Daphne Koller: Good morning everyone. And thank you for inviting me to be here with you this morning.

(See slide #1) So today I’ll tell you a little bit about what we’ve been doing at Coursera and where we think this is all going.

(See slide #2) This project started out as a Stanford University project in September of 2011, where based on a bunch of work that a group of us had been doing at Stanford, we decided to take three Stanford classes in Computer Science and open them up for anyone around the world to take for free. We were expecting an enrollment of a few thousand people in those courses once they were opened up. But within a matter of weeks, each of those courses had an enrollment of a hundred thousand students or more.

So the number hundred thousand is not one that we often hear in academic circles, so to put that number in perspective, the largest of these courses when offered at Stanford has an enrollment of 400 people. It’s considered a large class even by Stanford standards. In order to reach the hundred thousand students that enrolled in that course, my colleague Andrew Ng, who teaches that course would have had to teach his class at Stanford for 250 years. [audience laughter]

But I think even more important than the number is the fact that by doing so, he would have been able to reach 250 generations of very privileged Stanford students as opposed to the students from every age group, every country and every walk of life that were able to take his class by having it be made available to anyone for free.

So when we saw the impact here, we realized that there was a tremendous opportunity that was available to us to take what is an education that had been available only to a very small number of highly privileged students and provide it to anyone around the world at what is effectively a zero marginal cost per student because the cost of delivering this education to every additional student is closer to zero dollars than it is to one dollar. And that opportunity was really too big for us to pass up, the impact of change that it allows. And so with the support of Stanford administration, in January of 2012, so about 20 months ago, we spun
this out of Stanford and opened this up as a platform that al-

So that was in January, 2012. We officially launched in April,

So let me talk a little bit about each of those numbers in more detail. (See slide #4) So first of all, these are the universities that are offering courses with us today. On the left you can see the US Universities and you can see some of the best universities in the country, both public and private, including several UC’s. Private institu-

By virtue of being so international in both our audience and in our university partners, we’re currently able to offer courses taught natively in seven different languages. So English, French offered primarily in introductory level courses aimed at students in Sub-Saharan -- French-speaking Sub-Saharan Africa, Spanish, Chinese, Italian, German and Arabic.

(See slide #5) In addition to these university partners, we have recently launched partnerships -- recently be-

This is where we are today. (See slide #3) We have over 450 courses from 88 university part-

and Michigan. 37 courses and two hundred thousand legacy students from the Stanford courses in the fall. So that was about, what, 18 months ago or so.

35 of the top 60 universities worldwide, including the #1 or #2 ranked university in 15 countries.
and completion. And I'll talk a little bit about that at the end.

So that's the university partners. Let me talk a little bit about the courses. We started out in computer science. That is definitely not where we ended up. So you can see on the right there is a graph that shows the distribution of different course topics. And on the left you can see some of the sample courses in philosophy, in literature, poetry, business, chemistry, astronomy and medicine, entrepreneurship and many, many others. Just last week, Wharton put on the platform its entire first year MBA curriculum for anyone around the world to take for free.

One particular category of course that we're very proud of is that of teacher training. This was our response to a question that we kept on getting, which is, it's great that you're offering free high access higher education, but in many countries around the world, the problems do not start in higher ed, they start a lot sooner. What are you doing to help fix the access and completion problems of K-12 education? And we don't feel that this online experience is the right way to teach a seven-year-old how to read. And so the response that we came up with is, well what if we can just help teachers get better, become better teachers? And so in collaboration with a number of our top-ranked schools of ed that are Coursera partners as well as a number of others that are specifically aimed at teacher education, we put together a program that is intended for free teacher professional development for -- actually it's not even K-12. Some of our courses go all the way into early childhood. And so this is an international effort. Some of this is aimed at the common core in the United States. And some, as you can see in this picture, is aimed specifically at helping teachers in the developing world better teach their students so that we can perhaps help alleviate the teacher shortage of 2 million teachers worldwide.

