Online Calculus Course: Combining Two Worlds

Veselin Jungic and Jamie Mulholland

Introduction

The purpose of this article is to describe our experience in creating, promoting and running a web-based differential calculus course that has been offered through the Centre for Distance Education (CODE) at a Canadian university.

In May 2007, we were asked to design an online version of one of the courses offered by the department of mathematics at a Canadian university. At that time, none of the department's mainstream mathematics courses was being offered by distance education. The most natural place to start was the first-semester calculus course, Math 150: Calculus I with Review. Math 150 covers standard topics in introductory differential calculus. It is designed to go through the required material at a somewhat slower pace, giving enough time for the instructor to do examples in more detail and to spend more time communicating the important ideas that form the base of this mathematical field. Both of us have taught variations of this course a number of times over the past several years. Over those years we developed all class material together: notes, online assignments, paper assignments with solutions, a repository of exam questions, exam checklists, demos and so forth. All of this material was created and later edited in electronic form.

There are two main reasons why we accepted the challenge of creating a web-based calculus course:

- We felt that while building an online course we could create additional material that might be used in teaching our live courses.
- We wanted to experiment with the available technology and technological support provided by CODE to enhance the course material that we had created over the years.

From the very beginning our approach was to create an online version of the course that would be as similar as possible to our live offerings. The reasoning behind this approach was based on our belief that the ultimate responsibility of the mathematics instructor, even at the lowest level, is to lead each student through the course in a reasonable way, making sure that the student gets a fair chance, with an appropriate amount of work, to complete the course to the best of his or her abilities. In other words, we believe that the instructor's role is to be a demonstrator, a motivator, a moderator and a (fair!) evaluator. Hence, our starting premise in teaching mathematics is that a motivated student, in the appropriate learning environment and with the right support, has a chance to develop his or her mathematical talent to its fullest. Since the structure of our live classes is based on this premise, our view was that the online course should keep the same structure.

We note that mimicking live courses is not a common approach in teaching distance education math courses. For example, Akdemir (2008) claims that, "online learning requires a radical change in the way educators do business."

Clearly the main difference between any live course and its online version is in how lectures are delivered. Delivering mathematical content in a video lecture is not new. Academic Earth, iTunes University, Algebra 2 Go, WatchKnow and YourOtherTeacher, to name a few, host numerous video lectures at all levels of mathematics. Delivery of content in these lectures, however, remains somewhat uniform. They are either videotaped live lectures or video screen captures of a computer screen with a voice-over. In our view, there is value in a hybrid of live lecture coupled with computer screen captures, even though this approach is still in its infancy. In creating our course we focused on this hybrid approach and also on improving navigation through the recordings.

A seemingly simple fact—that the level of involvement of the instructor in an online course is substantially different from the level of involvement of the instructor in a face-to-face class---came as a surprising discovery for us during the first offering of the course. This discovery has led us to better appreciate our everyday interaction with students in our live classes. Also, it became clear to us that the instructor's role is the single biggest obstacle in an attempt to truly mimic a live offering of a course in its online version.

Creating the Course

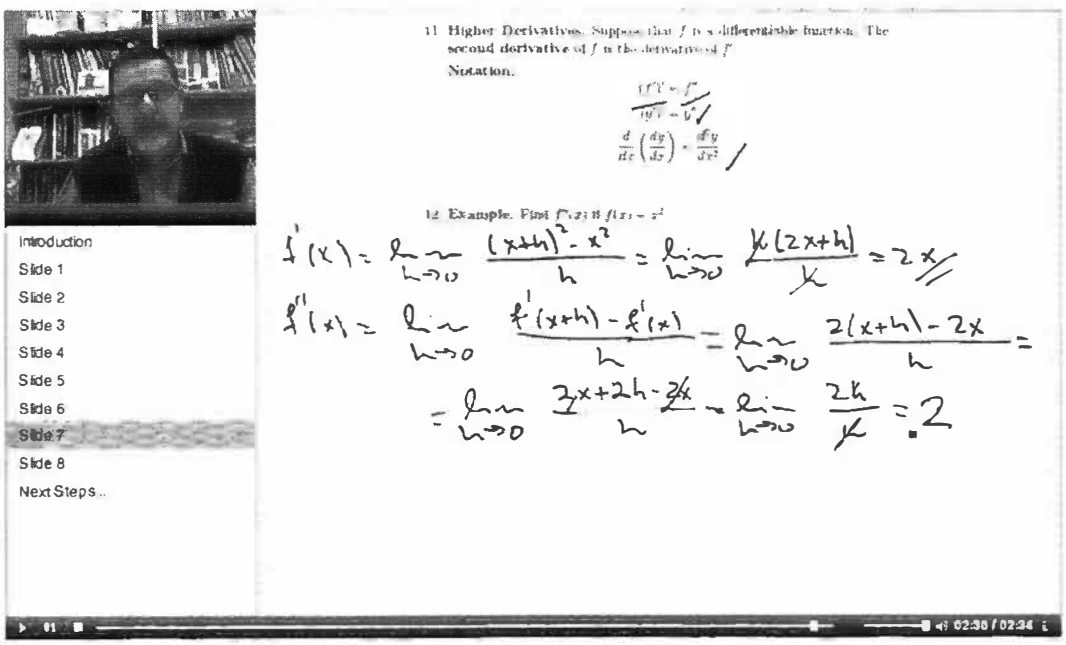
In addition to the problem of delivering mathematical content, creators of an online lower-division university math course, in our view, have to deal with the following two important issues:

- Structuring the course in a way that each student has to do a fair amount of work during each week of classes on his or her own—as the saying goes, "Mathematics is not a spectator sport."
- Taking full responsibility to ensure that a student who completes the online course is ready to take the next math course in the sequence.

To meet these two challenges, we abided by the following principle: to provide the students taking our distance education course with an experience as close as possible to the live classroom. Thus, our online course has the same structure as the live course and uses the same material: the same class notes are used in lectures, the same online assignments and the same concept of paper assignments are used to check students' weekly progress, and the two midterms and the final exam are created from the same already existing repository of exam questions. The main and obvious difference is that we deliver the content of our lectures using video lectures. Our videos feature two windows on the same screen: one shows the instructor's image and the other serves as a notepad for the instructor's writing or as a screen for various demonstrations (see Figure 1). Students are directed to download a skeleton outline of the notes and follow along with the video lecture to fill in the details. Having the instructor's face (and upper body) in the video means that we don't have to constantly be writing; we can underline what we are saying by using body language, making gestures and facial expressions, much as we do in class. Also, in this video we include animations and applets that have been created over the last few years to help students build their conceptual understanding of the material. All this is synchronized with the audio and video recordings of the instructor's comments and explanations.

As mentioned above, throughout the semester the students in the course have to do a significant amount of work on their own. For example, students are assigned weekly readings from the textbook, weekly practice problems from the textbook, and weekly paper and online assignment questions. The online questions are made in such a way as to encourage students to carefully go through each lecture and the course notes and/or use the textbook (see Figure 2 for a sample question). The paper assignment questions

Figure 1: A video lecture features two windows: one contains the instructor's face and upper body; the other contains course notes or demonstrations.



are chosen from various sources, including other textbooks and old exams, or they are constructed by the instructor, and are generally more challenging than practice problems. This means that students are expected to do 25 to 30 problems per week on their own. On average about 10 of those problems are submitted and fully marked, either online or by a teaching assistant. In our view, an important aspect of this process of students' learning is that they can discuss course content and assigned problems among themselves in chat rooms and on discussion boards on the website. Much valuable discussion takes place on discussion boards attached to each online assignment question, and since each student receives a different (randomized) question, the discussion is focused more on conceptual understanding of the material rather than on identifying the right answer. Both of these boards are constantly monitored and moderated by the teaching assistants and instructors. Students might contact the teaching assistant by e-mail or phone during teaching assistant's office hours to ask for advice regarding homework or a practice question.

This is similar to how our live course is taught. Again, we underline the fact that all the material—the skeleton outline of the notes, applets, animations, paper and online assignments—is the same as we use in the live class.

The ultimate dream of any math instructor is to have his or her students actively involved in lectures. This is an everyday challenge in our classrooms, and it seems to be another big obstacle in delivering an online math course. We believe that our concept, with captured audio and video images of the instructor explaining concepts to the viewer and completing the notes that are on the paper in front of the viewer, demands that the online student be an active participant in the lecture. We closely tie all our assignment and midterm exam questions to the course lectures to emphasize the importance of attending each lecture and using all the provided additional material.

As we have already mentioned, in our view the course instructor has full responsibility for all aspects of the course. One of the important aspects in teaching mathematics is the instructor's role as a moderator and a mediator. By *mediator* we mean the math instructor's role as a link between students and the mathematical ideas and techniques that students need to grasp.[1] By *moderator* we mean the math instructor's role as one who directs the learning process.[2] In a live classroom the instructor talks to a group of students and, based on the group's reaction (a question

Figure 2: A sample question on the online homework assignment. Parameters of the question are randomly generated, and the submission is computer graded.

For $f(x)=x^{4/5}-x^{9/5}$ find the critical numbers.

Solution:

Since $f'(x)=$ [ ], we see that $f'(x)=0$ if $x=$ [ ] and that $f'($ [ ] $)$ does not exist.

Therefore, the critical numbers are [ ] and [ ]

Note: List the bigger number first.

Submit Answer Tries 0/5

True or False:

The function $f(x)=|x|$ has no critical points on the interval $[-5,5]$.

