Flipping, Clicking, and Group Activities in Business Calculus: Advice for Novices

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Abstract

In the fall of 2015 I taught two sections of business calculus, one using a traditional lecture format and the other using a flipped classroom, with videos, midnight quizzes, clicker/peer instruction questions, and group activities. Students were assigned to each at random by the registrar, and they took the same pre and post tests and attitude surveys, as well as doing the same quizzes, tests, final exam, and semester-long project. I had hoped that students in the flipped class would do better on the conceptual quizzes and critical thinking, but the performance was similar in both classes (comparable to their pre-tests). The main difference between the classes was that the students in the flipped class spent significantly more time on the class compared to their time on other classes, and so they rated the efficient use of time lower than the control group. My major lesson from the experience was that creating top-notch clicker questions and group activities is just as time-consuming as making videos (which is very time-consuming), and they are the main reason for using the videos in the first place. If you are going to try to flip a class, it would be best to prepare most of the clicker questions and group activities (as well as most of the videos) before the class starts. If that is not possible, it might be better to add in excellent clicker questions and group activities a few at a time each iteration of the class, and make videos to make room for them if necessary, and build up the flipped class more organically. The paper also includes some other observations, lessons learned, and advice for anyone considering these teaching strategies for the first time.

Keywords: flipped classroom, math videos, clicker questions, group activities, calculus

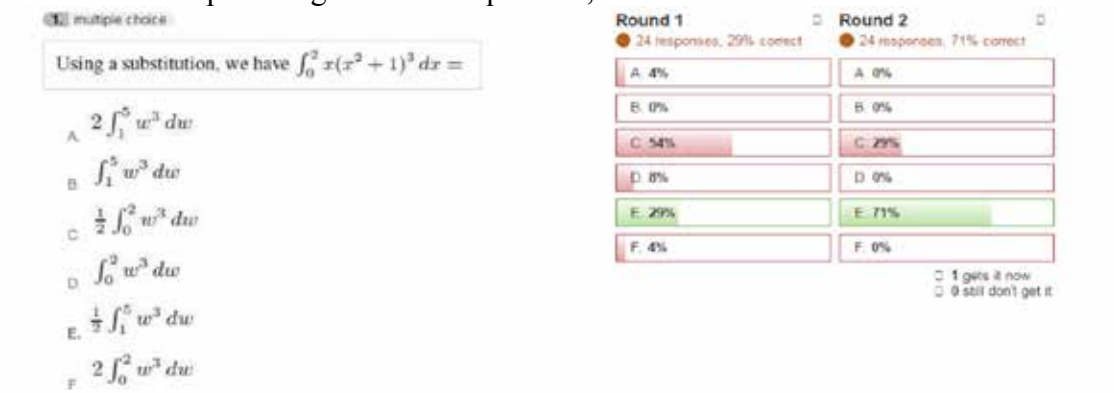
Introduction

Most of us who teach calculus (and most other topics in mathematics) have experienced the frustration of talented students in our classes complaining that we are moving too slowly in the class, and the weaker students complaining that we are moving way too quickly. In addition, one of my main goals as a teacher is to get students to the point where they can not only demonstrate the math skills and solve basic problems in the area of study, but can also understand the concepts behind those techniques, at least intuitively, and be able to use critical thinking to solve multi-step realistic problems involving those concepts and skills.

In hearing and reading about the flipped classroom, I realized that the problem of variable and individualized pacing might be solved. When I use the term "**flipped classroom**", I mean the idea of "flipping" the traditional pattern of primarily communicating content during a class lecture ("the sage on the stage") and having students work on homework outside of class, by communicating most of the content outside of class (such as by videos, but it could also be using textbooks) and then having students work in groups in class on homework problems, clicker (peer instruction) questions, group activities, etc., while the instructor circulates ("the guide on the side") to answer questions, and occasionally give mini-lectures on topics that seem to need clarification in this process. By getting most of the content from videos, the strong students can skim through them, play them at double speed, or possibly even skip them if they know the material, and weaker students can pause and replay the video as much as they need to absorb the concepts and skills being presented.

