FEEDBACK AND ENGAGEMENT: TEACHING CALCULUS WITH TECHNOLOGY

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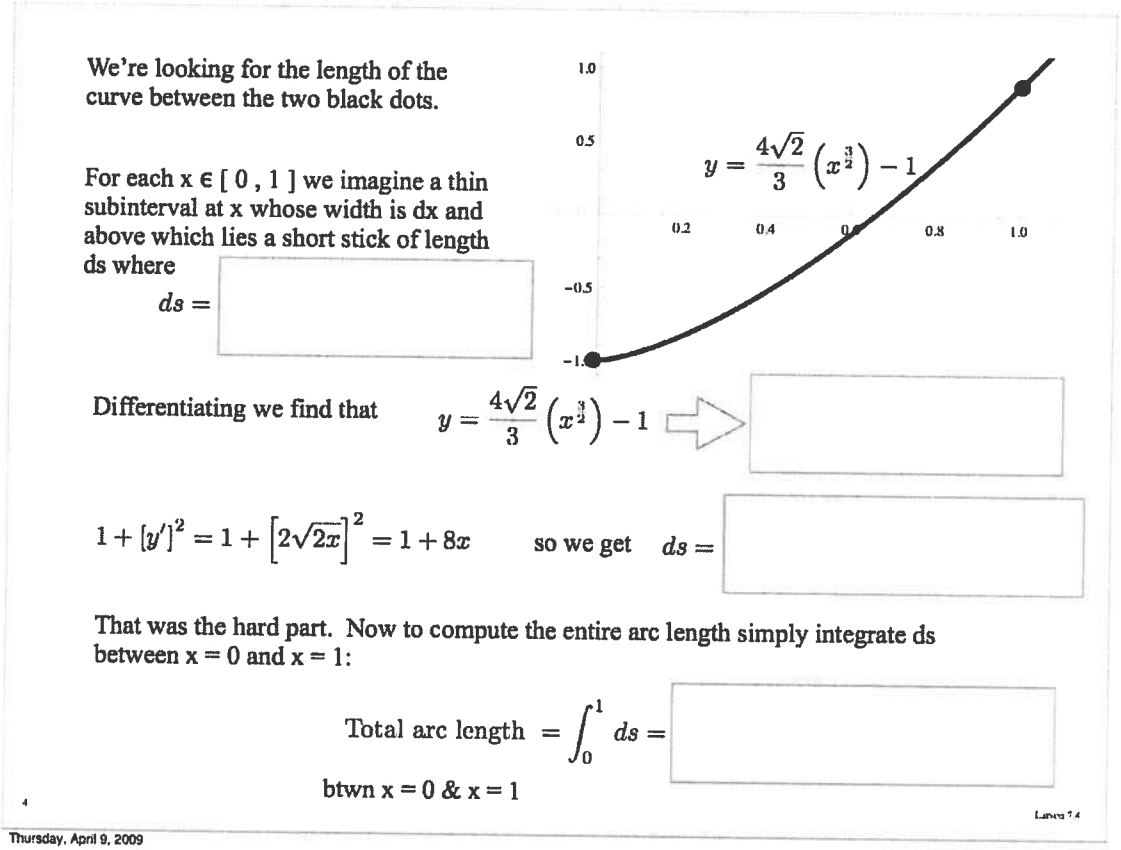
With no pretense towards having solved the problem we have as teachers in engaging our students, this note presents a collection of teaching techniques (rather behaviors) that have evolved during years in the calculus classroom. All that follows is what remains after having followed through on many dead ended investigations. Engaging students is a constant battle, and with new technology arriving yearly, the battlefield is constantly shifting.

The information bandwidth for a mathematics presentation has been advancing with each decade. Chalk talks gave way to overhead transparencies, which have morphed into computer-projected slide shows. At each juncture information density has grown by an order of magnitude, challenging note takers in the audience. Experience tells us that the content of a student's notebook replicates exactly what appears on the board (or slide, or screen), no more no less. The student's task of taking notes is becoming overwhelming in an environment where information flows like a fire hose from the front of the room. There is one possible solution that also provides useful material from which the student can study.

By distributing narrative slides, before the lecture, the class has an opportunity to get a preview of the talk, noting the high points, and enabling them to pay attention to the details during the lecture. The slides interpret the textbook in less formal language and provide an "alternative" picture of the material. Seeing the same thing from two different viewpoints lends the subject stereoscopic "depth". Of course this idea succeeds only when the students invest in "pre-reading" the lecture slides. Reading the slides for the first time in lecture divides students' attention between the aural and visual input, rendering neither one complete. Using a course management system (like Blackboard) to distribute these lecture slide packs helps the student share responsibility for their education by requiring that they print the lecture notes themselves. But it becomes their investment in the process since these notes are far superior to their handwritten "lecture snapshots" when it is time to review for an exam. Departmental resources are saved this way too.