If f has an absolute minimum value at c, then $f'(c)=0$.

If $f(c)=0$, the f has a local maximum or minimum at c.

If f is continuous on a closed interval $[a,b]$, then f attains an absolute maximum value $f(c)$ and an absolute minimum value $f(d)$ at some numbers c and d in $[a,b]$.

If f has an absolute maximumon $[a,b]$, then f must be continuous on $[a,b]$.

Every absolute minimum is a local minimum.

Submit Answer Tries 0/5

during the lecture or sudden silence in the classroom or puzzled expressions on students' faces, for example), she can usually perceive a problem and intervene accordingly. Hence, the instructor's mediation of the particular math topic and its moderation in a live classroom are subject to the interaction between the instructor and students in the class. On the other hand, we make our recordings as though we are talking directly to the viewer, as explained earlier. We are convinced that this is the right method to use when recording math lectures for online courses, but we are aware that this implies that we are taking a one-size-fits-all approach. We acknowledge this important limitation of our recorded lectures. Regarding the instructor's role as a mediator and a moderator, this limitation stresses the significance of the other elements of the course (notes, readings, assignments and discussion boards) and the importance of the quality of the recordings, what was done and said, which applets were used, and so forth.

We faced a contradictory situation during the first two offerings of the online course. As the course instructors and creators, we felt responsible for everything that was related to the course, from checking that all resources were posted in a timely fashion on the course website to assigning final marks. At the same time, we realized that the nature of an online course requires that a whole team of people works behind the scenes making sure that

- the website is running properly,
- paper assignments are collected on time and passed on to the teaching assistant for marking, and
- multiple sites, together with invigilators, are booked for writing midterm and final exams, and so forth.

This coexistence (rather than collaboration) between the instructor of an online math course and anonymous administrative and technical helpers is not without its negative consequences. For example, to put paper assignments provided by the creators of the course into the standard CODE format and not being familiar with LaTeX,[3] we had a CODE employee convert the original .pdf files into .doc files, edit them and convert them back into .pdf files. In this process, the assignment questions got mixed, the notation got lost, and the beauty of LaTeX got destroyed. Another problem is that CODE expects that the main contact for students during the semester is the teaching assistant in the online course—thus the contradiction between the level of responsibility that we as the course instructors assumed and the fact that we were not expected to be too involved in the day-to-day running of the course.

Here we mention a few pitfalls. Prerecorded lectures make it impossible to ask and answer questions. Not having students sitting beside each other to confirm understanding is a drawback (however, the benefit of the videos is that there is a rewind button, so this has an advantage over the live class—we used this fact to add a bit of humour to one of our promotional videos). Another pitfall is that our live course is serviced by a drop-in tutorial centre where students have access to teaching assistants five days a week. Since the vast majority of students enrolled in the online course are not on campus, they are not in position to use the drop-in centre. This implies that students in the online course lack opportunity for their work to be checked and corrected (or praised!) while they are completing the assignment. Even though we and the teaching assistant monitor discussion boards on a regular basis, we find that it has been difficult to match the communication aspect of the course with its equivalent in our live courses. For example, in our first offering we had a mature student working full-time and taking our online course. After scoring low on the first midterm the student expressed his disappointment and frustration by posting a message on the course discussion board. We sent him an e-mail to encourage him to keep studying, but this caused even more frustration on the student's part. In our experience, situations like this in a live course would be dealt with in a one-on-one conversation between the instructor and the student, and a resolution satisfactory to both sides would be more likely.

The hardware we used to create the videos was a tablet PC and an external webcam and microphone. We created the note templates with LaTeX and used PowerPoint to annotate the notes during the lecture. Video screen capture and audio processing were done using Camtasia. After the technician at CODE gave us a quick tutorial on using Camtasia, we were left to do all the recordings ourselves. This was a long and, sometimes, very painful process. Here are some points to keep in mind.

- Our estimate is that for each hour of recorded lecture we had to spend about four hours preparing/rehearsing, recording, viewing and reworking.
- We believe making recordings of this kind requires the presence and involvement of at least three people: the lecturer, a technician and another mathematician. The role of the second mathematician would be to spot mistakes, either spoken or written, and alert the lecturer to correct them right away.[4]
- A professional should manage the recording technology. In our experience, manipulating even relatively simple technology distracts the lecturer and

causes unnecessary mistakes, both in what is said and in the functioning of the technology.

- A technician from CODE did all the editing of the recordings. We believe the editing process should be a joint project between the lecturer and the professional technician. We have witnessed that for this generation of students even small editorial glitches or an abrupt transition between slides, for example, can cause frustration.

During the first two offerings of the online Math 150 course the results on assignments and midterm exams matched results from our live courses.