The last piece is the students. (See slide #7) And I can spend hours talking about student stories. I think we have hundreds and hundreds of student stories including dozens that come in every week from new students. And so I'm just going to do a few examples of the kind of opportunities that this opens up to people. And then we'll move one. So this is Amanda from Dominica. And I'm just going to read this out. “Coursera makes studying easier for me. I could sit at home and learn like I'm at school, no distractions just me, my headphones and my books. Everything is clear, the video lectures are just amazing. I could earn certificates and do quizzes to improve my learning, without spending a dime to get to my local school. It helps me a lot since my mom is in the hospital and financially, I cannot afford to attend school.”

So one kind of access.

(See slide #8 next page) This one arrived this week. It was one of the forum posts and the instructor drew it to our attention. This one, we read this out at company all-hands on Friday and people were in tears. I think you will see why when I read out:

“Two years ago I felt incredibly miserable. I'm coming from a traditional family, so I married young and all my
Two years ago I felt incredibly miserable. I am coming from a traditional family - so I married young and all my life I was either pregnant, breastfeeding or both.

I knew that I am talented, but all I had in life was cleaning, feeding, cleaning, feeding, working part time. I felt that all my talents and joy are buried deeply in the ground. I wanted very much to study like my classmates (and I went to study – I was sitting at the class at the real university) but it was very hard to find time. I started and left, started and left. I was deeply depressed. There was a moment when I thought that my family would be better off without me and I tried to kill myself. But we - humans are very tenacious of life and I survived.

At that time I found Coursera. My first course called the "game theory" expelled the depression and the desire to die once and forever. I feel happy and I enjoy my life and my family much more. In the last two years I’ve taken about 40 courses (I am addicted) and I am in love with on-line learning. Coursera breathes life into me. It gave me hope. I know that when my kids will grow up (in 10-15 years) I will leave everything and go to Oxford. I dream about it...

As Charles Dickens once said:

"Suffering has been stronger than all other teaching, and has taught me to understand what your heart used to be. I have been bent and broken, but - I hope - into a better shape."

(Anonymous)

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Post-traditional learners.

And finally, a yet different example. (See slide #9) This is Daniel in this picture, sitting on the right. Daniel is a 17-year-old who's severely autistic. He has a speaking vocabulary of about 150 words. He communicates by typing on an iPad designed by his father. By doing so, Daniel was the star student in the University of Pennsylvania Modern and Contemporary American Poetry class. And tells us via email that this was the first meaningful educational experience that he's had after a life of special ed. He and his father tell us that this is actually helping to diminish the severity of his illness, and he's actually spent some time travelling around the world meeting in person some of the teachers that have taught him in some of these online classes. And a couple of months ago, his father sent us this picture. This is Daniel standing in front of a wall of certificates that he has earned by performing in these online classes. We get a lot of these as well, people who for whatever reasons of disability, health, cognitive, or otherwise, are unable to come and study in a traditional college classroom. This is the reason why we do this.
So with that introduction, let me talk a little bit about the actual student experience in these online courses.

So in these courses, we have tried to give these students from everywhere in the world an experience that resembles that of our college students. So this is not a bunch of static, open-courseware material. This is a real course. It, just like a college course it begins on a given day. Every week there's work that you're supposed to do. There is video lectures you're supposed to see. There is homework that needs to be done. The homework is graded. So if you don't do your homework, you don't pass the course.

That model turns out to have the same impact on online students that it does on our own on campus students. And you can see that, the x-axis is time, y-axis is load on the site. You see that heartbeat pattern? It's the day before the deadline. Every week, the day before the deadline.

[audience laughter]

And at the end of the course, there is a credential. It's not credit-bearing by and large, but it is a piece of paper that the students can walk away with pride of their accomplishment. And we'll talk a little bit about that later on.

