Using Wikis to Promote Active Inquiry in First Semester Calculus

Louis F. Rossi

Students who major in mathematics, science or engineering love to solve problems, yet many struggle with application problems in their first semester of calculus. While mathematics is the common language for describing problems in science and engineering, it is difficult for most students to translate what they have learned about mathematics into other domains.

The reform efforts of the 90’s emphasized making mathematics more relevant (Ferrini-Mundy & Graham 1991, Wu 1996, Wu 1997) and using technology to free students from the burden of mechanical manipulation so they could explore “real world” problems. Technology can certainly improve the presentation of mathematics. It is less clear that enhanced presentations have improved learning or that students are more motivated when freed from mechanical manipulations.

Louis Rossi is a Professor of Mathematics at the University of Delaware. He received his PhD from the University of Arizona. His interests include vorticity dynamics, vortex methods, smoothed particle hydrodynamics, high performance computation, biologically-inspired algorithms and mathematical modeling. He enjoys teaching modeling, analysis and numerical methods at all levels. He maintains BlobFlow, an open source, high precision, parallel vortex method for viscous flow simulations. Dr. Rossi is Education Section Editor for SIAM Review.


**Background**

Two experienced instructors recently wrote a brief piece highlighting what many instructors already know: active learning requires participation from both individual learners and groups (Hoffman & McGuire 2010). The purpose of my project was to use technology to enable greater participation and learning in first-semester, university-level calculus by providing the experience of discovering mathematics in a variety of unexpected settings. The project employs two distinct strategies:

1. **Collaborative writing** to motivate and inspire students to explore mathematical problems in compelling settings.

2. **Peer assessment** to provide meaningful feedback several times during the semester, continually reinforcing the exploration.

While this two-pronged teaching method is useful for all science and engineering majors, it was developed for a special biology (bio) section of our calculus course in response to an initiative on campus to make our life sciences programs more quantitative (Usher 2010). The activity was designed for large lectures of one hundred or more students and makes use of the Sakai wiki tool.

There is considerable qualitative evidence of the benefits of wikis and blogs in promoting active learning in different settings (Minocha 2008, Parker 2007). However, using collaborative writing to learn mathematics requires special consideration:

- The language of mathematics is not properly expressed using ordinary text and
- Students need feedback on their mathematics as well as their writing.

When investing time and energy into instructional technology, it is always necessary to consider the trade-offs. The basic scientific question is whether the benefit is worth the investment. Is instructor time better spent marking homework or setting up interactive web pages? Is it better to devote class time to clicker-based activities or work a few more examples for the students? Can the technology build connections between the students and the instructor? Will it help connect students with course content?

In any course, students learn best when they make a strong connection with the instructor. When the connection is strong we say students are engaged, and engaged students succeed. Concepts, skills, questions and answers flow easily. These connections extend beyond the classroom. Office hours provide another opportunity to reinforce connections. When students complete problems and receive prompt feedback on their work, the connections grow stronger. Exams and other types of student work provide similar opportunities for learning. The effective use of technology can build new connections and enhance existing ones.

Instructors are at a distinct disadvantage when teaching a large lecture course. There is a physical distance between the students and the lecturer that often leads to a cognitive distance. Twenty-five to thirty-five students in a classroom feels like a community, but a hundred or more students in a lecture hall is a crowd. Students do not know one another and are more self-conscious about asking questions. Problem sets are marked by anonymous graduate students. The volume of problem sets means that students might not receive feedback on all their work, and the logistics of collecting and returning problem sets mean that extended periods of time will elapse between handing in problems and having them marked. Often, students do not look at scored homework because the class has moved on to a new topic, although automated homework and quizzes can help address this issue with some success.

Nevertheless, teaching calculus in large lectures is a reality at research intensive universities and, given this reality, there is considerable merit in devising new ways to engage students. Faculty have considerable resources at their disposal for enhancing student connectivity and faculty-student connectivity. A wiki for collaborative writing is one such tool.

**Approach**

The method described in this essay is powered by two hypotheses: that students are motivated by compelling problems of their own choosing, and that they have been exposed to a significant amount of mathematics prior to entering the university. This activity was developed for the bio section of our most rigorous calculus course. This course is taught in large lectures to students majoring in mathematics, engineering and the physical sciences. Beginning in the Fall of 2007, the course was required for all biology majors as part of a broader effort to bring more qualitative methods and techniques into our life sciences curriculum. The bio section covers the same curriculum as all other sections, and all sections take the same common final exam.
The first semester of calculus ought to be exciting for students. After covering differentiation, students are ready to learn about applications, and calculus opens the door to vast fields of problems that could not be addressed in earlier courses. In lecture, our freshmen science and engineering majors lean forward a bit as we present rigorous procedures for determining optimal geometries or pricing strategies or network configurations. The language of calculus explains why Snell's Law is no law at all but a mathematical fact derived from simple assumptions about the natural world.

Spending time with students in office hours is more sobering and grading exams can be quite disappointing. Many of those who were engaged in lecture have difficulty transferring mathematical knowledge from one situation to the next, even if the underlying mathematics is identical. Significantly, portions of the course dedicated to applications do not introduce any new mathematics. Most students have mastered the deep connections between functions and their derivatives. Almost without exception, they can mechanically differentiate just about any function you give them. Most can connect information about first and second derivatives with the shape of a function's graph. The problem is not that students cannot differentiate functions or determine where the derivative is zero. The problem is that students have difficulty quantifying problems, and they need practice.

To begin preparing for the activity, I download interesting images. Since calculus is the mathematics of change, the images should involve a dynamic process. The images need not involve physical motion, a distinction that is especially important to those interested in the life sciences. From the very first day, students learn that calculus is the mathematics of change and change occurs in many ways. Processes such as the corrosion of pipes or the cooling of a cup of tea must be elevated to the same level as the traditional motion of a particle. For the bio section, I use many images from the life sciences as well as more traditional scenes exhibiting change.

