WILLIAM BONVILLIAN: All right. Let's dive right into education. And, you know, this is the other side of the innovation equation, right? We've talked in terms of institutions and linking and connecting institutions, and we've talked a lot about R&D and the R&D system, but you know, from the first class on, Romer taught us that the talent base is a very critical consideration in innovation. And how do you build up the talent base? That's essentially our set of tests today.

So, first, Norm Augustine. I wanted to acquaint you with Norm Augustine, because in the science and technology community, he's known as St. Augustine. And he is just an incredible stand-up figure on issues like the importance of federal R&D investment. He was chairman for a lengthy period of time of Lockheed Martin. He won the President's Medal of Technology. Just a noted innovator, himself, but also a true expert on R&D issues, R&D policies. Unfailingly helpful and willing to volunteer for whatever task the National Academies or in many cases MIT, or other organizations kind of need help and advice from a real senior statesman, Augustine has always been willing to step up to the plate. So he's kind of a remarkable figure.

He led the rising against the Gathering Storm report back in 2000-- around the early 2000s timetable-- along with people like Chuck Vest, and a really noted community of other experts, that made the argument for a very significant R&D increase for the physical science agencies. Around that time, we had been doubling NIH. This report made the case for doubling the physical science-based R&D areas, as well. And it was a very influential and important report. He was one of the real leaders of it, and he played an important role, along with Chuck Vest, in helping persuade the latest Bush administration-- hi, Karen-- to adopt its recommendations. So there was a period of time of ongoing R&D increases for the physical science agencies. So the report had a result.

In addition, he came back and wrote this 2007 report that just kind of summarized the trouble the US has got on the Science and Technology education front. So it's a 2007 snapshot, but it's still a great little collection of key points. I'm just going to summarize it very briefly.

Key finding number one was that US children are not prepared for the 21st century jobs, and

he has data sets, as you know, to back all these points up. Children in school are being taught by teachers that are not trained in the fields of math and science that they're teaching in, which is a major underlying problem in those students picking up those fields.

US children are falling behind their foreign peers and counterparts in science and technology areas. The US K through 12 system just is not performing in a way that's comparable to many other systems in the world. And then, kind of a fourth point is that US secondary education isn't preparing students-- aside from the teacher problem-- for math, science, or engineering majors, and too few students-- this is the key point-- are majoring in those disciplines to yield the talent base that we need for technology-related careers. And just to underscore that, the US ranks 17th among developed nations in the proportion of college students receiving degrees in science and engineering, and it fell from third place 30 years before.

So these are dilemmas that the US K through 12 system has. So that's the K through 12 story. Then we shift to our friend Paul Romer, who we visited at the outset of this class. And as you know, he taught at Stanford, and then has been teaching at NYU. He's now chief economist to the World Bank, where he's been a fascinating critic of economics and changes and reforms that field needs to go through. But he came up with prospector theory, and in a way, what he's playing out here in this pretty noted critique from 2000-- which is still quite widely read-- his critique is, what happened to the supply? What are our supply breakdowns? And then he's identified those supply breakdowns with higher education institutions. What are they failing to deliver?

So the issue is that the federal government policies in science and technology tend to subsidize demand. So in the private sector, it's primarily tax incentives, R&D tax credits. And you promote demand to encourage science and engineering talent.

That policy approach, which is astronomically expensive-- those are very expensive policies-- that policy approach doesn't inquire about the supply response that hopefully those subsidies elicit. And he goes back and argues that the institutional arrangements in universities, which are the key institutions on the supply side, are geared to meeting the needs in a variety of ways. So there needs to be a new incentive system to start to turn around the supply side because the current demand-based tax incentive system just isn't doing that. So that's his overall frame.

In the 20th century, he argues, rapid technological progress drove unprecedented growth. We

know that argument. And that was fostered by a publicly supported system of education. So a steady flow of trained talent, trained in the scientific method, was a core policy that evolved over time, but that public policy approach ignored the structures that were supposed to deliver that talent base, i.e. the higher education system, and the incentives and disincentives within that higher education structure that make that supply side problematic.

So he would argue that a governmental-- set of governmental programs to speed up innovation gets thwarted by the supply side problem, in particular by the higher education structure. So government programs focused on the demand and not the supply side are going to undermine the innovation capabilities that we need.

Then he steps back and kind of makes the innovation argument for us. He argues that speeding up growth is really the only way we're going to be able to cope with the oncoming demographics that we talked about when we discuss the health care innovation system. He says that a conservative estimate of the return on R&D spending would be a 25% return. There's arguments that that's low, that it's well over 50%, but let's accept his 25%.