To promote the first offering of the course, we created three short videos and posted them on websites of the Department of Mathematics and CODE. The clips are also posted on YouTube. Two of those clips (Jungic and Mulholland 2009a, 2009b) humorously promoted the convenience of an online course (see Figure 3). The third clip (Jungic and Mulholland 2009c) explains in the detail how the course works and what the course website contains. The clips attracted a significant level of interest from the university community, and we see that they have inspired some of our colleagues to present their courses in a similar fashion.

Conclusion

We conclude by describing our experience using the recorded lectures as a supplement to our live courses. After each live lecture we posted our recording of the same lecture on the course website. We are aware of the risk that there might be students who would decide not to come to the lecture (which is normally held at 8:30 AM), but our experience has been that the vast majority of students use the recordings in the way that we anticipated. The following quote, from a student in the live class taught by the second author in the fall semester of 2009, supports this claim. "I remember a few lectures ago you mentioned your online lessons and I figured I would give them a shot. Personally, I found them very helpful (I watched them all already). They allowed me to fill in any notes I missed and gave me a handy review to help me through my homework. Nearly every question I had regarding my notes was easily solved by simply going to the respective video. This is a great idea. I think every teacher should do this."

Notes

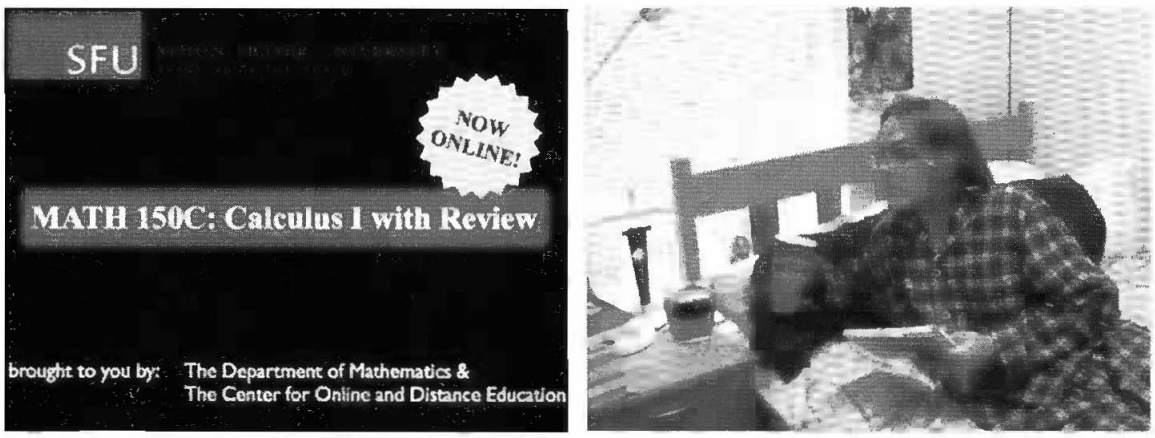
1. Each math instructor brings his or her own knowledge, understanding (or interpretation) and emotions into teaching a particular math topic. Thus, two instructors might mediate the same material to their students in different ways.

2. An instructor who needs to introduce (mediate) the idea of the limit of a function to his 8:30 am calculus class for engineers and his 11:30 am calculus class for social science students will probably moderate the topic in two different ways.

3. Editor's note: LaTeX is a typesetting system that is most often used for the production of technical and scientific documents. More information is available at www.latex-project.org.

4. We learned the hard way that the camera has no mercy; misprints, dysfunctional technology, stumbling, or a phone ringing in the background might momentarily destroy a recording of the best lecture the world was about to witness.

Figure 3: Scenes from the promotional video, which features a student struggling to get to his 8:30 am class on time. The student then finds the online course a convenient alternative.



References

Akdemir, O. 2008. "Teaching Math Online: Current Practices in Turkey." *Journal of Educational Technology Systems* 39, no 1: 47–64.

Jungic, V, and J Mulholland. 2009a. *Math 150 – Calculus I with Review*. Available at http://tinyurl.com/3oq97g6 (accessed September 22, 2011).

———. 2009b. *Math 150 – Change the Rate of Your Morning*. Available at www.youtube.com/watch?v=lLr053RL_Ps (accessed October 20, 2011).

———. 2009c. *Math 150 Distance: Calculus I with Review: The Info*. Available at http://tinyurl.com/3vsltjo (accessed September 22, 2011).

Veselin Jungic is a senior lecturer and adjunct professor in the Department of Mathematics at Simon Fraser University (SFU), in Burnaby, British Columbia. He is also the research director in the Interdisciplinary Research in the Mathematical and Computational Sciences (IRMACS) Centre. Most of his work is on Ramsey theory and the field of mathematics education. In 2007 he was a recipient of the SFU Excellence in Teaching Award.

Jamie Mulholland is a lecturer in the SFU Department of Mathematics. His research interests are in number theory and mathematical education. His interests in the field of mathematical education include use of technology and creation of new technology tools in teaching large math classes.