So now let's talk about the different components of the student's interaction. The first is the video lectures themselves. So let me show an example of what that looks like. This is one example. So this is from the University of Michigan Model of Thinking class. The instructor is talking. You can see that he scribbles on the slides. When the video hits the yellow notch, it pauses and the students get asked a question. They answer the question, are given immediate feedback as to whether they're right or wrong, have a chance to try again, and potentially get an explanation. So this interaction, which is interspersed into our very short video modules, they're about 10 minutes on average, is actually really important to keep the students' attention and to keep them retained and engaged.
Now, if you think about this as a comparison to a large lecture class -- and again, the comparison here is to a large lecture class, not to a 12 person seminar -- but if you have an auditorium with 150 people, sure, as instructors we can try and keep the students engaged by asking questions in class. And many of us do. But when we do that, at least speaking for myself, since as you can see I talk pretty quickly, 80% of the students are still scribbling the last thing I said. And then there's that smarty pants in the front row. [audience laughter] And it's always the same person, who answers the question before pretty much anyone else has even realized that a question had been asked. [audience laughter] At which point, the class moves on. And I'm guessing it happens in many of your classes as well, right? Here every single student engages with the question. And that helps students stay retained. Okay.

The other aspect of online, of this online interaction is that it also allows the students to personalize learning experience to their own needs and their own time and place. So they can watch it at 8 o'clock in the morning if that's their alert time, or at 2 o'clock in the morning. It depends on what their biological cycle is.

You can also break away from the constraints of in-classroom teaching in other ways. So as I said, these are short video modules. These are not hour and 15 minutes lectures. You can break it down into well-defined modules with well-defined learning outcomes that the student then traverses at their own time, at their own pace. And that gives them a lot more control over their own learning and they're able to sit and re-watch a previous segment. Or they can pause and take notes, or anything that allows them to sort of match the learning to their own needs.

You can also tailor the learning experience to the needs of different students by, for example, providing background material that some students might require but others already have. Or by providing optional extensions that some students would find interesting and motivating but might not be of interest to everyone. So this allows us to basically move away from the one-size-fits-all model of education that's forced on us by the need to deliver an education to 150 people all sitting together in the same classroom.

Let me skip past this.

So I talked about the in-video quizzes. The in-video quizzes are actually being used by instructors on a variety of different ways. So you saw the use of the in-video quizzes for asking questions to have students practice the basic concepts in the material. But there's other things that people use them for. So for example in the Duke Irrational Behavior class, they use this as a way of conducting surveys among the students in the class. So it's kind of like a clicker. It's an in-video clicker at this point.

Okay, so that's the lectures -- that's the lecture component. (See slide #13) But that's not where the meaningful learning happens. As we all know, students learn by actively doing stuff with the material themselves. And so that brings us to the topic of the weekly homework. Now the weekly homework, as I mentioned, are graded, and that obviously poses a challenge because you have a hundred thousand students. You don't have five thousand teaching assistants. So who's going to grade all that work?
So there's two solutions that we've developed that allow you to do grading at scale. The first is computer-based grading. And it turns out that you can do computer-based grading for a pretty broad range of questions at this point. So in addition to a good old multiple choice, there is short answer grading that you saw on the video. There is grading of computer programs and computer models and Excel spreadsheets. Anything that has a structured output. And grading of math expressions that looks not just at the syntactic form of the expression, but also at its semantic equivalency so that if somebody writes $0.5 \times x \times x$, the computer automatically recognizes it as the same as $x^2/2$. So you don't have to write down all the possible variations on the answer.

It turns out the auto-grading has been used by our instructors in very creative ways. (See slide #14) This is probably one my favorite examples. This is from Professor Mike Schatz of Georgia Tech who created a course called Introductory Physics1 with Laboratory. And so you might question how students out there in the general public in all sorts of remote parts of the world are going to do a lab class when they don't have access to a lab. And so what Mike did is he created this system that plugs into our auto-grading capabilities where he has the students do the lab with materials that are available to the in their own environment, like balls and tables and things like that. And he has the students video-tape the experiment on their cell phone. And then he has image analysis software that calculates velocities, accelerations, masses and things like that, and can thereby confirm the student's own measurements of those same quantities. And so you could actually do a lab class with materials that students happen to just have lying around, which is, I think, a really cool example of how one can be creative in these online courses.

