WILLIAM BONVILLIAN: All right, Steph. Let's go into Claudia Goldin and Lawrence Katz.

STEPH: Obviously, Goldin and Katz focus on the big picture issue, which is what you have drawn for us in the big picture-- pun semi-intended. And a consideration that I had was on the research and development process, which is not something that they touched on here, which could maybe provide a short-term fix. And I'd love to hear your input.

Is there, in the research and development process, people who openly talk about the ways in which their technology may cause social disruption? And if so, can you identify someone on a project that you've worked on or a firm that you know of that's concerned about the social or economic implications of the technologies that they are building?

RASHID: Don't VCs do this all the time? They decide--

MARTIN: No, they don't.

[LAUGHTER]

RASHID: But they might decide, this is my niche, this is what I haven't seen before, and these are the reasons why this particular technology would take advantage of this unseen market. And so I don't know if that's what you're trying to get at with--

MARTIN: No. I think her point was like, OK, if we do this, it will change society this way. Like Uber said, OK, if we do this, this technology will get rid of all these cab drivers, and there's going to be a social disruption. Is that your kind of angle?

STEPH: Sort of, yeah.

MARTIN: OK. Yeah. I think your angle was more like, oh, this is going to be a huge hit, and it's really going to change society, right?

RASHID: Yes.

MARTIN: OK, cool.

STEPH: Right, so I guess in my consideration of business and consumer markets, and in some of the research that I'm conducting for my paper on autonomous vehicles, one of the questions that I've been tasked to ask by anthropologists, two firms that I might be interviewing, or even as I'm going over literature base and public releases to the press, is essentially, who on the staff is in charge of answering questions or raising considerations about social disruption or economic disruption that your technology might cause? And if a firm can't answer that, then you have your answer-- that they're not-- that they don't consider that as a part of their research and development process.

And I think it's possible that some people would argue that that's beyond the scope of what the firm should be doing, right? They should be focusing on the technology. They perhaps should not have an ethicist that they should-- or perhaps they should just have an ethicist that they consult with, but it should not be someone who's formally a part of their staff.

So I'd love to hear your perspective on this as perhaps a short-term fix. As we sort of promote technological advances, should there be someone who's constantly raising a flag and saying, ha, perhaps this might not be a good idea to deploy in the time frame that we have set for ourselves?

SPEAKER 1: So I'm working on the mobility of the future project as part of my thesis. And so a lot of it is with autonomous vehicles. And it does seem-- well, first of all, with that example specifically, a lot of the companies who are working on it are very secretive about what they're doing. So it's not very clear as to what's going on within the companies. But outside of them, at least with this example, there is a lot of work and awareness about potential disruptions. I question whether that's always been the case or kind of the recent disruptions have spurred people to think about this more.

So there's a group at the MIT AgeLab, I don't know if you've talked to them.

STEPH: The what lab?

SPEAKER 1: AgeLab? Age.

STEPH: Age? Like, A-G-E?

SPEAKER 1: Yeah.

MARTIN: What do they do?

SPEAKER 1: Well, they do a lot of stuff related to how people are aging. But they also have a big group that's working on the autonomous vehicles, less so on the technology side, but how it's affecting people. So they have a lot of experiments where they're letting people drive autonomous cars and recording them with their consent, and they're trying to get knowledge about how people are interacting with these technologies, what changes it could have, what negative changes it could have.

So they showed us a video of this guy who was looking down at his phone for like two minutes while driving on the Mass Pike, which is terrifying. And so as we transition from a not quite autonomous vehicle to a fully one, he was talking about how he expects to see more accidents in the near future, until we get to the point. So I think people are thinking about how these technologies and their developments affect things other than just how we're getting from place to place. It's not such a simple story.

STEPH: And would you mind elaborating? The reason I bring up this point, and why I've been thinking about it so fully, is because Bill assessed that a very important component of driverless vehicles is the impact that it's going to have on the workforce, on truck drivers, and on delivery laborers. Do you think that those are considerations that have been raised vis-á-vis driverless cars? And do you think that there is maybe a role for someone to be highlighting that as an issue within each innovation team?

SPEAKER 1: Yeah. I feel like that hasn't been as much of a focus in our work. People talk about it, but no one really talks about-- they're like, that's going to be a problem.

[LAUGHTER]

And that's the end of the discussion from what I've seen so far. But I do think that, especially after this election, people are talking more and more about disruptive technologies. I hadn't heard people talk about it much. But then I was listening to a podcast today where someone was like, I noticed in *Logan* the movie--

CHLOE: I was just about to bring that up. Oh my gosh.

SPEAKER 2: Wait, if you spoil it, I swear--

SPEAKER 1: I haven't seen it.

[LAUGHTER]

SPEAKER 2: I haven't seen it.

MARTIN: Cover your ears.

STEPH: Me either.

SPEAKER 1: In the movie *Logan,* apparently-- I haven't seen it, you might do a better job describing-- but there's a scene where there's all these trucks around. And none of them have cabs, because they're driving themselves. And there was a senator talking about this. And she's like, wow, this really could happen. And then what happens to all of these truck drivers? I never thought about it until I saw *Logan.* So I think that's interesting how it's permeating through--

WILLIAM BONVILLIAN: So I want to hold this discussion until next week's class, which is about the future of work. I mean, it's exactly like-- it's about this problem. So we've gotten it on the table. Everybody's going to have a chance to think about it.

SPEAKER 1: Watch *Logan.*

WILLIAM BONVILLIAN: And you can go back and watch *Logan.* You can recount your favorite stories. But, Steph, do bring this up again when we go after these issues next week. But focus us more now on Katz and Goldin and Bamol, if you would.

STEPH: OK.

WILLIAM BONVILLIAN: Thank you.

STEPH: I have been redirected.

WILLIAM BONVILLIAN: I'm not trying to silence you, Steph.

STEPH: No, no, absolutely not.

WILLIAM BONVILLIAN: I promise you airtime in the next class.

[LAUGHTER]

STEPH: Well, I think-- I guess one of my critiques of my social science education-- and I think this is generally my critique of social science education generally-- is that there are benefits to talking about an issue, but there's only so much that public discourse can get you, especially in a round table setting, in an academic environment, where the most of us start to feel like, for the most part, are on the same side of an issue. So I struggle to come up with good questions and think about what might actually be meaningful, as we're having a conversation about an issue as large and as difficult to grapple with as inequality, especially as Katz and Goldin purported.

But I think one of you talked about how, relative to Bamol's analysis, if America should shift towards a focus on primarily promoting breakthrough innovations, where we can still maintain competitive advantages in the research and development system rather than even concerning ourselves at all with the fixing of the education system or the fixing of the R&D pipeline.

And this sort of hints at a question that Matt had asked earlier in the semester, where he said, is the impetus on us, as a civil society, to educate everyone? Is that even advantageous to us? Do people even want to be educated? And what are the benefits? And making this resource available to all, when it seems like we're already failing spectacularly at this experiment that is the United States of America.

MARTIN: I don't think we're failing.

SPEAKER 2: Yeah.

MARTIN: It's 300 years old, and that's relatively short. We're still figuring our stuff out, in terms of nations, right?