With respect to the problem of helping students achieve deeper understanding of concepts, Eric Mazur of Harvard has reported that this can be accomplished with great success using peer instruction, or **clicker questions**, as mentioned above. He found that, even though he was a very successful and popular lecturer, his students were not achieving the deep level of understanding he thought they were. A clicker question is a conceptual question designed to tease out common misunderstandings of concepts and procedures. In the most common form, the instructor asks a question (for example, a multiple choice question), and everyone in the class takes some time to think through their answer individually, and registers it in some form (such as with a "clicker" voting device that sends the response to the instructor, who can monitor the percentages for each response). The students then get into groups (such as of 3-4 people), where the responses in the group are not all the same. Each member of the group explains their response first, and then they work together to try to figure out the correct answer. The idea is that by committing yourself to an answer, you have "skin in the game" and are very motivated to figure out the correct answer. This would normally be done after the teacher has explained the topic, so if a student hasn't "gotten it" yet, they are more likely to be helped by another student, who typically has just gotten over the conceptual hump recently and can explain how they got over it more effectively than the instructor repeating their explanation or trying a different one. After discussing in the group for a period of time (a few minutes usually), everyone is asked to answer the question a second time on their own. Ideally, you want to find a question that somewhere around 2/3 of the students are likely to get wrong at first, but then over 2/3 will get right in the second round. If only about half of the students are correct in the second round, you could even go to a third round.

Here is an example of a good clicker question, and the results of the two rounds:



Notice that over 2/3 of the students got the question wrong the first time, and then over 2/3 got it right in the second round. Students often have problems with finding definite integrals with u-substitution, and this question gets at the heart of the issues they need to figure out to do them correctly.

With the possibility of using these tools to solve my pedagogical problems, I applied for and received a teaching mini-grant from the Villanova Institute for Teaching and Learning (VITAL) for the summer and fall of 2015. I was scheduled to teach two sections of Business Calculus (MAT 1400), and the students were to be randomly registered into the two sections as usual for the incoming first-year students in the fall. I applied for and received permission from Villanova's Institutional Review Board (IRB) for an **experiment** involving human subjects, and had the students in both sections sign consent forms to be part of the experiment.

The idea of the experiment was that the first section would be the **control**, which I taught as I usually do, in a format that is mostly interactive lecture, with students answering questions and working in class mostly individually on problems once or twice for a given topic, then doing homework for each class session outside of class that is handed in at the beginning of the next class (after going over questions) and graded.

In the **experimental** flipped section, I posted one or two videos (usually 10-20 minutes each, a total of no more than 30 minutes), and they had to answer a Midnight Quiz by midnight before the next class, usually 3 questions getting at the main concepts and techniques of that section. I then graded most or all of the Midnight Quizzes before class, and so I knew if I needed to do a mini-lecture on any topics they clearly needed more work with. Students also started work on the homework assignment outside of class, but were able to finish it at the beginning of class in groups. I assigned students to mixed-ability gender-balanced groups (which I changed twice, after each test, so they'd get to know about half the class very well), and the group started the class by going over answers and helping each other figure out the answers to problems they had trouble with (and one or two problems that I added at that time). I would then go over problems that multiple groups were struggling with, collect the homework, and do a mini-lecture related to the Midnight Quiz if necessary. Next, we usually did a clicker question, followed by a group activity, possibly followed by another clicker question or an interactive demonstration going over material related to use of technology or tasks and concepts needed for the semester-long student-generated project.

Both sections had 25-30 students, took the same pre- and post-tests and attitude surveys, conceptual quizzes (3 of them, with no technology or other resources), tests (2 of them, with an index card, Excel, and Maple allowed), and final exam (also with an index card, Excel, and Maple), and did the same homework assignments and projects. Quizzes and tests can be re-taken at a 30% penalty, but only after going over them *thoroughly* with me at least *twice* (until I am convinced they understand enough to do better). Homework assignments involved Required and Supplementary problems; to get a check-plus, a student needs to get at least 80% of the Required questions and at least half of the Supplementaries correct. The projects are done individually, and involve an optimization problem from that student's own life, such as finding the optimal amount of exercise to get in the morning to maximize their overall energy for the rest of the day, finding the optimal angle to shoot from on the 3-point line in basketball to maximize shooting percentage, or finding the optimal amount of time to microwave popcorn for to maximize eating satisfaction.