(See slide #15) We also support a lot of third-party integration, especially for grading of interesting assignments. So here you have two examples of that. We have integrated on the left with a Pearson MyLab's Chemistry Mastery, it's called, package that allows students to do fairly sophisticated assignments in organic chemistry and have them be auto-graded. The auto-grading all is done by the Pearson tools. And we just integrate with that to give the grades back to the grade book. And on the right there's one from the Berkeley School of music that is a music authoring tool. And again, integration with that. And this is the first few steps in the app platform that we're currently building up that's going to provide an integration with a whole bunch of third party or instructor-provided tools that is going to allow people to really create a rich ecosystem for their students from a whole range of different software components, which we internally are too small to build out and maintain in the long term. So this is a way for a very rich set of tools to be all integrated so that instructors can kind of mix and match and provide to their students what they think is the best course experience.
Okay, the important part about auto-grading is that it's not just about scalability. It's also about the instant feedback that is provided to their students as to whether they're right or wrong. This is to be compared to a lot of traditional grading where, between the time that a student learns the material, gets the homework, submits the homework and get the graded homework back, three or four weeks might have elapsed, by which point the student might realize that they didn't get the material. But at that point it's really too late to go back and do much about it because the class has moved on. Here, the students know immediately that they're not understanding. And that give us the opportunity to let them try again and basically achieve mastery by trying and trying again until they get it.

So here is a graph that demonstrates this. This is an aggregate over 29 classes that have been offered on the platform that allow this mastery learning, that is they not only give instant feedback, but also allow for resubmission of the same work with maybe oftentimes some randomization. So what you see on the graph on the right is first that the students are incentivized to resubmit. The x-axis is how much potential there is for score improvement, that is how far you are from the perfect score. And the y-axis is the probability of resubmission. And you can see that the students who are further away are more likely to resubmit, which is great because those are the ones who are most in need of learning the material better. And you can see on the graph on the left that the scores do improve over time. That is there is a significant difference in the distribution between the first submission, which is the blue graph, and the final submission, which is the green graph.

Now, this obviously begs the question of, sure you let somebody submit often enough, eventually they're going to get it. So is this indicative of actual learning that's going on or does it just indicate repeated attempt? And so we did an analytics -- we did an analysis of those 29 classes to try and gauge that. And basically, and I have the data if somebody wants to look at that at the Q and A, that shows that for students whose baseline performance is similar, those who engage in this mastery-based learning tend to do better not just on that assignment, but also on the final exam. And so this does, we believe, provide a basis for better future learning as well. So that's great.
But obviously automatic grading will only take you so far. (See slide #18) There is a whole range of assignments that a computer really cannot grade effectively right now. And that includes a lot of the open-ended critical thinking style work like essays, designs, critiques and many performances and many others. And so in order to allow scalable grading of that type of assignment and thereby support courses in the humanities and social sciences and all of the less quantitative courses, we put in a framework called peer grading. This combines ideas from a technology called Calibrated Peer Review that was developed at UCLA, integrating ideas from crowd sourcing, which is what makes Wikipedia and Amazon Mechanical Turk work. Putting these ideas together. The basic notion is that the instructor puts together a well-designed grading rubric that is provided to students generally after they submit their own work. And they are then trained in the process of grading automatically by the system. And at the end, after they’ve demonstrated the ability to grade, they then are given five assignments of other students in the class to critically assess relative to that rubric.

(See slide #19)
And this is an example of such an application in a Penn Genomics class where the assignment is actually to critique a scientific paper. And students were critiquing the critique as part of this peer grading process. You might question whether students who are not qualified in the material are able to accurately grade the work of others. And the answer is sometimes. It depends on whether the assignments and grading rubric are designed to support that.

So here is an example from the Princeton sociology class, which was the first humanities class -- it was a very humanitarian sociology course -- to use peer grading.

And they did an experiment to test the accuracy of this by having the TA’s grade separately each of the 1200 final exams that comprised three essay-style questions. What you see here, the x-axis is the TA grades; the y-axis is the peer grades. And you can see a very strong correlation, which suggests that, again, when the peer grading rubric is well designed, this achieves highly reproducible results and meaningful feedback to the students.
It turns out that this approach allows us to do a much broader range of courses than you would think can be done in a scalable format. So here, for example, is the Wharton Design Course. It was an 8-week project class. That was the assignment, an 8-week project. And each week the students submitted successively more and more elaborate versions of first a problem specification, a case study, a prototype, and finally an artifact and got five pieces of feedback from fellow students in the class. So that at the end, they were able to get some pretty spectacular projects coming out of this.