SPEAKER 2: Yeah, I'd say we did pretty well. We're not great, not anymore. But-- so let's make it great again. [LAUGHS]

MARTIN: I think it's kind of like bubble thinking, like people losing their minds in sensationalism. I think it's more like-- because their argument's pretty much like-- it's like saying, oh, yeah, we have a McDonald's, everything's set up to do McDonald's. But look at Chipotle. How do we make McDonald's, the burger, be Chipotle, right? It's like you really can't change one system to a whole new one. What you do is you have to make Chipotle, and then make Chipotle a poppin' chain.

[LAUGHTER]

You have to go and make the next system--

SPEAKER 2: Poppin'?

MARTIN: Yeah.

WILLIAM BONVILLIAN: I'm going to use this metaphor, Martin. It's good.

MARTIN: I mean, because people are freaking out. It's like, this hamburger just can't be a burrito. And I'm like, why? Well, the whole infrastructure is made to make hamburgers, right?

STEPH: Well, see, and I think that at the heart of what you're saying, to sort of elucidate where I'm coming from in asking this question, there is an education professor who I grew close to during my time at Wellesley, who in his first year of his PhD program, his advisor posed to everyone, if you had the option, would you blow up the education system and start again or would you change it incrementally? And his answer was blow it up and start over.

But we don't have that option. We don't have the privilege of bringing in the Chipotles and then seeing if they work, and then adopting all the McDonald's to suit that consumer market, right? We very much recognize that students are humans and that humans have a very particular ethic consideration than do technologies or other kinds of research and development projects.

So if we are to meet the kinds of goals that Goldin and Katz and Bamol and Freeman are advocating for in improving our education system, how do we deal with the fact that these are human lives with whom we are experimenting?

MARTIN: I think it's a good point, but I'm not talking about that. What I'm trying to say is like, what are we defining as education? Are we defining education as I want people to know math and science really well to communicate it, to think innovatively in it? Or are we defining it as like, we're going to get out of a four-year college, right?

So I think a lot this argument is, the current infrastructure or the relationship for the last 100 years has been colleges. So we define education as graduating a college. But if you make it as, I want to make the best, most educated person with all my tools right now, and being able to import them into society well, in terms of into jobs really well, how would we make that ideal system? You start making that system. And it's not going to change overnight, right? You don't grow up two years old and the next day you're-- I mean, there is the movie *13 Going on 30,*

but it's very rare, right?

[LAUGHTER]

So I think it's you start making the new system and you kind of start to pour over. There's a whole issue with trying to change a current system, because they're already playing-- well, this happens with later, mature markets. What happens is there's going to be three or four or five players, right? So when we talk about institutions, we have Harvard, MIT, Stanford. They're trying to fight against each other, because they don't want to-- it's hard to be different when we have to compete against someone like that. And so they have to play their games. The reason an innovator can come in is because they don't have to play that keeping-up-with-the-Joneses games. That's my point.

SPEAKER 2:   You're throwing out a lot of metaphors.

[LAUGHTER]

STEPH: Yeah, [INAUDIBLE], Chipotle--

[LAUGHTER]

LILY: *13 Going on 30.*

MARTIN: So there's a whole book on communication where it's like, if you make-- I could explain it in a super technical way, but you're not going to get it. And I can say something like that, and you'll be like, OK, kind of.

WILLIAM
BONVILLIAN: Well, we're--

[LAUGHTER]

MARTIN: The other thing is that you won't forget it, because it's so out there, that you're like, OK, OK--

SPEAKER 1:   Chipotle.

MARTIN: You guys are going to remember the three points, right?

SPEAKER 2:   Well, no. I remember that Chipotle versus McDonald's was discussed. I don't know--

MARTIN: OK.

WILLIAM BONVILLIAN: Well, you know, let me say something here too, which is that we are going to dig into the textbook reading on legacy sectors, because there's no question, but education, and higher education in particular, are legacy systems. And the whole issue of how do you bring change into legacy systems is kind of an underlying theme here. So I'm glad we're right at the brink of trying to figure this out.

I guess I would posit that the meaning of Freeman's reading for us, I think, was that there are real economic consequences to your leadership in the science and engineering talent base. And that Katz and Goldin take us to kind of a next step and enable us to address a larger set of societal problems and tie it significantly to the education system.

In other words, the growing problem of the polarization of our society and the growing income inequality in our society that will affect the quality of the democracy, and probably already is, that's very much tied to these curves here and what portion of the population we're moving onto that upward technology curve and what portion of the population we're leaving behind. That's the meaning of that crossover point in the 1970s. And what are the policies that would really address trying to get those lines back into parallel, right? Because that seems to be a pretty important societal problem.

So Freeman identifies a set of economic issues that draw us to be concerned with the science and engineering talent base. And Katz and Goldin tell us, by the way, there are very deep societal well-being problems that are tied to the education system as well. And then Bamol points to us and says, by the way, these folks are studying the higher education system, but that's not the only route here. We have to understand this other dimension if you want to introduce innovation into the overall economy. Education for incremental advance is probably not the only system we ought to be worried about.

And that's kind of what Steph's round of questions here was driving at, I think, if I've interpreted you right, which is what is that more disruptive education system that we have to contemplate here if we want to educate not only for incremental advance, but for true innovation as well? Is that fair? Sort of.

STEPH: Yeah. I think if I were to have one last maybe point or question, I would ask if any of you read--

WILLIAM BONVILLIAN: Yeah, why don't you make some key points in your mind about what these pieces mean. You just heard my version, but--

STEPH: Yeah. So I guess I last started off with a straw poll. As you know, I favor these. How many of you have heard or read *Pedagogy of the Oppressed* by Paulo Freire? Do you know what pedagogy means?

LILY: Maybe Martin can explain it to us with--

[LAUGHTER]

WILLIAM BONVILLIAN: I'm going to rely on Lily for this one.

STEPH: Yeah. So was there anyone who had read *Pedagogy of the Oppressed?* Have any of you ever taken a course in education, education policy? How many of you have very strong feelings--

WILLIAM BONVILLIAN: Except for this course, of course.

STEPH: Except for this course. How many of you feel like you're stakeholders in a conversation about the change in national education policy or in state education policy?

SPEAKER 2: OK, I think we found something.

STEPH: OK. Who feels like they're a stakeholder in the education policy realm?

SPEAKER 2: I mean, don't we all?

MARTIN: A stake stakeholder or active stakeholder?

STEPH: Like an active stakeholder, like you're willing to show up to Congress, to go to protests, to talk to legislators, blah, blah blah, blah, blah. I mean, that kind of highlights, to me, the divide between the kinds of stuff that Goldin, Katz, Bamol, Freemen, et cetera, are talking about. And this is, again, hinting at my issues with the way in which we teach social sciences. That so much of the Socratic method, which is essentially Bill explaining to us what it is that we read and then having us flesh it out and debate in a lively and analogical way. The Socratic method is to get us thinking about what this means truly in implementation and how to grapple with theory.

RASHID: I think, yeah, as you start bringing that up, it might have been maybe instructive for us to have

a couple of readings by a couple of states who are grappling with education issues and grappling with some issues, particularly those that are like, I am the lead administrator, I'm in charge of the education for maybe the city of Chicago versus the state of Illinois, and how they're actually going about grappling with these public institutions trying to change these things.

