in *math* class, we have generally been impressed by the efforts they put into their essays. Often students work on the essay the full 20 minutes as well as 5 extra minutes after class ends. In the specific sample assignment above, we learned that the students knew more than we thought, although this is not always the case. Many of the students who performed poorly on quizzes surprised us with decent essays. One common misunderstanding revealed by the essay responses (to the above assignment) was that the students seemed to think there were *only* three types of discontinuities: removable, jump, and infinite. Perhaps this misunderstanding arose because only three kinds of discontinuities were explicitly defined in class, and so the students concluded that these were the *only* types of discontinuities. Feedback similar to the above can alert instructors to the need for additional coverage of certain concepts. In this particular example, we followed-up with additional lecture notes; however, an alternative approach would be to design a group activity that highlights other types of discontinuities.

Motivating students to write an essay during calculus class which will not be graded presents a challenge. One strategy that has been successful is to make the assignment part of the class participation grade. Students generally see this as an easy way to improve their grade. As mentioned earlier, we usually make class participation a small, but not insignificant part of the overall grade.

Journals: One disadvantage of essay writing is that it can consume a considerable amount of class time. To address this issue, one possible modification is to assign the essay as homework and count it towards the homework grade (or participation grade). To that end, we have designed an out-of-class writing activity, the journal, that incorporates elements of both of the above activities.

The journal assignment grew out of a similar assignment that we piloted in an Abstract Algebra class, as well as our desire to continue the lengthier writing assignments without taking up as much class time. We had the students keep an Abstract Algebra Journal as part of their class participation grade. The journal served two primary purposes: (1) a venue for the students to reflect on the material that was covered in each class meeting and (2) a venue for the students to document their participation in each class meeting. After each class meeting the students would write a journal entry that addressed the following:

- How did you prepare for today's class meeting, and how much time did you spend doing so?
- What do you feel was the main point in today's lecture?
- Briefly summarize the major concepts of today's lecture.
- What unanswered questions do you have from today's lesson and/or what concepts are you having difficulty understanding?
- How did you participate in today's class meeting?

While we did glean some valuable information from the students through their journals, this particular assignment was problematic for several reasons. Because the questions did not change, the students had a tendency to repeat short, uninspired answers from day to day. In addition, even though the students were writing after every class, journals were only collected every few weeks. Due to the volume of journals and the infrequency of collection, it was often too late to address problems or questions that arose in the students' writings.

During the current semester (Spring 2007), we are implementing a journal activity for Calculus I. The students will be turning in a journal assignment about once a week. There will be two basic types of journal assignments. One will be used to assess a student's understanding of calculus concepts. A sample assignment of this type might be: explain why two functions that have the same derivative may or may not be the same function. The other type of journal assignment is a self-assessment for the students. At the beginning of the semester the students completed the following journal assignment:

- Write an **essay** on how you plan to have a successful semester in calculus class. Include your strategies for learning the material in this course as well as what you expect to gain by taking this course.

At mid-semester and again at semester's end, the students will be re-evaluating their answers based on their performance.

Conclusion

As stated in the curriculum guidelines of both ABET and the CUPM, engineering and mathematics students must have mathematical knowledge, the ability to work effectively in groups, and the ability to communicate effectively. These skills are necessary for the students to be successful in the workplace. In an effort to meet these challenges, we have described in this paper the integration of communication and teamwork into our introductory calculus courses by using team-forming activities, find-the-error problems, calculus bees, collaborative team take-home oral exams, essays, and journals. These activities are designed to develop a student's proficiency with mathematical content, communication, and teamwork. We plan to continue to modify existing activities and create new ones to further encourage a student's development of these essential skills.

In the future, we would like to implement some team-based writing activities in calculus. We have experimented in other classes with team and whole-class writing activities, but we have not yet designed an activity for calculus. Such an activity would be geared toward meeting both the teamwork and written communication outcomes. The activity would be similar to a "regular" group work activity, but the main form of communication between the group members would be writing as opposed to speaking.

We have received feedback and some evidence that the students have found the team and writing activities helpful in learning calculus content. A small sample of student surveys and exam scores has indicated that the mastery of concepts is enhanced when teamwork and communication activities are used. As a result of this preliminary feedback, we are designing a formal study of the effectiveness of emphasizing teamwork and communication in developing students' skills and depth of understanding.

The study that we plan to implement will use a series of assessment instruments including a concept pretest and posttest as well as an attitudinal and experiential survey on group work and communication. We will focus our attention on a few specific concepts and corresponding activities. We hope to show that the use of these innovative teaching activities results in an improvement of a student's content mastery, communication skills, and ability to contribute effectively in a team environment.

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