Now the other really, I think, important aspect of peer grading is that, again, just like auto-grading, it turns out to have pedagogical benefits as opposed to just scalability. Because students in these classes tell us, and this is anecdotal, we don't have data to support this, but anecdotally, that they learn as much or more from grading the work of their peers as they did from doing the work on their own because they learned to critically think about what makes for a good assignment and what makes for a not so good assignment. They learned to see how the same problem can be tackled in different ways. And then having seen all that, in many of the classes, the students are then asked to go back and apply the same rubric to their own assignment so that they are then forced to think about did I do well on this relative to the rubric and relative to other solutions that I've seen from students in the class? And that's a really powerful learning mechanism for those students. And so a lot of the faculty who have applied peer grading in the public classes are now using the same ideas in their own private classes on campus as well.

The final component of the student experience here emerges naturally from peer grading, which is the aspect of community. One thing that just does not scale to 10,000 students, and frankly does not even scale all that well to 500 students or even 150 students is the instructor's ability to interact in meaningful ways by answering questions of students in the class. We all know the burden of email and how much work it is to answer emails from all these students. What we've done here is we've replaced the hub and spoke model of a single instructor responsible for answering all the student questions with a peer-to-peer interaction. That is, students post questions on a discussion forum and other students answer those questions. And because these are such large courses, it turns out that for any given question, there's usually going to be an expert there somewhere in the class who's capable of providing a really good and often a very detailed answer to the question that's being asked. And so students often get responses that are certainly faster turn-around and in many cases as good or better as what an instructor would have done simply because of lack of time.

It turns out that you could also, then, start combining these things in interesting ways. So
driven by Professor Al Filreis in the Modern Contemporary American Poetry class at Penn, we put in the mechanism by which students' work is posted on the discussion forum together with their peer assessments. So each one is a separate thread. And then you have the ability for other students to go and comment on the work of others in just as a general commentary. And some of these threads have hundreds of comments of people looking at the work of others and saying, ah, I like what you did here, but I didn't like what you did there. And it really creates a very exciting intellectual discourse around, in this case, essays about poetry.

So here's an example of that. (See slide #23) Community also happens not just in the virtual setting, but also physically. This is something that emerged organically. Students basically came together just saying, hey I'm in Kandahar and I'm taking this class. Who wants to come and do a study group with me? We'll be meeting at this coffee shop Thursdays at 5. And we now have several thousand of these communities around the world in dozens of different countries of people getting together once a week to help each other over the challenging parts of the material.

I'd like to highlight one of these communities as being particularly interesting. (See slide #24) This is a community of students in Ohio who are not among life's most fortunate. These are primarily women from minority backgrounds in their 40's and 50's. Only one of them has a college education. They're all either unemployed or working in low paying jobs. This wonderful woman who you see in the top left, Sharon Watkins, brought them together and said, let's take a class together. And she brought ten of them. They picked a class. They picked an entrepreneurship class from the Darden Business School at the University of Virginia. And they took it together. And of the ten people who began this class, nine of them stuck it through to the end, and six of them completed an MBA level -- successfully passed an MBA level final exam for this course. Remembering
that only one of them has a college education. So I think this is a really important testament to the benefit of combining really high quality online content with the kind of support that you get from a face-to-face community. And I'll talk more about that in a little bit.

(See slide #25) Okay, so the final piece of the student's experience comes at the end. We talked about this credential. What is this credential? Well every student who successfully completes the class generally gets just a letter from the instructor, which was something called a Statement of Accomplishment. This says, congratulations, good job, you finished the class. But in addition, for those students who want something a little bit more rigorous, we put in place in January of this year something that we call the Signature track, or the verified certificate. This is a mechanism by which students authenticate their identity by submitting a picture ID which is compared to their Webcam photo by a human. And then at the same time, they create a biometric profile. In our case, the biometric profile uses keystrokes, because it turns out that if two people type the same phrase, their patterns are going to look very different. And it's really impossible to forge. How do you teach somebody to type in the same rhythm that you type? It's just not possible. And so that allows us to identify the person every time they log in and confirm that they are there participating in their own learning.