Because it's really nice to kind of look at the macroscopic level and be like, OK, we're not graduating enough [INAUDIBLE] science and engineers. But in reality, education, as we said, because we have this really distributed model in the US compared to Sweden, it's like, I'm looking at this not only community college by community college, but state by state. And that's how folks sort of interact with these education issues.

And I think maybe to Steph's point and what I'm trying to get from her is like, you have these active stakeholders that are really involved in their small pools and might have a little bit more of an effect or a lot more ideas on how to innovate within their small pools to get to this state where we want breakthrough education in addition to incremental advances.

And so I think my recommendation would be, is there someone maybe in this *Pedagogy of the Oppressed* book they could offer an alternative opinion. Are there folks who do education professionally and who do educational administration-- do they have these same thoughts and are they worried about these same things? And are they trying to look at these problems at the same level?

STEPH: And are their opinions-- and I think this is a crucial point for me-- are their opinions respected? Because a PhD from the Stanford Graduate School of Education or the Harvard Graduate School of Education does not mean the same things to most people as a PhD in material science from those same institutions. And that concerns me, right? Because if it's the individuals-- there's also, I guess, an undercurrent in education, and we have mentioned it before in this class, of those who can do, those who can't teach. And it is that sort of point of disrespect that we got at at the beginning of class that I think merits far more consideration by this group than do perhaps the contents of the economics readings by Romer.

Because if we, ourselves, are not convinced that teaching is a worthwhile profession and that the education of young people is a worthwhile activity, then who can be convinced of that if we are involved and invested in the promotion of more equitable education of science and technology? Because we know that that's the key to driving economic growth, and also

prosperity and decreasing inequality.

And so that's why to me, when Bill says that Goldin and Katz are talking about what are the policies that would address us getting back to a more equitable economic system, to me it's not about policies, it's about culture. It's about our perceptions of other people and what they are doing with their lives and about our distancing of ourselves as, but that's not my issue, that's not my problem, right? So I think it's unfair and a little bit intellectually irresponsible of us to claim that distance while also critiquing it. So I would posit to all of you that, if you have time in the next maybe two or three years to pick up this book, *Pedagogy of the Oppressed* by Freire--

MARTIN: What's the book about?

STEPH: It's about the education system in Brazil and about the ways in which students have been disregarded by the system and conceived of as passive recipients of knowledge rather than as active learners. And the metaphor that he utilizes is that they're receptacles, and that we dump in knowledge, and then we expect them to regurgitate it out and to be able to apply it in the field. Where as his understanding of pedagogy, which is the study of teaching and the study of learning, is that individuals have to grapple with something.

And that's sort of at the heart of what Lily will be talking about in the MITx reading, when they start talking about Seymour Papert, who was a brilliant professor and researcher at MIT who created the field of constructionism, which is the study of something by doing the something. And that is actually being very widely adopted in Southeast Asia in countries like Singapore and Thailand, who are experiencing momentous economic advances in the research and development sector. So I think very much pedagogy and considerations of culture become really relevant when we talk about education.

LILY: Well, I think we need to get back to dollars here, though. Because if you're head of household, single parent, or single-income family-- who in here thinks that you can have a family on a K through 12 teacher's salary? You can't. And even if you're-- yes, the average K through 12 teacher salary is higher in, say, Los Angeles than it is in central Illinois or rural parts of the US, so they compensate for living expenses, but you still cannot be single parent head of household on K through 12 salary.

So sure, you can think that K through 12 education needs to be reformed, you can be passionate about teaching. But if you are financially responsible for a family unit, you can't be

a teacher in K through 12. It doesn't matter how much you care about it.

MARTIN: There's a part from the reading that was like-- I think they needed 50 hours to get a $1,000 or something like that [INAUDIBLE].

WILLIAM BONVILLIAN: So I'll tell you what I'm going to do. I'm going to push us, so we can get out of here at a reasonable time level. I'm going to do the last reading from our textbook, and then come back to the MITx reading.

MARTIN: Yeah, we need more graphics, Bill, because all these have been so great.

WILLIAM BONVILLIAN: I figured I'd put myself up here.

MARTIN: Did you get Michael [INAUDIBLE] to do it?

WILLIAM BONVILLIAN: I had to really struggle with this, Martin, I can tell you.

[LAUGHTER]

So, look, here's what's different. So new technology innovations are very slow to enter legacy sectors, right? Remember discussing energy? We invented fire-- I don't know how many millions of years that took. Then, we burned trees. We did that for a millenia.

RASHID: I think the word invented was hastily used.

[LAUGHTER]

MARTIN: Discovered.

[INTERPOSING VOICES]

WILLIAM BONVILLIAN: Shall we say lightning struck, right? And we moved to coal, right? Moved to coal, and then we moved to oil. And that's about as far as we've gotten, essentially, since that time.

SPEAKER 2: I mean, the rate of adoption has increased exponentially. So I think we're doing OK.

WILLIAM BONVILLIAN: Yes, compared to wood.

MARTIN: The population, too, has gone up.

WILLIAM BONVILLIAN: So similarly, another legacy sector, higher education. What was the last really big reform in education? So we went from--

STEPH: Allowing women to participate.

WILLIAM BONVILLIAN: Well, that was an advance. There's no question about it. But we had the platonic academy, and then a momentous breakthrough around 1500 years later-- we came up with the book. That was clearly a great breakthrough. That's, from a technological advance period, that's about it, until we finally figured out how to use this kind of stuff. And we're starting to figure out how to bring that IT revolution into the classroom.

So that presents-- if the issue is bringing change into this system, technology, obviously, can be a change driver. And that's an interesting story. That's not the only change and reform story, as you just pointed out, Steph. There's other important changes that have to be considered. But really, within the last five, six years, we've actually seen the entry of IT-type tools into the classroom setting with potential momentous change.

So there's an open question here about whether MOOCs and online education are going to be a disruptive innovation and whether they will disrupt higher education and substitute-- in effect, create a new model. Is this a Chipotle replaces McDonald's kind of approach? See, I told you I'd still hear your metaphor, Martin. And how will higher education respond? Will it respond with a blended model? Or will it attempt to keep its existing model? So we'll talk about that for a minute.

As we've seen, universities present a deep problem for this kind of disruption, because they are legacy sectors. And like all legacy sectors, they tended to resist disruptive change. Institutions of higher education conduct almost no R&D on education itself-- almost none. It's astonishing. The services sector, generally, are not particularly good at this, but higher education may lead the pack.

There are very perverse pricing issues in higher education, as you all are paying tuition at the moment understand. It's a very decentralized model. It's very hard to spread change and spread new ideas, to transition new ideas, because this is a very decentralized system. In legacy sector terms, there's a collective action problem. How do you get collective action across literally thousands of institutions? And I'm just focused on higher education at this point.

There's a whole additional story for online and the K through 12 sector.

What's happened? You all are familiar with edX, the entry of a nonprofit model here. And frankly, I have to give tremendous credit to Rafael Reif, because I never thought universities themselves would originate potentially disruptive changes for themselves. That kind of violates my rule set. But Rafael basically, personally, drove a fair amount of this.

And his background-- he was a poor kid growing up in Venezuela and from a family that had not sent children to college. And he managed to get to go to the technical college in Venezuela. It was a real breakthrough for him. And ends up at MIT through a series of miracles and becomes president. And he thinks all the time about that community that he left behind. I know from knowing him and conversations with him just how he saw this online education model as a remarkable new tool to get education and educational platforms everywhere.