His argument is that if you-- in theory, that if you increased R&D spending by 2% of GDP, voila, we'd get a half percentage point of growth. Right? In an economy that has 0.7% growth at the moment, this is not a minor concept. Right? And the data would tend to-- it at least in theory-- bear him out.

But then you run into the barrier, right? You have to look at the full system, and that means also looking at the talent. So just increasing the R&D spending per se doesn't address what he calls the supply side, and if the total number of scientists and engineers is fixed, then you limit-- and this is pure prospector's theory, as you remember from our first class-- then you limit the biggest input into innovation, and thus into growth. So by not expanding its supply of scientists and engineers, i.e. the talent base, then the US is limiting its growth capacity by a pretty significant amount, he argues, in economic terms.

So what's broken down? What what's the heart of the problem, here? And this is a deep critique of higher education, which was highly controversial when this came out and occasioned a lot of criticism of Romer, but it's hard to dispute his data, and you will probably see this from your own experiences or the experiences of colleagues in other universities.

So what's broken down on the talent supply side? He argues that universities measure themselves by their ability to select top SAT scoring students. In other words, they measure

themselves by the quality input they're able to attract, not by their output. There's no output measures in this system. They're competing with each other in things like US News and World Report on the students they attract, not on the student outcomes that they're creating.

So the traditional liberal arts university, he argues, faces little pressure to respond to skills needs. That economic messaging that's inherent in the system doesn't get translated back to the higher education system. So, meanwhile, the university has a fixed investment in its faculty that are teaching in many areas-- including the sciences, but obviously outside the sciences. There is internal pressure to maintain the relative size of those departments, which are-- they have invested in. And that, in turn-- and we'll discuss why in a minute-- but makes it more difficult for students to get science degrees.

So the science faculties, he argues, are happy to do what they call "maintain professional standards," i.e. have a lot of lower grades. And effectively what that does is force out of the system a tremendous amount of talent because, again, they've got fixed faculty sizes that aren't coordinated with what national talent supply and needs may be in science and technology. There's no pressure on universities to address those corresponding faculty sizes to what the national need may or may not be, and therefore what's happened is essentially a bifurcated education system, where sciences and engineering students have one grading system-- and as you all know, it's a tougher grading system at liberal arts universities than other majors in the social sciences and humanities. And you know, we know that there is significant grade inflation in the non-science, non-engineering fields, and that there is limited if any grade inflation in the tougher technical fields. So that's what he's talking about, here.

We maintain essentially two grading standards, the net effect of which is to substantially discourage entry of talent. Now this is not in this report, but the National Academy of Engineering has explored extensively whether the people dropping out of majors in engineering are stronger or weaker students than those staying in, and they can't find any basis for concluding that they are any weaker. In other words, we're just driving talent out of the system through these mechanisms, is Romer's argument.

So the supply problem-- by running this bifurcating grading system to drive out talent, to maintain class size numbers and make sure you don't have to advise too many people-- the supply problem, in turn, drives graduate school numbers, because of course, undergraduate degrees are prerequisites. So how does US industry cope with this? Essentially what it's done-- and this is not bad-- it's encouraged wholesale immigration from all over the world to fill the

gap, which it's done very systematically.

And that's why, for example, industry is so concerned about this H-1B visa set of proposals that the new administration has recently proposed. What are the ramifications of that in terms of access to this talent supply? Obviously, worldwide talent, as we've talked about before, is a very important competitive advantage for the United States. But here we're in a circumstance where we're not creating parallel opportunities for folks in the US.

Moving on with Romer's indictment of higher education, because that's really what it is, he argues that PhD programs train graduates for the academy, but as all of us in this room know, there's-- there's a complete oversupply of PhDs in terms of what the academy itself-- in other words, university teaching-- actually requires. So then we have to invent new mechanisms to keep this talent base around. So we invent long, endless, seven or eight-year graduate programs.

England somehow manages to get its PhDs done in three years. Are they worse? I don't know. But we have a seven or eight year old graduate-- eight year long graduate education program, and then we invent this whole class of essentially apprentices that we call post-docs-- another substantial army of people-- because there's no space in the academy to accommodate these people.