There are milestones along the way: Topic Ideas, Proposal, Initial Data, Smooth Draft, Presentation Transparency (an executive summary), and Final Report. Students gather their own data, use Excel to fit a model to the data, define the model (including specifying the assumptions), use calculus by hand to find the optimal input value (and test it for local and global optimality), verify their solution using technology (we use Maple), validate (do a reality check of) their model and solution such as by trying the optimal input a couple of times and comparing the actual outputs to what is predicted by the model and commenting on how well the assumptions hold in real life, doing sensitivity analysis (seeing how plausible different data affects the model and solution, such as by deleting points identified as Unusual, where the output was significantly affected by a factor *other* than the input variable value), trying alternative models (including one based on a subset of data closest to the optimum), evaluating and comparing the models on their fit to the data and to the problem and simplicity, then synthesizing the various solutions to come up with numerical values and margins of error, and expressing the results and conclusions in everyday language. In both sections, I also collected a Questionnaire and Math Autobiography at the beginning of the semester (to get to know them and their teaching style preferences), optional Math Journals each time the project milestones were handed in (for feedback during the semester, when there is still time to make adjustments), and an option to submit Extra Credit suggestions of how to improve the course in the future (up to 3 points on their final average, judged by the usefulness of the ideas and conciseness). In both sections I also did occasional special demonstrations, such as juggling to give a motivation for calculus as the language of continuous change (à la Newton's apple), a physical demonstration of why the minimum average cost happens where the line from the origin is tangent to the cost curve (using a rubber band), showing the difference the mean (the vertical-line see-saw balance point of the positive pdf graph) and the median (the vertical line cutting the positive pdf into 2 pieces of equal weight on a balance scale), and singing my calculus parody of Blowing in the Wind ("…the answer, my friends, ain't in the back of the book – the answer's in Math 1400").

My **hypotheses** for the experiment were that the students would feel that their learning would be more individualized and personalized because of the videos enabling them to go at their own pace, and that they would get a deeper level of conceptual understanding and critical thinking because of the clicker questions, midnight quizzes, and group activities.

Unexpected Observations

As the semester progressed, there were a number of observations I became aware of about the flipped classroom that were total surprises to me:

1) The Midnight Quizzes provided a great opportunity for me to give *individualized* feedback to every student every night. I had mainly conceived of them as the motivation for watching the videos (if necessary) and practice for the conceptual quizzes, and had simply never thought about the fact that, through Blackboard, I could easily zero in on specific conceptual misunderstandings of each individual student and communicate that to them. In practice, I wrote up a generic explanation/solution for all of the questions, and could then delete parts they already understood, or add individualized comments.

2) The flipped class developed a *deep* level of community cohesion, *much* more than *any* class I had ever taught at Villanova. Now that I think of it, it is not at all surprising, but I had never even considered that it might happen beforehand. For example, when I handed back homework or quizzes or tests, almost every group sent one representative to pick up everyone in the group's work – nothing like that had ever happened before, except for one or two pairs of friends. In fact, as this community cohesion developed within groups, I started to realize that being forced to work on a clicker question *individually* for the first round was actually *extremely difficult* for most of them, since they were so used to working together as a group.
3) The flipped section did not see me as the primary content expert for the course as much as in the control (traditional) section. Perhaps because the videos were not me physically in front of them and because they were helping each other so much this is to be expected, and perhaps this is largely what we want (to help them become independent learners), but it was unexpected and somewhat disconcerting. I did get the feeling at times that it was counterproductive, such as when they were turning to each other for help in studying for the conceptual quizzes rather than to me, since their peers were less likely to understand some of the subtleties of the concepts.