I mean, it is a remarkable new entrant possibility in education. And he did this, frankly. He drove the creation of edX. And there were corresponding examples coming out of Stanford Udacity and Coursera in a comparable period. But he wanted to do a nonprofit model, because he thought it would be better-geared to this mission of significantly improving education everywhere, that a new tool set would be at hand. Suppose kids like him growing up on sandlot baseball lots in Venezuela could have had access to MIT courses, right? What would that be like?

So that was his story, and that's the story behind the creation of edX. And the nonprofit model enables certain kinds of things. A for-profit model enables other things. But one of the interesting features of edX is that it is an open-source model. It's an open-source technology platform. And people contribute and constantly build up the quality of the technology behind the model. It's harder to do that in a for-profit kind of approach. It's still finding its way towards a business model, and we'll talk about it. The other major MOOC providers are listed here. You're familiar with them. They're on for-profit models.

The political world took a look at these MOOCs and had different ideological reactions. On the right, to some extent, they saw an opportunity of these free online educational courses as an opportunity to get rid of these pesky left-wing universities that are constantly training the wrong people. On the left, there was a sense that, oh, we can finally get rid of tuition, have the Bernie Sanders free tuition dream, because online education doesn't cost anything, and we'll just do

that. Obviously, that's a little bit of magical thinking here on both sides. But states have begun passing laws, doing things like requiring $10,000 BAs and comparable kinds of issues.

But the deep question here is, what's going to happen to the residential campus? Is online just going to displace this whole thing? And if not, why not? So online, I think as all of you understand, it can do some things really well. It's a whole new tool set for visualization, for representation. It offers incredible opportunities for reinforcement and assessment that a lecture can't do. You can use feedback loops and repetition to do continuous assessment, which there's no way your standard college and university lecture class can ever replicate those kinds of capabilities, and they're pretty important.

So online is going to have some features that are better than what lectures can do. And then, potentially, if you move the lecture online, then you can free up your classroom for much more interchange and interpersonal kinds of communication and more of the learning by doing opportunities that Steph was suggesting. So maybe it frees up what the classroom could become.

Now, vital educational elements remain face-to-face. At least at the moment, online can't replicate these. So oral expression, oral presentation, advocacy skills, the way in which you have to organize your expertise to be able to speak about a subject area-- face-to-face can do this. It's really hard to do that effectively, at this point, with the technology online.

Written analysis-- so far, online writing evaluation leaves a lot to be desired. Research-- look, in the end, you really do research on lab benches with colleagues. It's still quite face-to-face. And you can replicate some of that through simulation and modeling, but a lot of it you can't. So there's a lot that probably needs to stay on the face-to-face side. So these kinds of skills.

Learning requires a lot of human scaffolding for discourse, argumentation, mentoring, for making the case, for research, for making the conceptual leap. And a lot of what occurs in the classroom, the socialization process of the classroom drives a lot of learning-- the kind of back and forth, the kind of competition, the kind of connections between people, friendships that build, the kind of community feeling of a class comes together. Those are very powerful learning aids. These are very powerful learning tools. And obviously, you can't get that stuff sitting in a basement in front of a blue screen.

So the real question here is, how do you optimize the two sides? How do we let online do what it does best? And how do we let the face-to-face piece thrive and do more? That's really the

opportunity that we now have, is to completely restructure education with a whole new tool set that, in turn, will enable that face-to-face education to kind of rise to a new level. That's the dream. That's the hope. That's the reform this potentially enables.

So it's a human machine symbiosis, remember? It's JCR Licklider. Let the computer do what it's good, and let people do what they're good at, and you have a symbiosis of the two. That's what we could get in education now. That's the opportunity space. And that's a blended learning model.

Now, the technology is going to change, and it's going to get better at some of these things. But that's an ongoing and extended process. What happens to the university? For a long time, newspaper journalists were writing articles, oh, ha, ha, what's going to happen to universities is what happened to us as journalists. All our newspapers went out of business essentially, right? Ha, ha. It's going to happen to you too, see? This online revolution is going to drive you under.

It's problematic if we do that, because frankly, universities create the course content. They are fairly important institutions, after all, on the content side. They're research engines as well as teaching centers, so we kind of need that research in the American system and many other countries. We blend the research model and the teaching model, so that there's a lot of learning by doing, more so in the graduate education phase, but there's a lot of learning by doing in that system. So you need these institutions for that stuff.

And if you use the model to drive the university model under, you've got these underlying really deep kind of problems. So there's a question about whether or not universities will adapt. And part of that story is bringing learning science to online education, and we're going to get to that in just a minute.

The online revolution does create incredible opportunities. We talked earlier about the possibility of worldwide availability of high-quality education. It's not a blended model, but it's pretty good. It's pretty good material. You can learn a lot from it. That's a staggering new opportunity for education worldwide. And that's precisely why Rafael Reif pushed this effort. That was the vision that he saw, frankly. Martin?

MARTIN: OK. So the US probably won't do a DARPA for education. But I was thinking a lot, especially when talking with this about JCR Licklider--

WILLIAM BONVILLIAN:	Mm-hmm.
MARTIN:	Is that right?
WILLIAM BONVILLIAN:	Yeah.
MARTIN:	I always want to say Licklicker.

[LAUGHTER]

So what if they did a little special institute that just focuses exactly on what the vision is? Because JCR focused a lot on the vision of what ARPANET would be, so the vision in an ideal education world. Which I know they have that as an initiative, but have that DARPA intensity with project managers and moving initiatives forward.

WILLIAM BONVILLIAN:	I mean, it's an interesting idea. And there was discussion of creating a DARPA within the Department of Education. I have to say, I was skeptical about whether that could work, because there's no real tradition of R&D in the Department of Education. It's really quite limited. And would they understand the model enough?

Interestingly, today-- or yesterday-- DARPA issued a broad area announcement for, you guessed it, develop a learning machine for lifelong education. That's the challenge, right? So DARPA is now in this territory in some very interesting ways.

And actually, the military is in this territory. The military has done more than any other organization by far to use computer gaming as a training tool, right? And computer gaming, as you all understand probably a lot better than I do, operates on an education kind of model. In other words, learning that game is a very complex process and is acquired over time. And a good game gets that flow right of helping introduce the new elements of the game to you and the learning that the game requires in manageable steps, and then reinforcing that and reiterating or put you back in the feedback loops so that you get it, and then driving you to the next stage of the game. That's a very interesting potential educational tool.

Probably some of the best work in the country that's being done on that is being done by Eric Klopfer here at MIT, who's developed a whole new set of education games for K through 12. I'm surprised that industry hasn't moved in on the sector. I think it's gradually starting to

happen. But that's an interesting part of this story, because the only story here is not MOOCs.

MOOCs came about because a whole bunch of computer nerds at places like MIT and Stanford saw, wait a minute, we got broadband around the world. We have a whole new delivery mechanism. We've got a whole new tool set. Let's do something. And they rushed to fill that void. And edX was created by folks out of our computer science department. Rashid? Go ahead.

