# Flipping the Analytical Chemistry Classroom

With so many modern teaching tools at our fingertips, shouldn't we be making more of the time we spend with our students? I decided to "flip" my classroom in an attempt to answer that question. Here is how it went.

*By Christopher Harrison*

For the spring semester of my analytical chemistry class this year, I chose to implement the "flipped classroom". In it, the conventional approach to teaching is turned on its head: instead of using class time to learn material in a lecture format, students use it exclusively to answer questions and work on problems. The time that the students would normally spend doing problems or homework for a traditional lecture is instead used to watch pre-recorded lectures in preparation for the work to be done in the class time. Simple!

The flipped classroom is in no way my creation – I learned of it from a seminar on teaching held at SDSU. To me, it's the latest installment of my quest to find the best way to engage a large group of students in the beauty of analytical chemistry.

## *The back story*

I have been teaching analytical chemistry at San Diego State University since the fall semester of 2007. The course is the traditional introductory analytical chemistry course, often called quantitative analysis or just "quant" for short. Its focus is to get students to think analytically about chemistry:

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to begin to consider the complexities of equilibria, to understand the statistical significance of the numbers that they see and report, and to gain a foundation in how accurate measurements can be made in chemistry, both in the classroom and in the laboratory. To a large extent, it requires the application of a lot of math to chemical systems to understand what is happening within them. As with any university level course, some students love it, most work their way through it, and a few dislike it.

My early teachings followed the traditional lecture format. I would spend most of the class time explaining the concepts, theories, or equations pertinent to that section of the class, including some sample problems that I would solve for the students by walking through each step. The problem with this approach is that it doesn't provide a significant amount of experience to the students. Sure, they get to listen to me – and hopefully learn something from that. And they get to see me solve a few problems along the way. But it does seem like a very odd way to learn how to do something. Would the traditional method work if you were teaching someone to do something complex, such as fly an airplane or perform surgery? Absolutely not! Practical experience is crucial, which is why we have practice problems and homework. (Does this course not have a practical laboratory component?) But when do students do this work? At home in the evenings? The night before a deadline? Ever? From my experience, I would say one or two days before the deadline is when most students try to complete the problems. I can quite accurately gauge this by counting the number of students that drop by my office with questions. In a week without any homework deadlines, I had nobody coming by. But on the week of a deadline, my office was packed, and I was usually answering the same questions over and over…

It is likely that many of you with lecturing experience will have had a similar experience. I would even go so far as to venture that, much like myself, you have probably come to feel that you are better able to teach your students during your office hours than you can during your lectures. After all, it is in these office hours where you can determine what their individual difficulties are and how to best aid. If only all interactions could be like that. Instead, most contact hours with your students are spent presenting a repackaged version of the textbook or other written course material. Given your level of education and expertise in the subject, your time could inevitably be better spent doing something other than what amounts to reading. Right?

## *Student engagement*

It was during Pittcon 2011, in the middle of our spring semester, that I was inspired to make some serious changes to how I would teach the analytical chemistry course. The inspiration came from a talk by Steven Weber from the University of Pittsburgh, who described how he got his students to calculate the pH values for the titration curves of various amino acids; each student was assigned an amino acid. Steven would introduce the material and then have the students dive into the work during class, so that he could supervise and answer questions. The approach struck a chord with me and I realized it could be nicely adapted for use with my material.

With 40 students in the class there aren't enough amino acids for everyone, so I asked the students to work in groups. Each group were given one of five amino acids whose pH they needed to calculate at various points along a titration curve, which allowed me to have numerical answers that I could share and compare with the students. I used the first half of the class to cover some basics related to polyprotic titrations and then commenced the group work.

The hard part was just sitting back and letting them do the work. Until you have actually tried to leave a lecture to it's own devices, it is hard to describe how uncomfortable it feels. That doesn't mean that it didn't work out – but not everything went perfectly. A couple of students adamantly refused to work in groups and elected to leave the class. Most students did get into groups and, after some chatting, began the work. As I circulated around the classroom, I answered questions that arose in each group. I also noticed that groups were benefitting from peer mentoring, with students helping each other.

The experiment offered two positive insights into how effective active learning can be. The first was that many of the students wanted to know the correct answers to the calculations at the end of the lecture. It was great to realize how engaged the students were with the problem. The second sign was actually quite unexpected. Every instructor can easily tell when there are less than five minutes left in any class; students start to pack up their books and stop listening entirely. But in my experimental class, this didn't happen. In fact, students were still working on the problems at the end of the class when the next lecture started to enter the room.

Given my success, I continued with the approach for the next few years. Though it was somewhat effective in getting a large number of students to do problems during class, the amount of time for doing problems was rather limited. After introducing the materials and possibly solving a sample problem, there was little time left for group work. Additionally, some lecture topics were not as conducive to such an approach or simply needed more explaining. And there was the inevitable decrease in attendance for the class, with only a third to a half of the class attending any given lecture, which pretty much reflected declines I'd seen when using traditional lectures. Yes, the approach was working pretty well, but it could certainly be improved; I was still spending at least half of my class time lecturing, rather than letting students work on problems or ask me questions. At this point, the concept of the flipped classroom began to make much more sense to me.