And so at the end, we're able to confer upon them a certificate that has a little bit more heft behind it, which is this verified certificate, which our university partners have allowed to carry their university brand. Even though it's not a for-credit certificate, they've said that it's okay to do that.

Now, this is an important thing for us, not only because it provides great value to those students, especially the ones who want to use it for job seeking purposes, but also because it's a sustainability mechanism for the effort. This is no longer a free offering. I mean, the course is free and you can take the course for free without getting one of these certificates, but if you want one of them, then you have pay for that identity verification process and it's costing on average between $40 and $60 to participate in this program. And for us, this is an important thing because it allows us to make this a sustainable thing financially without charging students for access to content. So nevertheless, $50 is a lot of money for some students, certainly for students outside of the United States, and so in addition to the paid version there's also basically a fee waiver, a financial aid mechanism that students who really need one of those certificates but can't afford the $50 have a mechanism for getting anyway. And I'm not going to read the stories here because we talked a lot about student stories at the beginning.

So I'd like to use the Signature Track as a way of addressing one of the criticisms that has often been levied around these open online courses, which is, oh, these courses can't be any good because only 8% of the students who start the MOOC them will complete the MOOC. And that's true. Only 8% of the students who sign up for one actually complete it. That number doesn't mean, however, the same thing that it means in a traditional college class because in a traditional college class, when a student signs up for the class, they usually do so with the firm intent of completing it. And if they don't, then it's a failure. It's their failure or the system's failure or something. Most of the students who sign up for a MOOC have no intent to actually do it. They're exploring. They are treating it in the same way as taking out a book from the library where they're intending to
read two, three, four chapters, get a sense for the material and then putting it aside. So to evaluate that you can use the Signature track, because if students sign up for the Signature track, presumably they have some intent of getting some kind of credential at the end. Otherwise why bother paying for it?

(See slide #26) And so here’s one graph that demonstrates the differences here. So here you can see that among students that sign up, whereas students outside the Signature track completion rate. And this cohort was about 5%. In the Signature track it was over 60%. So 63%. Now the Signature track is actually not a very high bar because for a lot of students $50 is not a lot of money. And some of them are actually viewing it as a donation to support the effort. But if you look at an entry survey and ask students: Are you committed to completing the class? -- which is the next graph that I’m going to show -- you get numbers that are even more striking.

Among students who walk in to these courses intending to complete them, completion rates is about, again, 64-65%. Those who sign up for Signature track, completion rates get close to 90. So about 88%. Now 88% completion rate is incredibly high for an online activity, even an online activity that’s all about fun like social games. Far less for something that requires 5 to 7 homework every week. So this is an indication that for students who are actually interested in completing the class, these classes are something that do retain those students.

Okay. And finally, I’d like to sort of talk a little bit about the other aspect of community, which is the community of institutions that’s coming out of this. And that’s also going to lead to the next part and final part of the talk. One of the things that we’re all trying to do here is learn together. Because these online courses are sort of a new direction for many institutions. And I think that we’re going to go back in three years and look at what we’re doing today and say: I can’t believe we so naive in how we’re implementing these online courses. There’s so many things that we now know better. And so to accelerate that process of learning, we are also building a community of institutions that are participating in this. And this is the Partners Portal that you can see has a lot of technical documentation as well as a community where people can show good examples of best practices or things that have succeeded in their classes and so on and so forth. So we can all learn, for example, how to increase retention rates even further, how to do good peer grading and so and so forth.

(See slide #27) So the last part of this talk is about how this might help us improve learning outcomes for our own students in our own campuses.