RASHID: Yeah. So it might be instructive-- I'm going to go from past to present. But it might be instructive to take a look at, when we figured out the printing press was a thing and we could mass print books, who was the one who decided how do we change maybe from a Socratic teacher-student-apprentice relationship to teacher and then large lecture hall? What were the driving initiatives? Or who started with these large lecture halls and these same maybe Licklider-based vision for how is education going to look once I have a textbook? And so now, how is-- you need the same people to start taking a look at, how is education going to look in this blended learning model? And I don't know-- even if MIT or Stanford and all these people have any sort of idea of what that vision for that blended learning model is.

WILLIAM BONVILLIAN: Well, I think we're starting to look at it in a pretty serious way here and a number of other places, as well. Good intellectual work is ongoing. Let me close off with a couple of points about this. And let's be sure to hold on to your question, because I think it'll be particularly relevant when we talk about the learning science piece too, Rashid.

One thing that we're learning about these MOOCs is, how many people want to go and sit in front of blue screens in their basement and take a one-off course?

MARTIN: Bill Gates.

WILLIAM BONVILLIAN: Maybe Bill Gates.

[LAUGHTER]

I have to confess that I probably came to college because I wanted the degree, right? That's probably why I took all those courses in the end. I wanted something that would translate into economic gain for me. That's obviously a profound motivator. So platforms that are organized simply around offering one-off courses without a coherent framework, without a resulting credential, that's not a very good economic model. So the MOOC offerers had been very

much moving in the direction of trying to find some kind of certificate that will certify that you've accomplished something.

So a lot of people will be just interested in content. And I've certainly taken MOOC courses just because I was intrigued with the content. But a lot of people are going to be motivated by that credential. And MOOCs are moving in the direction of offering credentials for completing things. I mean, Georgia Tech and Udacity have a master's degree in computer science now, which is available online at a remarkably reasonable price-- far low in class, on campus tuition levels.

MIT is, in a very innovative way, doing these mini master's courses. I think we did one in an area MIT is famous for, which is supply chain management. And there's several more to come. The D-Lab has just picked one up or the world development community is doing one. There's going to be more at MIT. That's a very interesting model. You get a, quote, "micro master's certificate" for completing the course. And you pay, because there's got to be assessment, and that costs. Somebody has got to do that assessment, so that's going to be a cost. So you pay a modest amount for that assessment, and you take a year-long micro master's course. And then MIT, if you've done really well-- MIT will accept you for a semester on campus.

Now, they can only offer that to a modest number of the thousands of people that are getting the micro master's degree. But interestingly, other universities now, once you complete the MIT micro master's piece, they are enabling you to come on campus and get a real master's in the course of an additional semester of work. So that's a very interesting model. That's obviously much more of a blended model. You get a lot of content and information, which online is pretty good at on the online side. And then you really come in for an intensive classroom experience, which is much more the way in which they designed the micro master's here. When you do the real master's, it's much more learning by doing. Steph?

STEPH: Well, I just wanted to note that a similar model exists at the Harvard Extension School, except it's obviously in person. The extension school is perceived as a back door into Harvard in the same way that you can take one-off courses at MIT if you talk to a professor and they approve you. So there's lots of opportunities, I think, to take a look at Harvard's extension school model to think about how blended learning might happen.

WILLIAM Right. And MIT used to have an extension school in its early days, called the Lowell Institute,

BONVILLIAN: which is essentially an adult education program that was available for citizens in Boston-- very innovative and interesting, on its old historic campus, right across the river in Back Bay. Somehow that got lost in the process. But in a way, MIT has just opened a whole new school. That's MITx. And it's a massive--

MARTIN: It's very global.

WILLIAM BONVILLIAN: --worldwide global extension school. So there's a whole new school here. We just haven't fully recognized it yet. And, look, lifelong learning may be the best application. Because in lifelong learning, in theory at least, you've already learned those explanatory skills, those oral presentation skills. You've already learned those writing skills. You've already got a lot of those fundamental pieces, which are largely a part of the undergraduate education scene, but also part of the high school scene. In theory, you've got some of those down.

And then what you're in for, after doing work in a relevant area, you're in to enhance your career or skill set in a lifelong learning setting. The average age of a student at a community college is 29. In other words, they're already in the workforce. 40% of what community colleges now offer are certificates in quasi-professional areas that, in effect, certify to employers that you've got an additional skill set.

That's very interesting, that lifelong learning opportunity to upgrade your skill set and qualify, for you, a new set of career areas. That's a really important feature. That's a really important problem for those people who got left behind through this failure of our higher education system to graduate enough people. That's a really interesting, promising option for what online can help us with. And lifelong learning may be the best tool we've got that MOOCs and online education can apply to.

So those are some features of what online education may offer us. The economic model, we're still feeling our way. What's the business model? How are these cost centers going to justify themselves? We're not there yet, but it looks like this certificate, micro master's kind of stuff is probably a good way to do this. Lifelong learning may be another very good way to do it.

Will universities be willing? In other words, we're sort of at a situation now where universities offer a bunch of MOOCs over on one side, purely online. And then they're running their same old university with lecture classes. And nothing really changes. Because as we've discussed, the blended model is what's key to the reform, because that will drive a new kind of classroom,

the kind of cultural change you're talking about, Steph, right? It could be a driver for this.

So unless universities are willing to really think hard about the blended model, then we won't get the revolution that we really need, a kind of transformation of what goes on in the classroom, and then full utilization of this whole new tool set that gives us essentially information and content access. So we're still going to need-- and the term, think you were looking for, Steph, in your argument, and it's a term that we use in the legacy sector analysis, who are the change agents going to be? How are we going to drive change here? And then that gets us into our next reading.

MARTIN: Well, but you'd also change the university business model. Because I know when I was on the executive board for my fraternity, we were looking at a lot of internal reports for MIT. And they make a lot more money off of grad students than undergrads usually. So potentially becoming more of-- because MIT is pretty much just a research institution.

WILLIAM BONVILLIAN: Well, MIT provides huge subsidies to graduate students in a massive system of fellowship. So they're not paying tuition.

MARTIN: But they end up doing a lot of prolific work that MIT is known for and research studies.

WILLIAM BONVILLIAN: In term of the research side, yes.

MARTIN: What is the output of the institute? So ideally-- or the way I've seen it usually is--

WILLIAM BONVILLIAN: Yes, research output, graduate students are core. But tuition, believe me, undergraduates are key.

MARTIN: But I feel like a better business model would probably be getting government funding for certain research that has to happen for the government or something like that. I mean, you get a lot more money that way.

WILLIAM BONVILLIAN: Right. We'll see. I'm not yet clear who is going to drive this revolution of blended learning education model. MIT is now exploring it. I mean, there's over 90 online classes. And over 90% of MIT students-- you all can tell me this is true-- according to my friend Sanjay Sarma, VP for online learning, Sanjay says 90% of undergraduate students now have a blended learning experience in their undergraduate careers. Does that sound right to you all? OK, I'm reassured.

Let me try to lay out, and then we'll have 20 minutes plus for discussion. The authors of this 2016 report on learning science were Sanjay Sarma, Karen Willcox at AeroAstro, Eric Klopfer, who I mentioned before, Philip Lippel in my office in Washington.

The new online platforms, as I said a little earlier, came out of computer science departments, because they saw these incredible broadband access opportunities. And believe me, they were real. I was in Egypt about four years ago teaching at the American University of Cairo for about 10 days or participating in programs there lecturing. And I realized that the availability of these things is a complete worldwide phenomena.