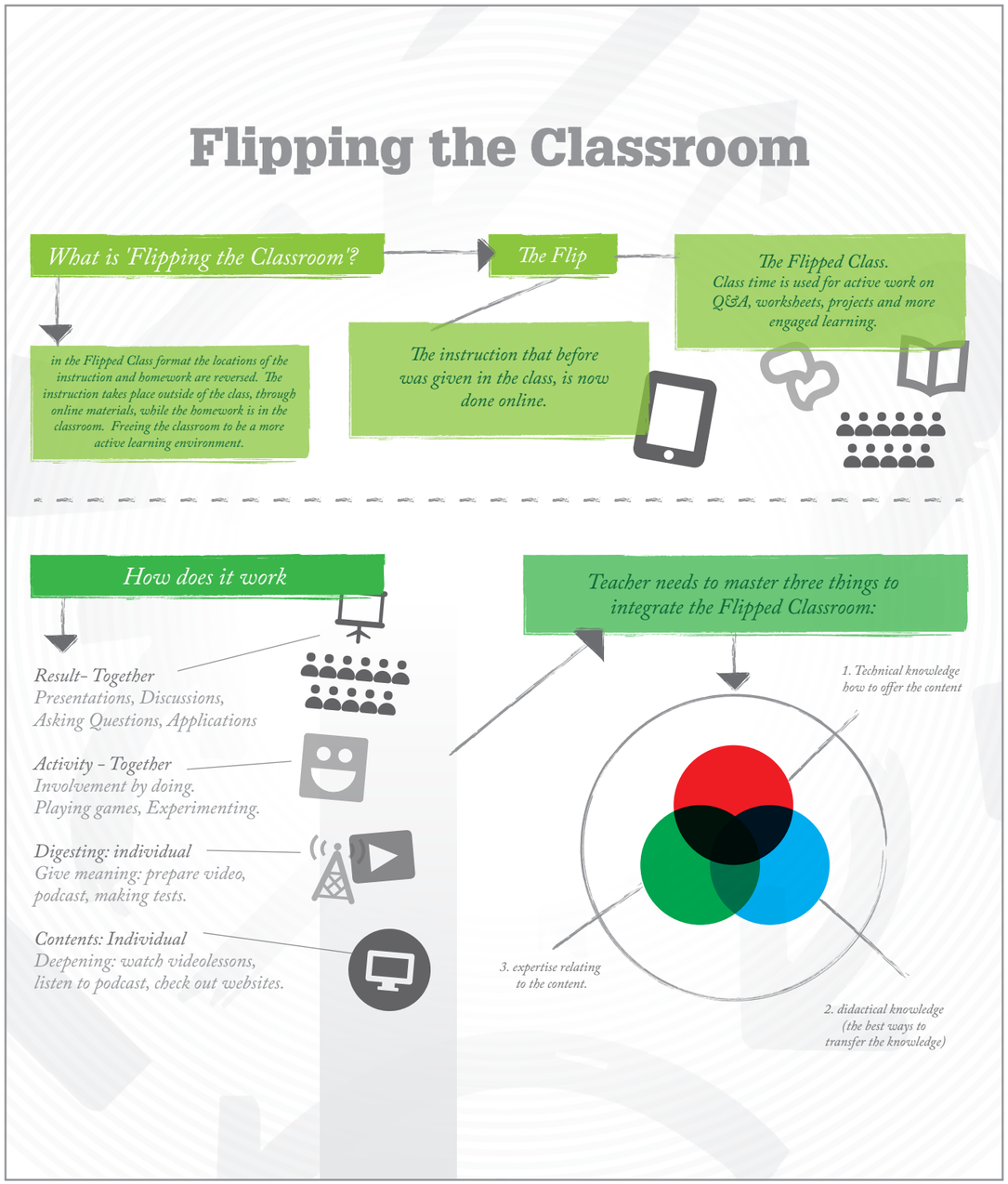
## *Learning to flip*

I should note that the implementation or rigidity of a flipped classroom is entirely up to the instructor. I opted for a more open structure, without any imposed deadlines on the watching of lecture videos or the submission of questions. Rather I had prepared problem sets (those used in the previous years of the course) that I wanted the students to work on in groups. For the first couple of lectures, I had created video reviews of the labs that they would be doing during the course of the semester. In keeping with that theme, I provided the students with a summary of a lab, along with the "data" collected from the analysis – a silver chloride precipitation titration experiment. The objective was to get the students to do the calculations for the standardization of the titrant, during which they would need to deal with statistical issues, such as the exclusion of outlier data points. It was a glorious teaching plan in my mind – the students would complete so much in just 50 minutes. It was an utter failure…

In reality, after introducing the class and answering a few questions, there was little more than 30 minutes left, which was nowhere near enough for the students to grasp the complexities of the problem. Instead of students asking questions about the validity of data and how to interpret results, questions revolved around how to get started.