(See slide #28) And there’s, I think, several different ways in which this can be done. Some that leverage the online component and some that leverage the stuff that we can do in the classroom once we have the online materials there. So in the online component, first I think, and maybe one of the most exciting opportunities that we have available to us is the visibility that the data gives us into the performance of our own students and the performance of our own courses. The platform that we have is fully instrumented. It means that we measure every single event that happens. Every
time a student pauses a video, stops watching it, rewinds to take notes, submits and incorrect answer to a quiz or a correct answer, looks at a forum post, all of that's recorded. Which means that we can now on a daily basis look to see what's working in our classes and what's not as opposed to the more traditional view, which at least in my case, is you know, you grade the final exam and you say: Shoot! I thought I really explained that concept better. [audience laughter]

Here you get this immediate feedback. And so I'm going to give you one example of how that works. And there's many others that one can do. This is a distribution of wrong student answers in one of Andrew's machine learning questions. Each little cross is a one-off wrong answer, a unique -- a student that came up with a unique way to be wrong. [audience laughter] Creativity is always good. The one at the top left is where 2000 students came up with the exact same wrong answer.

Now if two students in a class of 100 make the same mistake, you'd never notice. But if 2000 students make the exact same mistake, it kind of jumps out at you. And so Andrew and his TA's went in, understood the basis for the misconception, and then used the capabilities here so that whenever any other student's answer falls into that bucket, they now no longer give a generic: Sorry you're wrong, try again. They get a: Sorry, you're wrong and you might want to think about this. And that helps channel the students toward better learning outcomes faster avoiding frustrations and so on and so forth. So this is one way in which we can benefit from big data in order to personalize the learning experience for the students.

(See slide #29) Which brings me to what I consider to be one of the bigger opportunities that we have available to us. Almost 30 years ago, renowned educational researcher Benjamin Bloom wrote a paper called "The Two Sigma Problem." In that paper, Bloom studied the achievement distribution in three populations. The first is the traditional lecture-based. Not even a very large lecture room, 35 students. And that's their distribution. The second is the distribution of students who still studied in a lecture format but in a mastery learning paradigm, which means they couldn't move on to the second topic before demonstrating competency in the first. The final distribution is that of students who were lucky enough to get an individual tutor. And you can see that each of those interventions gives rise in Bloom's data to a full standard deviation improvement in the distribu-
tion of achievement scores.

Now, a two standard deviation improvement would be an awesome thing for us to get in terms of student learning outcomes. But that gives rise to the title of Bloom's paper, "The Two Sigma Problem" because as Bloom pointed out, as a society we can't afford, as much as we would like, an individual tutor for every student. So he titled his paper "The Search for Methods of Group Instruction That are as Effective as One-to-One Tutoring." But now we can maybe reformulate the question. Maybe we can't afford a tutor for every student, but perhaps we could afford a tablet. In India, the Indian government is building this thing called The Aakash Tablet, which is not nearly as fancy as an iPad but is fully functional and costs $40 to manufacture and is subsidized by the Indian government to cost $20. So they hope to give one to every Indian schoolchild within three years. So the question is can we now use technology to move us to methods of instruction that are as effective as one-to-one tutoring? Nice thing is that mastery learning is well within the capabilities of a computer. The computer genuinely doesn't mind showing you the same video five times. They're okay with that. [audience laughter] And so mastery learning we can do. Individual personalization at the level of a gifted tutor, that's a little bit further out on the horizon, but we've seen some elements of personalization in the watch at your own pace and the personalized feedback that the data allows us to provide. So I think there's glimmers of hope and it's a really fascinating research question for us as a community.

Finally, the place where we can improve learning outcomes is in our own college classes. This is one of my favorite quotes. It's from a 19th Century educator Edward Slosson who said that, "...college is a place where professor's lecture notes go straight to the student's lecture notes without passing through the brains of either." [Laughter] Perhaps a somewhat negative view of the college education, but when you look at that example down there, you kind of begin to wonder if that's true.

And so what we'd like to propose is this notion of, which I think has become very popular at least in discussions in the last few months, which is that of that of the flipped classroom where the students get a lot of the basic concepts and the basic skills outside of class, come into class prepared. And we know they're prepared because they have to do the quizzes and we can check that they do the quizzes because it's all instrumented. And then they come to class and they actually engage with the instructor in meaningful ways doing active learning, problem solving or perhaps letting the instructor identify the students that are struggling with a particular concept and helping them overcome that hump. (See slide #32) So we've had a lot of success with that in terms of our own instructors.