And I asked my Egyptian friends, how many people in your country do you think have access to an iPhone? They thought about it, and they said, well, you know, between friends and neighbors and connections, we probably have well over 80% of our population with access to iPhones. So in other words, this is a pretty poor developing country. That's an astonishing access system. That's an amazing access system.

There's a whole new delivery vehicle out there. And the computer science departments, logically, saw that first. So they realized there was a new tool, and they raced to create content to do that, largely just videoing classrooms, right? And what this group felt was, look, we better figure out how to optimize the online education pieces that we're now doing. How do we understand what's been happening in cognitive science and learning science, which comes out of the education side, and the neuroscience, and take advantage of what they've been learning about learning in the last 15 years and try and embed those capabilities for better learning into our online courses? It was a great aim, because the MOOC development community hadn't frankly, seriously, in an organized way, thought about this. So this report made a real contribution.

And there's now a whole research community. And I attended their annual meeting last month at MIT. And it was a community from all over the world. Universities from everywhere were present. It was fascinating.

So there were four key recommendations. Integrate learning science from education with cognitive science and neuroscience. These are disciplinary communities that never talk to each other, that are in no communication. They're coming up with significant territories, and there could be a lot of benefit from crossover. So that was one of the points.

Optimally structured online courses and modules can be an important facilitator for higher education, emphasis on optimally structured. So there are all these phenomena. And this report looked at a number of the phenomena that affect learning, like mind wandering, segmenting learning into more bite-sized, understandable, manageable pieces. Retrieval learning-- in other words, what's the right mix between study and test-- the reinforcement mechanism. How do you do space retrieval? In other words, recovery of information over an extended period of time. How do you optimize that? What's the role of curiosity? Can you use that as a driver in the learning space?

So they began to look at all of these phenomena, which have actually been studied in a number of these fields, and attempted to incorporate them in. I'm not going to try to wander through each one of these elements. But here's some of the literature.

And the MRI scans show you mind wandering. I mean, different parts of the brain are zipping around the different territories. And it's a phenomena that needs to be accounted for. It's a very natural phenomena. Mind wandering is-- it's Darwinian. It's very important for our minds to wander. If we're able to completely stay on topic, the saber-toothed tiger would probably leap through our thatched cottage and finish us off. We've got to be keeping an eye out for the saber-toothed tiger.

So this is very Darwinian. It's an important skill to have mind wandering and the ability to move from topic and area to area. It's an important part of the creativity of the brain. But it's been viewed, historically, as an enemy of learning. Teachers want students on the task for that full time of the classroom experience and are worried when they get distracted.

So how do you do this? One approach is to segment learning into bite-sized pieces. So we attempt to do a bit of that in this class with 10, 15 minutes of talking head, i.e. me, and then turning the discussion over to you all. So that you've got varying things occurring, and you never have much more than 10 or 15 minutes. And it probably should be 8 to 10, frankly, on a single presenter. And then you move to attempt to absorb the material in the discussion and have folks who were presenters of that material develop the content themselves.

SPEAKER 2: What is that graph?

WILLIAM BONVILLIAN: Hmm?

SPEAKER 2:   What is that graph?

WILLIAM   You know, it doesn't quite match exactly what I was attempting to show to you. But it does
BONVILLIAN: attempt to show a tutorial versus a lecture model and what the median time frame is in any
given limit. So in a tutorial, one-on-one setting, you can see that there's more focus on topic
over an extended period of time. Whereas your median point starts to switch in a lecture
model and gets shorter. So frankly, tutorials are a better way of learning than a lecture. But it's
a fairly unaffordable model.

Another lesson-- retrieval learning. The study-study-- in other words, you study and then you
study, right? You study and you study it again versus you study and then take a test about it.
And over what period of time, which works best?

So if I was imposing this graph, we'd have a test every week, just so you know. I'm sparing
you. But that would be the optimal model. This is one week retention-- study-study, 42%
retention, 56% versus study-test. In the words, being forced to regurgitate and focus on the
material definitely does serve a learning purpose.

Curiosity does make a difference-- in other words, if you can bring curiosity into the game. And
there's something famous in education called an Ebbinghaus Curve, the forgetting curve. In
other words, people forget. After about a week, it's history. And maybe after a month you
remember some vague outline. So there's a profound forgetting curve in the human mind. And
can you do spaced retrieval to try and change that curve to retain it longer? These are all
fundamental issues in learning that this report attempted to start to grapple with, as you saw.

Recommendations three and four were to support the profession of learning engineer. So MIT
got into this situation where, first of all, there's a lot of faculty resistance on every faculty of
these online courses, because the faculty is thinking, this stuff's going to put me out of
business, they're going to take away my job. So there's always a lot of anger, frustration, and
resentment when the online course arrives.

So MIT very cleverly attempted to get some of its top-noted teachers to take on online
courses. In other words, if the most respected of your peers are doing these online courses,
how can you complain? That was a model here. And they were able to do it on the sales point
to the faculty member that, hey, how many people have you taught in your lifetime at MIT? A
few thousand? Your first course is going to have 30,000, so you're going to be famous. That
was the sales pitch. That's an attractive pitch.

So MIT got its senior faculty and most respected faculty teaching the early suite of a lot of these courses. And that was interesting. And then they had this experience, right? They gave their best lectures, and then they built in all this assessment and the 10-minute rule and all this kind of stuff into the class, and they had to completely redo their lectures to fit all the requirements that Sanjay Sarma and the edX team was forcing on them. So they had to rewrite all their lectures to fit the new formatting. And then they gave their course and they put it online, which, of course, every student can take.

So then they go back to the regular semester, they're giving their lecture class, no one shows up. They've all taken the class online already. Why are they going to show up? So then the faculty member realized, I'm going to get zero attendance here unless I develop a completely different kind of content. So then the faculty members started to, in interesting kind of ways, rethink what the content was going to be in the actual face-to-face classroom.

That's not easy for a faculty member who has never looked at learning science problems or studied MOOCs and studied the technology. So MIT began equipping them with graduate students were really interested in this stuff, who wanted to use it in their own teaching experiences and decided to dig in, realizing they would be better teachers and potentially more saleable if they had this kind of background. So these what MIT called "learning engineers" were assigned to the faculty member.

Now, the faculty member was willing to accept the graduate student, if the graduate student was studying in their field. In other words, they respected the graduate student for having mastered the professor's own territory. They weren't interested in having graduate students, know-it-alls, trying to dictate to them from a totally different field. But they were prepared to accept the graduate student, if the graduate student had already shown mastery of their own fields. That was respected learning. So that was another piece in this learning engineer experience at MIT.

And it's worked, so we created this whole community of graduate students. When we talk about how to bring about the revolution, a whole bunch of graduate students now at MIT are getting experience as learning engineers, helping these ossified faculty members, like me, learn how to do this fancy MOOC, online, blended learning, change around your face-to-face classroom, optimized learning experience stuff. And that's, you know, these are all change models. These are all potential ways in which change agents can operate.

But there's a very deep question about, how do we do a change model within a higher education legacy sector? Because it's a very decentralized system. And MIT's learning lessons, and other universities that are doing this are learning lessons. But how do we exchange these lessons and get these lessons adopted through the community? That's a tough assignment. That's where all of Steph's points about her implication was, how do we get change agents willing to step up to the plate drive this stuff?