Results

As the semester progressed, I was excited to notice that the flipped section was doing a little bit better than the traditional section, since that suggested the new format was having a positive effect. However, toward the end of the semester, I finally got around to compiling the scores on the pre-test, and it turned out that the flipped section was also a few percentage points. The level of improvement from the pre-test to the post-test was almost identical, and far from statistically significant, and there were no clear better results for either section on any of the common components of the course. From the pre- and post-attitude surveys, there was no significant difference between the sections in their change in attitude toward math. I guess you could say that at least the experimental section didn't do *worse* than the control section.

On the other hand, there *was* something from the attitude surveys that was significantly different between the sections: the flipped section averaged more than 5 ¼ hours per week outside of class *more* than in their other classes, while for the traditional section it was only 3 hours more. Since MAT 1400 is a 4-credit-hour class, and most others are 3, an increase is expected (and the flipped section students tended to spend a little more on their other classes than the traditional section students, validating that they were slightly stronger students to begin with), but an extra 2 ¼ hours per week is a lot of time. Not surprisingly, the flipped section also scored the item on "used time efficiently" scored lower.

The other main difference in results was that the flipped section rated me lower on "answers questions effectively". This is probably related to the observation above that they did not see me as the content expert as much, which could be partly the nature of the flipped structure. I think there was also a component related to my taking some time to figure out how to best take advantage of the flipped format as the instructor. Early on, I had a tendency to have them work on the homework at the beginning of class for longer than was probably ideal, and did not realize the

importance of wandering as they worked in groups, especially near the groups that tended to struggle more. I think part of this was being distracted by figuring out how to run the clicker questions. I think I also had a tendency to *not* provide a satisfying summary mini-lecture, especially after group activities, at first.

Lessons Learned

1) I'm glad that I decided to make my own videos (so I could teach all of the concepts and techniques in my own way), but it takes an incredible amount of time! Using videos from another source, such as Khan Academy, might also work well. Just figuring out the details of what camera to use (I used a Canon), what format to use (I used mp4), how to edit (I used Camtasia, which worked very well), and how to post videos on Mediasite And Blackboard took a lot of time.
2) The reason to do a flipped class is to get the benefit of excellent in-class activities, such as clicker questions and group activities. Creating such clicker question and group activities is as time-consuming as making good videos (which take a huge amount of time). If you have never done this before, try to have at least two of these three categories mostly finished before the start of the semester. You might be able to do one of them pretty well on the fly (and that can be a good thing, to get feedback and learn as you go), but there really isn't time to do more than that well. I was so focused on making the videos that I did not have time to put in the needed effort for the clicker questions and group activities to be as effective as they should be to justify the time spent watching the videos outside of class.
3) My Midnight Quizzes were effective at motivating the students to watch the videos (most students watched most of each video, when I looked at the analytics), but didn't lead to better results on the conceptual quizzes. The intention was for them to do the Midnight Quizzes without looking back at the videos, their notes, or the text, but there was no way to enforce that, and so they didn't necessarily have to internalize their understanding to answer the questions.
4) Good clicker questions helped students learn the concepts, but without working hard on creating excellent questions, they can also *not* add a lot. I ended up not having time to craft enough top-notch ones to result in higher concept quiz scores.
5) Many of my group activities worked well, especially those that focused on technology and project skills and concepts. Activities that relate to the real world are best. It is important to sum up at the end to convey a sense of closure (even if they haven't finished everything, give them a sense of what completing the activity could look like – have something prepared in advance).
6) 10-15 minutes is probably enough time to have the groups work on homework at the beginning of the class. During this time, and while they are working on group activities, it is very important to constantly circulate, and spend the most time near the groups that tend to have the most trouble. As you become aware of common difficulties, don't be afraid to do mini-lectures to clarify those problems.
7) Most students in the flipped section said they didn't like the flipped format. A few of them did, especially weaker students who appreciated being able to pause and replay the videos to learn the material solidly. I think the main reasons for the majority response are

explained in Lessons 2, 4, and 5 above. I don't feel that I gave the format a fair trial, because I didn't have the time to create top-notch clicker questions and group activities.