Unfortunately, this scenario repeated itself in the next period, as there had been no time to alter the plan. Once again, my students were confused with material presented to them. Clearly, I was not preparing them well enough and had overestimated their capabilities. Fortunately, I was able to adapt my plans for subsequent classes; I resorted to using the problem from the more traditional format of the course, which made classes much smoother.

I have to say that I really did not account for how much time the lecture recordings would take out of my schedule. I had been toying with the idea of doing a flipped classroom



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for some time, but never found the time to record the lectures prior to the semester when I decided to implement the process. As such, I found myself scrambling to prepare videos each week for the topics to be covered. Though I had lecture materials from my previous iterations of the course, significant modification of those materials were necessary to make them amenable to a lecture video. Add to that the time to record the lecture, edit the final product, and upload it, and the workload starts getting heavy. Sometimes I was only able to get the lectures uploaded the day before the class period – clearly not ideal; however, it did not prove to be such a big problem as most students were a few lectures behind after the first few weeks of the course.

Another surprising lesson that I learned during the semester (which probably shouldn't have been surprising at all) is that, if classes are unstructured and optional, many students will not attend. I realize this response is not unprecedented. Certainly, in the past when I had taught this course as a traditional lecture, I would consistently see below 50 percent attendance in the latter third of the semester. Some students had just given up on the course, others made use of the course materials that I provided (audio recordings, sample problems, lecture slides) rather than coming to lectures directly. However, using the flipped classroom, the decline in attendance started sooner and went to a much lower level, with as few as a quarter of my 80 students attending lectures regularly.

## Assessing the flipped classroom

I would be lying if I said that I didn't want all my students to come to every class, but the reality is that, though working on problems in groups is a great way for most students to learn, it does not mean it holds true in every case. Moreover, because of the lack of strict deadlines, the course effectively became a self-paced program; students were less likely to be at the same point and thus less likely to be able to work in groups. The big question is whether or not low attendance is a problem.

In a traditional course it would clearly be problematic – students would be missing out on the basic instruction for the course. However, with a flipped classroom, that's not necessarily the case. The lecture materials (including videos, problem sets, solutions, and online homework) are fully available, so presence in the class is not a direct indication of their efforts to learn the material. In fact, if the dropout rate for the class (meaning those who did not withdraw from the course but elected not to write the final exam), is compared to the historical average, the change is stunning. Under the flipped classroom approach, the only student who did not complete the class withdrew in the first few weeks of the course. Historically, about 10 percent will not write the final exam, having given up before the course finishes.

I have to say, it is not fully clear whether or not the flipped classroom approach was the principle factor in the improved retention of the students. Other changes, including a revision to the structure and style of exam questions may have also played a role. However, comments from some of the students, including one who had failed to complete the course in the more traditional lecture format, shed some light. In the traditional lecture format, if a student does not grasp the material being taught, it's rarely possible to get a second chance. Of course, with lecture videos, the student can replay sections over an over, so if motivated, has no reason to fall behind in their understanding.

An inability to ask questions of the lecturer while watching videos was inconvenient for some. But there are two solutions to this problem: (i) email the instructor the question or (ii), as I suggested to my students, they could

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actually opt to watch the lectures during class, where I would be available to answer questions on the spot. Admittedly, this takes us almost full circle, but because the recorded lectures are much shorter than the class time allocated, it still presented a better alternative, since I was available to answer as many questions as required.

Over the course of the semester I elicited feedback from my students about their feelings on the flipped classroom. The responses varied widely – some loved the new approach and others hated it. Complaints fell into two main categories, students either preferred the live lectures over the videos or wanted to see sample problems solved rather than stepwise calculated solutions.

The craving for traditional lectures may stem from comfort and familiarity – at least one student admitted as much in the feedback. And yet, given the rate at which I normally see students stop attending classes – and their total lack of participation – I am struggling to share what benefit they derive from a formal lecture period. The inclusion of videos illustrating solutions to sample problems was something that I did change. It was easy enough to accomplish with a whiteboard, iPhone, and a camera tripod, and added a more dynamic feel to the narration of slides.

Am I a flipping convert? Absolutely! Overall, I feel that the flipped classroom was very successful. The students completed the course, and did so with far better grades than my previous traditionally taught classes. Despite the success, I do know that I can make the flipped classroom an even better experience for my students. Many students lamented the low numbers attending the class times, echoing my feelings. And while I recognize that students can be (and often are) successful without coming to class, I would like to be able to push the students further.

I will be redoing my videos before the start of the semester to better integrate examples of problem solving. I will also significantly shorten the videos, making more in the process. After all, the traditional lecture habit of repetition is not one that is needed when the students have access to a rewind button!

I see the flipped classroom as the inevitable evolution of much of our teaching, if only for the reason that as educators we can be far more effective when we directly engage our students and help them solve their specific problems. Given the success that I saw with my first – and admittedly clumsy – attempt at flipping the classroom I see no reason to go back to the traditional lecture format.

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