STEPH: And get them respected, as you've just noted.

WILLIAM BONVILLIAN: Yes. All right. We've got 20 minutes for Q&A. Lily, it's you.

LILY: That's me. I will start-- which one would you like me to start with?

WILLIAM BONVILLIAN: Whichever one you prefer.

LILY: Hmm, that's tough. OK. Let's start-- we ending with the MITx online learning, so let's go to that paper and discuss it.

WILLIAM BONVILLIAN: OK.

LILY: A couple of people had questions, including myself, as to what subject areas the online or blended learning could be-- or what subject areas could readily adapt those practices, and if it's just impossible to really implement this sort of style in some subject areas. So, for example, I would not have wanted to take this course if it was an online course. I don't have a three-hour attention span sitting at my computer.

And I wouldn't have-- sure, you could have a discussion group, and everyone tunes in on their own devices, and so you could have this pseudo-interactive discussion. But there is just something about sitting around a seminar table and interacting with other humans, for me. So I wanted to hear what you all thought about the applicability of the MITx in certain fields.

SPEAKER 1: Yeah, I've always questioned how either it could be improved or whether it is suitable for a lot of engineering classes, just from my experience both as a student, and then as a TA grading stuff. So many of the questions are not just about getting the right answer. It's about making sure you understand how to approach the problem. Did you just make one little mistake along

the way and that gives you the wrong answer? A lot of times there's not even numbers involved.

And so I know they did solid-state chemistry as one of the classes that was first really involved with edX. And I know the students would get really frustrated with it, because they were like, oh, I rounded this number wrong, and that's why my answer's off or all these little things that edX just wasn't sensitive enough to pick up on. And so I don't know if that's a question of the technology improving, such that we have better machine learning artificial intelligence to tell what students are doing, or whether that's just a limitation that will be present with this field.

CHLOE: Yeah. I think building onto that and from our earlier discussion about whether teachers and professors still have a role in the very much more online or automated education, is that one of the important features of being physically in a classroom or interacting with a TA like yourself, or with other students, or with a professor, is that they're most important-- even more valuable skill of theirs, as opposed to knowing their material inside and out, is having the teaching ability to identify what your problem is and understand the student's psychology and understand the learning process.

They can't just point at your answer and say, this is wrong, because you did this, but understand why you're wrong and then redirect you and then course correct you. So I think that will always be an important element of a truly well-rounded education, and you only get that from interacting with other people.

KEVIN: I do think that technology as a sense now, the face-to-face component, is critical in a lot of learning, especially in a class like this, right? But what's to say 5, 10, 20 years from now we can't all just slap a pair of VR goggles on, and then we're sitting in a simulated room, and then Bill doesn't need to fly in for every lecture.

[LAUGHTER]

You get that same experience--

WILLIAM BONVILLIAN: Great idea, Kevin.

--how we market it. And you get the same experience of sitting around, but you don't have to leave your couch or wherever you are.

CHLOE: Yeah, I think that's allowable and achievable. But I think--

KEVIN: As it stands now--

CHLOE: Yeah. We don't have to physically be in the same room, but there's still a role for a human educator and for human students to interact with each other.

WILLIAM BONVILLIAN: So far, I think, Chloe and Kevin, so far, much of our communication is not the words that we're mouthing. It's the expressions we use. It's eye contact. It's hand expressions. There's just a whole range of stuff that accompanies what we're actually saying, that we use as part of our communication systems. And so far, the technology has not been precise enough to enable us to capture that incredible depth that face-to-face allows.

And to some extent, it's frustrating. In other words, because that mix of non-spoken communication skills doesn't get fully picked up, people are frustrated by the experience. This is a notorious problem in conference calls, even in video conference calls, right? People don't quite see what the other person is driving at or trying to communicate, because this raft of other kinds of communication is not picked up.

Now, that's not to say that this won't get a lot better. And we've obviously moved to a whole new level of high definition and a lot of different machinery. So it may well get better. At the moment, it's not good enough yet to substitute for being next to you.

MARTIN: But I'd add an addendum, though. Because we're kind of seeing how, oh, it's not how the original is. But form follows function. And because it has a different form, you have other functions that we wouldn't have here. So if it's all online, then other people can be telling me what they got wrong or I can get recommendations. But the thing is the system hasn't been perfected as well. Or like you said, you don't want to stay in a three-hour lecture. I usually watch videos at 3x if they're educational, and I'll just go through the content, go back and forth. That's why I talk about it. Because it was like, yo, yo, OK. But I'd get a lot more done, and I'd just focus on the stuff I want to do. So there's new functions you can do.

Another really important aspect that I thought of from an organizational standpoint is, in this class, certain people are going to talk up more. And other people that might be more shy might not want to say something. So that's why you got people that online are talking heads, but physically won't say a word. So that adds new dynamics. And depending on the personalities, other people can excel, right?

WILLIAM BONVILLIAN: That's why I try to make some of you-- all of you-- be discussion leaders a lot in the course of this semester.

MARTIN: I mean, the issue also is racism, equity, sexism. Like if you don't know the gender or the background of a person, you only judge them based on the ideas. Or the content of their character isn't a layer that you get.

CHLOE: I think-- sorry, were you still expanding?

MARTIN: Well, I was going to make a point of so that allows other people to lead or excel in this setting.

CHLOE: Yeah. I mean, there's two sides to every coin. So I agree, the anonymity advantagement could definitely be a huge plus. But, I mean, when you have people trolling your classes, that's just as quickly--

[INTERPOSING VOICES]

MARTIN: So the thing is, the post is like Piazza, right? Your posts can be anonymous, but the instructors know who you are. And I think--

[LAUGHTER]

So they can just say, oh, please, or they'll just kick you out.

CHLOE: True.

MARTIN: And that's very like an 80-20 parental principle where-- I mean, I don't think everyone's going to just start trolling unless it becomes a thing. But it's an interesting dynamic.

LILY: Yeah, Matt?

MATT: I think even if we got to the point where the technology-- well, [INAUDIBLE]. Even if we got to the point where the technology was perfect and we could simulate being in this class together, I think there's still a lot of value in the fact that on my way home, I'll pass by the MechE lounge, and I'll talk to someone about their next startup idea. Just like when we talked about decentralizing manufacturing, there's a lot of know-how and innovation capability embodied in just having things together physically.

But also with the whole blended learning model, I don't think anyone's really trying to say that

we're going to throw away face-to-face interaction or anything like that. And then back to your original point about, what does online learning work really well for? I think right now my experience has been it works pretty well, or it's always better for quantitative kind of classes.

But I've been working over the last semester and setting up an undergraduate law class here. And one of the initiatives is putting on a lot of the content online. And what we found that the MOOC format allows us to do is give maybe some of the instructional video in bite-sized pieces online beforehand, and it opens a lot of in-class time to actually do a case discussion and opens up new opportunities there.

LILY: OK.

STEPH: Oh, I was actually going to add to yours. I participated in the Europe and STS for a year with a professor named Louis Bucciarelli, who started off in mechanical engineering, has a PhD also in science, technology, and society, I think at the same time. And he talked for a long time, I think in AeroAstro, as well. So he's a very storied professional emeritus now.

And he's starting a program called Liberal Studies in Engineering. And one of the challenges that we had when producing modules for the program is that although it did have the quantitative components that you're saying that I think are pretty easy to communicate, there was a lot of nuances behind the materials that we had selected that made it really complicated for us to convey both the content and to then ask questions about it.