Student attention during lecture falls off with narrative slides, though. Occasionally some graphical "eye candy" can keep their attention, but with the entire presentation laid out before them in a slide pack, there appears to be even less reason to attend lecture.

So magic boxes evolved as an attempt to address the apparent weak points of the narrative slide solution. Here's an example of what a student might bring to the classroom:



Opaque magic boxes obscure important information on their slides, and vanish during the lecture revealing the missing material and allowing students to complete the presentation for later study. This small twist serves to engage any wandering attention as well as discouraging what might have been a skipped class.

Again, pre-reading these slides with magic boxes is the surest way to successful learning. There is little change from a traditional classroom, and, any time for homework problems and/or group work in class feels impossible to find. There were a few experiments with clickers in class. However the lack of a free response capability made them not worth the effort. Composing probing multiple choice questions requires careful thought to build the "distractors", the wrong answers that would be popular. Allowing the students to answer "sin(x)" or "16.4" seems to be far more desirable.

Feedback: Learning anything requires practice followed by feedback on performance. The best learning happens when feedback follows performance immediately. Feedback delayed is feedback devalued. After every performance activity, either homework or

exam, solution sheets are available on the course management system, through a timed release schedule allowing students to print and study this available "feedback" on their recent work right after they hand it in. This omits the usual delay between submission and reinforcement. Good thinking is rewarded right away and erroneous thinking is extinguished immediately. There is a side benefit for the instructor here, as well, because it provides him/her with a reasonable justification for offering no make-up exams and accepting no late homework submissions.

Recognizing the value of immediate feedback, a company in North Carolina, WebAssign, has grown a business by offering on-line homework with grading and record keeping. By hooking up with several textbook publishers, WebAssign gives instructors control in assigning problems, deciding feedback and deadlines. Their attention to detail gives an instructor confidence that WebAssign is not just another "publisher sponsored" add-on designed to sell books. Perhaps most important though, is that WebAssign will tell students directly after they submit their response whether they answered correctly. Normally students will rush through homework assignments filling up a page or more with work, driving towards the end which, unfortunately, is having something to hand in at the next class. WebAssign's immediate feedback will urge them to "try again" if they are incorrect (depending on the instructor's settings for multiple attempts), so that more time is spent doing homework, and this time with the right goal (doing it properly) in mind.

Feedback in the other direction is just as important. Periodically throughout the semester students are reminded to provide facial feedback when rhetorical questions are asked in class. Something called "TV-face" has crept through the school, whereby facial muscles have grown limp because movies and TV demand no participation from the passive audience. Students need to be reminded that they are active participants in this educational adventure, and are encouraged to "flex their face", nod or otherwise communicate with the instructor during lecture. In addition, weekly e-mail journals allow students the opportunity to feed back to the instructor their opinions on how the class is being conducted. Some small portion of their course grade (2%) should be based on this journal experiment as otherwise, participation would suffer. Depending on class size, the experiment is far more successful when individual responses from the instructor back to the student follow on the next day. Friday night at midnight seems to be a good deadline for journals. Early submissions are fine.

Engagement: Many of these feedback opportunities are of the opt-in variety, requiring students to actively seek feedback. Engaging them to do so is not as easy as making feedback available. Students will feel more invested in the learning process if it is personal, and nothing is more personal than hearing your own name. Some universities provide photo rosters for every class. Memorizing students' names prior to the first class is a big (and pleasant) surprise sending the message that the instructor is engaged from the start. WebAssign and paid work/study homework graders make it possible to assign lots of homework. As class sizes grow in places with no homework grading help, there

may be a temptation to require smaller assignments. Systems like WebAssign make that unnecessary. Like it or not, homework promotes engagement.

Newer software for slide show presentations will record the instructor's audio during lecture delivery, resulting in a slide show movie with the slides showing over the instructor's voice. Archiving these movies on Blackboard provides students with the ability to catch up or replay prior lectures if some points were difficult to assimilate the first time. Other technology-based avenues that promote engagement are calculators, and software like Mathematica and LaTexit. Some universities have labs where Mathematica is available; others have a site license allowing every student to enjoy their own copy while enrolled at the school. LaTexit makes it easy to typeset formulas in pleasing mathematical type for the slide presentations. Finally a tight course organization, scheduled planning of the semester, and specific exam dates give students a clear set of expectations for the course.

An exploding variety of technology tools make this an exciting time for instruction. With these new capabilities it becomes even more imperative that we examine closely the dynamics of instruction and how they can be improved. This has been one early journey in that direction.