8) I used Learning Catalytics for the clicker questions, which they can do from a laptop, smart phone, tablet, or other mobile device. If you use a Pearson text, it is free; if not, it is only $12 per student per semester, which is less than most clickers. In creating and editing questions, I found Learning Catalytics somewhat clunky and awkward, but otherwise I liked it a lot. It can even display graphical and other kinds of answers that have great potential.
9) Some students want and need more worked-out problems than others. I made a number of them, and they were appreciated, but I didn't have time to do all that I would have liked to do. The Lumens Ladibug was a great tool for creating these videos.

Suggestions

1) Since excellent clicker questions and group activities are the main reason to flip a class, don't flip a class completely unless you can prepare at least two of the three main components (clicker questions, group activities, and videos) before the start of the semester.
2) If that is not possible, instead of the above *pull* model, try a *push* model: Create a few great clicker questions and group activities first. If you can't find a way to fit them into class time (perhaps by cutting topics not required in the syllabus, such as half-life in Business Calculus), then create videos just for those classes if needed. Each semester, add a few more, and maybe you will end up with a completely flipped class at some point, but maybe that's not really necessary.
3) Midnight Quizzes are a good way to motivate watching the videos, but could possibly be only one or two questions, and may not lead to deeper conceptual understanding. They are a great opportunity for regular individualized feedback if you have time.
4) Keep individual videos to no more than 10-20 minutes (some would say 5-10) each, with no more than 30 minutes total for a 75-minute class equivalent (20 for a 50-minute class). (My sections both had two 75-minute meetings, and one 50-minute meeting.) Have one video for each separable topic. Some students appreciate extra worked-out problems. A good format would be to have a minimum number of examples in the main video, then a separate video with a couple of extra worked-out problems (with you narrating the reasoning behind the solution as you work it out), so that those who need them can get them and those who don't can skip them. My students reported that they didn't like it as much when I skipped showing myself writing things out on the whiteboard to save time.

Conclusions

Having videos is great, even for a traditional class, especially to have available for students to look at to study for quizzes, tests, and the final, and for snow days or other emergencies when your institution is unexpectedly closed. So even if you try a flipped class and decide it is not for you, you have that resource available for the indefinite future to enhance your class. Even if you don't

do a completely flipped class, making videos of extra worked-out examples with your narration of the reasoning behind the solutions is another great resource for some students.

Research shows that active learning is much more effective for deeper student learning and retention of knowledge. If you can't do a complete flip of a class, think about topics where an excellent clicker question or group activity could be very effective. See if you can add them into your course in your usual mode, perhaps by looking at the syllabus and thinking of topics or subtopics that really aren't important for that class and could be cut or condensed. If the syllabus is too full for that, try making a video to make the space for the high quality activities. Keep building up and adding these activities until your class is largely or entirely based on active learning.

The semester after I did my experiment, I was scheduled to teach one section of the course. By the time the class started, I hadn't had time to fully analyze my results, and I decided to use a bit of a hybrid approach. I posted all of the videos, and students appreciated having them for studying, and we were able to use them one day when the University was closed. As a compromise between my traditional 3 conceptual quizzes and the Midnight Quizzes for every flipped class, I have started doing weekly conceptual quizzes, and I think that has had a bigger effect on fostering deeper conceptual understanding than flipping, because it makes the amount of material to be mastered more manageable (so they are less likely to try to memorize). I highly recommend this! I have also been able to add some more worked-out example videos for various sections, and that has been very helpful to certain students. And I tried to work in at least one clicker question per week, especially in the middle of a 75-minute class (the one when I wasn't giving a weekly quiz), which I think also worked well.

Some research has suggested that the flipped classroom might be best for upper-level undergraduate courses. The reasoning is that first-year students tend to be at the developmental level of dichotomous thinking – things are wrong or right, black or white; they want *the* answer. Based on my experience, I can't really make a judgment about the answer to that question. Since I didn't have the time to create first-rate clicker questions and group activities, I don't feel I gave the format a fair trial. I still believe that flipping *could* work well for Business Calculus, but I'm not *positive* it *would*. I look forward to doing more experimenting and hearing about other's trials and results.