And I think one of the examples that most stood out to me was when we were doing a module on wells, and specifically implementing wells in the developing world in the community of Tanzania. There is a drawing of a well that had been built I think in the 16th or 17th century that he had scanned and put into the module. But it was not-- the mechanism by which the water was pulled up from the ground was not very clear, and the piston just was not very well-drawn. And that prevented a lot of-- I was the one who was writing a lot of the material, and it was then sent to me, and then I had to do it. And then I had to give him feedback on my process of doing it. And it prevented a lot of my ability to actually do the problems.

So I think that's one of the really interesting things about MOOCs as well, and especially multidisciplinary MOOCs, that there are so many nuances behind the material, that even if the content seems fairly straightforward, if you have no way to interact-- or rather, if you don't have an immediate way to interact with the instructor, it does add an extra layer of complication in your ability to solve something.

And I think that that's precisely why we benefit from the blended model, because then you can come to class and say, hey, professor, you uploaded this image in the problem set, and I have no idea how the piston actually operates. Could you explain this to me more thoroughly? Or could you redraw it and reupload it?

WILLIAM BONVILLIAN: So part of the motivation, by the way, for filming this class is for us to think about whether or not we take more of the lectures segments online and then have even more of an organized discussion focus in that face-to-face classroom. So part of the reason of the filming here is to create an online course. But it's also possible to use this for more of a blended model here.

LILY: So I wanted to come bring something up that Bill mentioned earlier, which I think will also transition us into the Bonvillian and Weiss reading. Bill mentioned graduate programs online. So you complete a year-long certificate sort of program, and then can complete the remainder of your graduate work on site. I think that's a really interesting model and idea, so I could see that working well for things like-- well, first of all-- I could see that working well for things like maybe business, engineering, computer science, et cetera. And those graduate programs are typically quite expensive and can be two to three years. And unlike a lot of PhD programs or science programs, it's not paid for. So we're talking maybe $50,000 a year for two to three years.

Which brings me to something that came up in Bill's reading, which is student loans and increasing levels of student loans. And I was doing a little bit of research. Does anyone have any idea what the current outstanding student loan debt is in the US?

SPEAKER 2: Isn't there trillions?

MARTIN: Easily in the trillions.

LILY: Yeah, $1.5 trillion. [LAUGHS] And they're not collateralized and the default rates are increasing.

SPEAKER 2: Wait, they are? Last I heard, I thought they were down.

LILY: Not according to the 2017 statistics.

SPEAKER 2: Crap. What I heard was in 2016, so--

[LAUGHTER]

LILY: So with that in mind, could the master's program blended online, then concatenated or shorthand on-site learning, improve the situation with student loan debt, while still qualifying the person with a graduate degree?

SPEAKER 1: I would just be curious what the breakdown is between different fields. Because I know for MBAs and law schools, so much of it is building your network while you're there. So people are willing to take on hundreds of thousands of dollars in loans just to have connections to the Harvard community or whatever. So if that is only a small section of the total loans that are outstanding, then I think this could be impactful. But if that's outweighing it--

WILLIAM BONVILLIAN: I'm not worried about that class repaying the loans. They're OK.

[LAUGHTER]

SPEAKER 1: But that would still be considered part of the statistic, right? Because the first year out, they might owe $300,000 in loans. And while they are paying it back, I think they would still be willing to take out $300,000 of loans regardless of new technologies.

STEPH: This also assumes the goodness of the programs that are putting out these courses. There's a lot of, I think, predatory-- what is the name of the one that just got shut down that was really bad, the University of Phoenix?

SPEAKER 1: It's called The University.

LILY: That's the one. [LAUGHS]

[INTERPOSING VOICES]

STEPH: Yeah, it sort of presumes the goodness of a lot of these organizations.

MARTIN: Well, yeah, we're assuming they're all elite ones, where it's like, we're sure you're going to get something [INAUDIBLE].

STEPH: Yeah, exactly. And it also presumes that they're useful, like there's an instrumentality or a utility coefficient that you gain from having participated in these courses. And I don't know if the return on investment is going to be good for someone who doesn't already have a

foundational degree in something. It assumes that the job market is willing to accept the people who are graduating with this knowledge. And I don't know if that's true right now.

LILY: There's a really good breakdown on four-year universities, by the way, not just graduate programs. So, yeah.

WILLIAM BONVILLIAN: So, Lily, do you want to make a closing set of points about these two readings?

LILY: Yeah. Pay off your student loans and don't default on them or else our entire economy can collapse.

SPEAKER 2: Again?

LILY: Again. Well, these are the kinds of numbers-- you know, there's a critical default number, just as with the housing market.

SPEAKER 2: All right, so we need to all buy shorts--

[LAUGHTER]

LILY: I don't know, how do you short something that's not collateralized?

MARTIN: There's a whole thing about-- yeah, this being a bubble, the education bubble. I read a big thing about Peter Thiel since we brought him up in the first class.

RASHID: I think my favorite example is there's federally subsidized student loans. And if you get clever, you can use your federally subsidized student loans to invest properly, and then flip those, because those are inherently safer. So even if you don't want to-- I should say, there are a lot of options to pay back your student loans.

WILLIAM BONVILLIAN: So, Lily, bring us to a couple of key conclusions about the two readings.

LILY: Conclusions, let's see. Let me go to my notes. I think, in general, the readings led us to believe that online learning, or at least blended learning, is going to increase in usage or popularity, whether the institutions, the universities, like it or not. And I don't know. I think I covered everything else that I had thought of.

WILLIAM Good. Let me do just a quick wrap up. Freeman taught us about the talent base and how it's

BONVILLIAN: going to affect the innovation system and made us aware of the fact that the SNT talent base is going to be a pretty key component of US overall comparative advantage, as other people move to copy the model.

Romer's core point was that government policy is focused really on a capital supply and really on the demand side of the equation, right? And that the talent supply system really was not a particularly significant federal government focus. It probably needs to be, because that's a very important factor in innovation, as we've discussed earlier with his prospector theory.

And then he drove us to look at higher educational institutions and how they don't get the economic signaling that would lead them to increase the supply. And he helped us think about what some of the barriers were and how you could change that economic signaling to change the way in which the higher education system dealt with the supply kit question.

Katz and Goldin taught us about the tie between the ever-increasing technology requirements of the economy. Since the Industrial Revolution, we've been on a rising curve, and it may be accelerating. And then they demonstrated for us how important it is to keep the education curve, the talent base, ahead of that curve, playing off of that curve. If you let them cross, like we did in the 1970s, then you start to drive towards pretty serious economic inequality problems, because you're leaving a large part of your population behind, unable to get back on that rising parallel and stay up with the technology curve and earn the corresponding incomes.

Bamol alerted us to the fact that education for invention and innovation, by the way, looks different than standard education systems in science and technology today, which are more geared, historically, towards incremental advances. MIT's Online Education Report got us thinking about learning science, how you could apply learning science to really optimize both the online model and the blended learning model. And then the reading from the textbook showed us a set of the challenges for online education, how it's a potentially disruptive tool in a legacy sector education system, and got us thinking about, who are the change agents that might really drive the optimal model, which is really probably a blended learning model.