Those who have offered the online courses are now bringing that material into their on campus classes in a flipped classroom model. I'm not going to read you all of these quotes, but let me just do the first one. These are two computer science instructors at Rice University who say: "I will never, ever, ever teach a class any other way as far as I can tell. This is so much better. I had so much more fun teaching and the students learned so much more, I will never get up here and lecture. I just don't see the point anymore. I can do better this way."

And that's a fairly common response from all of the instructors that have moved to a flipped classroom teach-
ing using this type of technology.

(See slide #33) And this is data that we didn’t come up with. It was -- this is based on several years’ worth of flipped classroom teaching at the University of Wisconsin at Madison where they have largely converted many of their first year engineering curriculums to a flipped classroom approach over the last five to ten years. And what you see here is in comparison and then Introductory Electrical Computer Engineering course. The big effect that happens is that the students in the DWF category, the ones who fail, are much less likely to fail in this flipped classroom teaching. So it also helps to move some of the B’s into A’s, but the big effect is down at the bottom of the distribution.

Okay, I’m going to -- so the next to last slide is one that summarizes what I think is an important view of what these MOOCs are and what they offer. (See slide #35) This an observation that was made by Christian Terwiesch who is an Operations Management Professor at the Wharton Business school who taught Operations Management on Coursera. In his last lecture, which is available on YouTube -- I highly recommend it -- is a case study of MOOCs. And he argues that instruction by nature is a tradeoff along a [inaudible..perado] optimal curve where you tradeoff between faculty productivity, which you might define as the number of students that you can teach in an hour, relative to students’ learning outcomes. So the black dot is the large lecture hall. It’s pretty productive. You can cover 300 people all at once. Learning outcomes are so-so. At the top left is the kind of individual tutoring that you get in office hours. Great learning outcomes but very unproductive in terms of the number of the students that you can cover.

He argues that this online learning technology actually what it does is it moves the curves entirely to the right. That that curve now provides us with a different set of tradeoffs than we had before. We can take the quality of instruction of the large lecture classroom and provide it to not 100 or 300 people but to 30,000
people thereby reducing significantly the marginal cost per student. That's one way of using this technology. But a different way of using that same technology is also not trying to reduce the cost, but rather trying to improve outcomes. That is, you take the same quality -- you take the same amount of time that an instructor can devote to the students in the classroom, but instead of having them spend the time delivering content and grading work, they can spend the time much more productively on actually engaging with the students in a dialog. Which right now, any of us just don't time to do given all the other responsibilities that we have. And so this is just a different way of constructing a tradeoff curve. And each institution for every class needs to decide where it wants to be on that curve.

(See slide #36) So I'm going to end this topic going back to the beginning of it and just talk about one aspect of this, just going back. The big goal of this whole thing is education for everyone. Only a third of our students, of our 5 million students, are in the United States. 40% of them are in what the State Department defines to be the developing world. These are not just the brick countries, not just the more emergent economies like Brazil and Russia and India, but also every country in the world is represented. Every single country, including the poorest countries in Africa, Haiti and so on and so forth.

For many of these students in those other countries, it's not a question of are their colleges good enough? There are no colleges. There is no -- the capacity in those countries is simply insufficient to accommodate the growing demand of people who need a higher education in order to have a good life for themselves and their families. India, in order to achieve its educational goal of having 30% of its students, 30% of its population have a college degree would need to build 1500 new campuses in India. Now even if you ignore the somewhat daunting logistics of building 1500 campuses, currently their existing campuses are at about 25% staffing levels because there’s not enough qualified instructors in India to teach. Where are you going to staff 1500 new institutions? And this is India, relatively advanced educationally. What about Nigeria, Bangladesh, Ghana? So without something that provides a different mechanism, education is going to stay out of reach for most people for at least a generation, probably more. So what we hope to do with this effort is take education that in most parts of the world has been a privilege of the few and turn it into a basic human right. Thank you.

[ Applause ]

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