I place the images on a wiki page (Figure 1). Students then sign up for an image and form teams of up to three students. Each team creates a wiki page for the project, and the image will be the centerpiece of their activities throughout the semester. It is important to note that students are not choosing to learn some topics and not others. By choosing the image, students are choosing an application area, and most students enjoy this process. However, everyone learns the same topics.

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During the semester I also use class time to draw attention to specific projects where teams are doing interesting work. The wiki environment is ideal, because it provides an open space where students can view the efforts of other teams, get new ideas, and gauge the quality of their work against that of their peers.

The central goal of this project was to facilitate student writing in mathematics. Students who write about mathematics think about mathematics. Students who think about mathematics learn mathematics. In this activity, each team creates a wiki page where students do their own writing. The Sakai wiki tool allows students to set equations properly in LaTeX which is a distinct advantage over writing tools that lack this feature. Using an easily readable and editable format for mathematics helps students write and revise their ideas.
In order to think critically about one another, students must understand that merit is not infinite, so I limit the total number of points that can be allocated among team members. On a three-person team I might allow 40 points to be distributed. This forces students to reflect upon the distinct roles different members play on the team. Most importantly, students must provide a written statement of why they have assigned specific scores. If the narrative is not complete, the assessment is returned for revision.

At each stage, I score the project on its quality. Individual students receive a project score scaled by their peer assessment score. Peer assessments are always confidential, but the project score is known to the entire group, so everyone on the team knows roughly how well their work is regarded.

Every team faces challenges. Often a challenge is technical, but sometimes it is interpersonal. When a team member is unhappy with a score, their first instinct may be to take the problem to me. However, students need to first work out the issue with their teammates. I strive to provide a rubric that can effectively shape student expectations, performance, and (hopefully) learning.

Peer assessment is used to provide valuable feedback at each stage. This makes the workload more manageable for the instructor, especially in a large lecture situation. However, peer assessment does require active instructor participation. In my class, each student on each team submits a confidential peer assessment at each stage. The students assesses every member of the team – including themselves – according to the following four categories:

1. How my teammate (myself) thinks.
   0 (no original ideas) to 10 (has brilliant ideas, takes others’ ideas and makes them better).
2. How my teammate (myself) writes.
   0 (has written nothing) to 10 (has contributed great material, edits others’ work and provides feedback on everything).
3. How my teammate (myself) responds.
   0 (has not interacted) to 5 (comes to every meeting, answers every phone call, responds to each email).
4. How my teammate (myself) leads.
   0 (provides no leadership) to 5 (brings the team together, makes others better, smooths out difficulties).

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Results

When reflecting upon this activity, I looked at outcomes along two dimensions. First, I examined whether students responded positively to the project by monitoring peer evaluations and the overall quality of the work done. Second, I studied whether students learned the material better than they had in the past. I maintain records of student performance on specific exam questions, so I could see if there was any noticeable change.

Students did respond positively to the activity. A small number were somewhat bewildered at the newness of the assignment. Learning to use a wiki and being expected to write about mathematics were new experiences to many, but clear stages combined with regular feedback from me eased the transition. Before lecture, I often showcased interesting student work on the wiki as a way of reinforcing my expectations to the class. Over the course of the semester, I could tell that students were taking pride in their work.

In terms of learning, the wiki project improved my students’ understanding considerably. I have tracked performance on final exams over the course of many semesters. Typically, exam scores are lower than the average course performance in several categories, including the ability to solve word problems involving related rates or optimization. I attribute this to the fact that students first learn to solve specific types of word problems from the text and then struggle to generalize the process. Prior to the wiki projects, only half of my students could solve word problems on the final exam.

The wiki activity directs students to create problems, and so they focus on the general structure of word problems. They need to see how the processes they are studying can be made to fit within this structure. They also monitor what the other groups are trying and borrow successful ideas for their own projects. That is, they transfer mathematics knowledge between application domains. Solving a problem on the final exam becomes just another exercise in transference. On the final exam, 85% of the bio section students could solve related rates and optimization word problems. What is more surprising is that the final was a common exam used across all lectures. The other sections covered material from a more traditional perspective for physical scientists and engineers, and the word problems on the exam were not drawn from the life sciences.

Recommendations

While this collaborative writing activity helped students see mathematics all around them, there was still room for improvement. Technology was the great enabler of this project, but there was still considerable overhead for the instructor in managing peer evaluations.

Learning management systems like Sakai should incorporate peer assessment tools. A successful tool would be flexible enough to allow instructors to place students in groups or allow students to form their own groups. Instructors could configure evaluation forms to allow students to enter scores and comments confidentially. Peer evaluation would be approved by the instructor or returned to the student for further explanation and reflection. Finally, peer assessment needs to be linked to the grade book by mathematically combining peer information and the instructor’s assessment of the work product. This kind of tool would be fairly sophisticated, so it is no wonder that such a thing is not generally available, although some institutions have implemented specialized tools for their own purposes.

This was a successful project that helped students apply mathematics in different settings. The activity used collaborative writing facilitated by a wiki to encourage students to actively use their knowledge in a variety of settings. The development of this project did not come from a particular educational theory, but rather from an observations that many instructors have made over the years: students need to actively practice what they learn, and they need feedback on their work. The availability of a solid wiki platform capable of setting mathematical equations properly made this particular project a reality and, in this case, there was a substantial benefit in terms of student learning.
The LTC began in 1998 as a partnership of institutions with similar instructional goals, strong technology and faculty support programs, and an interest in collaboration around teaching and learning with technology. The members are:

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