



Bruce Clemens teaches materials science online

Interviewed by Piper Klemm

In the last decade, many top schools from around the world, including the Massachusetts Institute of Technology, Harvard University, Oxford, and Stanford, have put teaching content online. Often these are free courses that anyone in the world can access, and some institutions grade the work and offer certificates for passing. Science in general, and materials science in particular, have been largely left out of this open-access revolution, due to difficulties of translating course material to online lectures and the inability to simulate laboratory portions.

Last fall, however, Bruce Clemens, the Walter B. Reinhold Professor in the School of Engineering at Stanford University and 2012 President of the Materials Research Society, offered the first online course in materials science. The course, “Solar Cells, Fuel Cells, and Batteries,” was completely free and was managed by Clemens and a team of three teaching assistants. Of the 12,400 students to sign up for the course from around the world, 400 finished with a certificate of completion. The course was billed a success, generating over 700,000 page hits.

The course will be offered again this fall, free of charge and without any enrollment limits. See solar.class.stanford.edu.

MRS BULLETIN: Why did you start an online course?

BRUCE CLEMENS: The main reason I started teaching it online is for the students at Stanford University. When I teach “Solar Cells, Fuel Cells, and Batteries,” I typically have students from 12 different departments ranging from freshman to advanced grad students. I felt like the regular lectures weren’t effective because people were either lost or bored. I thought that if I could put the lectures online, then I could spend time with students, helping them to work the problems. They could take the time they need to understand the course material—so if someone already knew it, they could zip through my lectures and if they didn’t know it and really needed to focus, they could watch a couple of times and go back and forth. Then I thought, well, as long as I’m recording the lectures online, why don’t I offer a version of the course free to the world? So, we offered it.

Who were the people that took the course?

Most people had a Bachelor’s or an advanced degree, the ones who finished it in particular. The course tends to be technical, so it is not for the casual student but rather for the focused student. This course was for students who wanted to understand the fundamental science of how these things work so that they could then make progress and research in this area. I was really impressed with the online students who finished it—they spent a lot of time just for their own edification, just to learn. They’re not doing it to get a degree, they’re not doing it to benefit monetarily, and they’re just doing it because they want to know this stuff!

There were some people who didn’t [have a Bachelor’s degree]. There was one person who at least self-reported that he was a 10-year-old kid who finished the course. It is a little bit scary to think about some 10-year-old in North Carolina who is integrating the

density of states times the Fermi-Dirac distribution function to find the electron concentration in the conduction bandwidth, but that’s what he did.

How do you account for the number of students who completed the course?

We had only about 400 students actually finish. I think a part of that is because the course covers a wide range of topics at great depth, so someone interested only in fuel cells might take only the fuel-cell portion and not the solar cell and *vice versa*.

We did give a statement of accomplishment to those who finished, which was a motivating factor for people. They wanted the statement from Stanford. The big takeaway was that peoples’ level of comfort with the material in the course increased dramatically as a result of taking the course. They went from, on average, pretty poor understanding of the material to pretty good understanding.

How did you stimulate student-to-student interaction?

We hosted a Forum on the course which was very active. People spent a lot of time answering as well as asking questions on the Forum. It’s great to see the enthusiasm and the energy that people put into it. One person transcribed every lecture, typed every word I said, and put it online, even though we had subtitles for the lecture. There was a group who worked in Spanish—they all got together and had their own Facebook page on the course—it was pretty remarkable, the amount of effort that people put into that.

You worked with Head Teaching Assistant Chinmay Nivargi and two other TAs to execute the course. How difficult was the execution?

It was fun, and the excitement that people had about the course was really an experience, but it was not a labor-saving device. It was an absolute ton of work for all of us. The TAs did more than I did. I would answer questions only occasionally, and for two reasons:



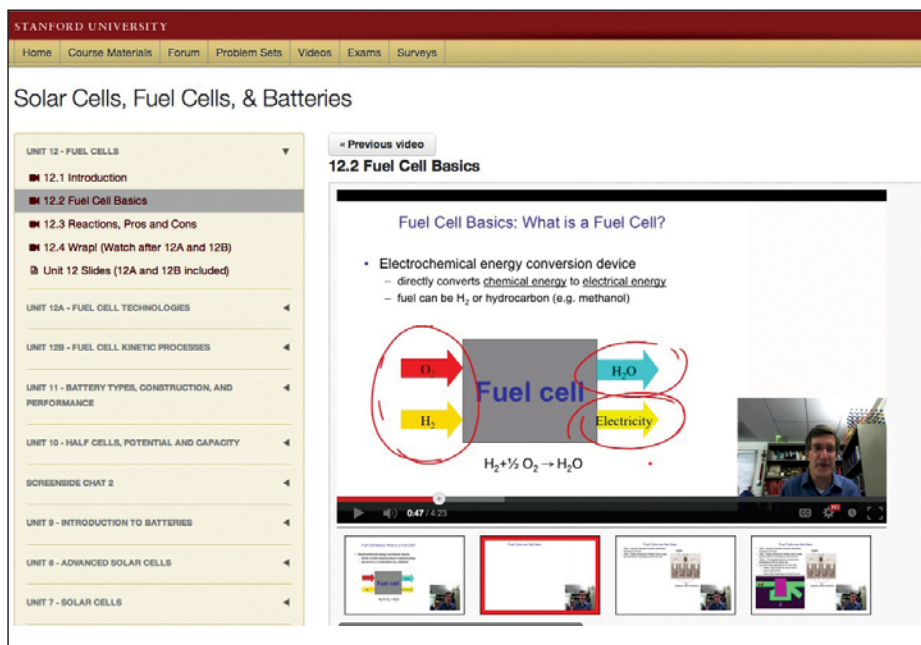
(1) I was swamped getting lectures made and (2) it put an end to discussions when I weighed in. People would say “That’s the answer and that’s that.” I liked the ongoing discussion, so I avoided being heavy-handed with answering questions on the Forum.

How did the students learn in the course compared to a typical lecture hall?

It doesn’t work for everybody, and it doesn’t work for all kinds of learning. I actually think that almost all the learning I did in school was from homework problems. This course has homework sets associated with it; I think that helps. For some people, the video lectures are just too dry. I tried to spice them up with some jokes—for some people that worked better than for others. Still, it can be hard to watch a video for longer than about five or six minutes before your attention starts to wander. For really dedicated students, particularly if they start working the homework problems, they can find themselves wondering, “What was it he said again?” and they can go back to the lecture and watch the part where they were confused. For those types of students, this is a pretty good format. It’s reviewable—it doesn’t go away. You can go back to it again and again and understand it at the level you need in order to work the problems.

Will this be a significant part of teaching in the future?

I think, as far as the future goes, we’re at the cusp of huge changes and I don’t think anybody has a clear idea of exactly where it’s all going. We’re all trying experiments; some will work, some won’t, and I think completely new ways of teaching are going to emerge from this. We have to be careful that we keep the good associated with the current methods that have been around for generations or longer, but we also have the opportunity now to have quality education more widespread than it ever has been before. I think that’s an exciting thing. As an educator, you’ve got to say, ‘wow, that’s great!’ if more



and more people have access to quality education. It’s going to make the world a better place.

I’m a big fan of trying to make this happen in some way, but we have to make this happen without losing human contact and the “person writing on a wall with chalk” that has been around for about 30,000 years. We have to be careful that we don’t homogenize education to the point where it can’t be adapted to different students and different institutions. If you give people enough depth, and enough time to deal with it, they can come to their own understanding rather than trying to give everyone an “observer’s view” of education. We want people to participate in their education!

My crystal ball is probably fog-gier than most peoples’ on this, but huge changes are coming and it’s an exciting time to be in education—a tumultuous time.

Is a free course a long-term feasible model for online education?

I think Stanford’s philosophy about this is good; they’re not looking at this as a way to generate revenue. But on the other hand, you have to be careful that you don’t sidetrack the attention of faculty away from the students who are

actually here at Stanford. It is a little bit of a tricky issue. I think that the way we did this course was to try to make it better for the Stanford students. If it’s not, then one needs to question whether we can continue spending a lot of time offering this free to the world.

I think Stanford University feels that it has an obligation to do as much as it can for the people of the world. They’re willing to put some effort into this, particularly in this crazy, experimental, “let’s see how this works!” phase of the educational endeavor. The way the Internet works, startup companies, and such, is similar in philosophy. People often go start something.... They just try to get billions of people excited about something, without any real business model of how to make money. You get people excited about it; if there’s attention focused on it, if it ends up providing some service to people, then it’s something that you continue. We’ll find a way to do it. I don’t know how, exactly. I certainly don’t want to put any limits on it. It’d be great, though, to see more students from around the world take the course.

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