And yet the training system is not geared to the location where there are extensive opportunities-- whether in established firms or startups-- which is for industry because the training system is really geared for entering the academy, not for entering industry. And obviously, it tends to focus more on basic than applied for obvious reasons. So this-- we're just multiplying the problems here, because the core input institutions, i.e. higher education, are not organized around the skills problem society has got. That's Romer's indictment.

I had the privilege of working with him on legislation, and when this piece of legislation came out, there was considerable interest on Capitol Hill, and we're hearing all the time on Capitol Hill in this era about, we've got a talent base problem, and there was considerable interest in the critiques that Romer had made of the system, and how do you change the system? So, like other senior staffers, I read his stuff and thought gee, how are we going to turn this around? We're going to have to spend a fortune on creating a massive new kind of fellowship program across the country, on top of what we already have to encourage science and engineering education. We'll have to significantly increase that-- maybe by a factor of two or

more. How are we going to afford this? Where's that money come from?

So I had a conversation with Romer, and he said, Bill, you have to think like an economist here. You have to bribe the gatekeepers. Right? So I-- what are you talking about? And he said, look, figure out who the gatekeepers are in this entire system and you bribe them to make them turn around their behavior. So in this case, it's the departments and the colleges and universities as a whole-- it's their administrations. Bribe them to get them to change their numbers because if they're not producing enough scientists and engineers net, then pay them to do this. And by the way, bribery is a heck of a lot cheaper than creating a massive new national fellowship, and much more efficient.

So obviously, bribery is not the apt term here, but we ended up creating a program at the National Science Foundation, which Congress passed, called The Step Education Program, which essentially offers very significant funding to departments that guarantee they're going to turn their numbers around, and then present pathways by which they're going to do so. In other words, maybe they offer much more one on one kind of tutorial attention to keep students in science and engineering. Maybe they offer fellowships with industry, so you're guaranteed summer employment in an interesting, relevant, applied field.

In other words, there may be a whole slew-- and there turned out to be a lot-- of ideas on how to begin to turn those numbers around.

AUDIENCE: Are you talking at the undergraduate level?

WILLIAM BONVILLIAN: I'm talking at the undergraduate level.

AUDIENCE: I'm--

WILLIAM BONVILLIAN: Go ahead, Max.

AUDIENCE: I'm kind of confused how you can simultaneously have a problem where you don't have enough science engineering workers but you also have this army of post docs that you don't know what to do with.

WILLIAM BONVILLIAN: Well, I mean that's kind of the next stage of the problem. So his next piece, Max, is innovation and graduate education training. So in other words, create curricula that are relevant not only

to training for the academy, but curricula that are also relevant to training for entry in the industry, and we're obviously starting to see some of these things materialize. So a school like MIT-- but it's by no means alone-- has a massive entrepreneurship curriculum now available in all of its schools. This is not just a business school program, this is available across the board, and as you undergraduates know, it's really quite accessible.

There's a substantial number of business majors who do a lot of entrepreneurship-- business minors-- who do a lot of entrepreneurship-esque features in their education. That's now much better understood by students going to universities as an option for what their route ahead might be than it was even 10 years ago. So there has been some change here, but that's another change he would make, is to make the training much more relevant to entry into established firms and to startup firms at the graduate school level.

So overall, he would attempt to use some federal funding here to, in effect, redress the imbalance in federal demand and supply programs to create an input of support on the federal side-- on the supply side. All right, so that's two of our three. You want to pause here? Because this one's so nicely controversial that we could discuss it, and you all can disagree with Romer or indicate how correct he is. Shall we do a quick pause?

Who's got this one? You've got it, Max? Do you want to quickly summarize Romer? Let's do Augustine, too.

AUDIENCE: Oh.

WILLIAM BONVILLIAN: Great.

AUDIENCE: All right, so Augustine talks about how, while as a lot of us know, education in the United States isn't great before the university level. So he gives a lot of statistics, how we're doing pretty poorly in math and science when compared to other countries, how, for whatever reason, it seems that as people stay within the American system, the longer they stay in, the poorer their ability to compete with other countries is.

So actually, I found out one of the things-- some of the-- so America has, in the past few decades, been famous for the concept of a brain drain, where it would take the best and brightest from other countries, like India and China-- they would come over here for our university system, which is nice. It's great for us. It's not great for them, but apparently this

trend is slowing as we find out in this article, because of some of our more isolationist policies. And I really appreciated that he mentioned it, because often a lot of people tried to talk about, isolationism is bad because we are the world, but this actually gives a more concrete reason for why isolationism actually causes some significant problems to our innovation system and to our economy.

So one of the questions that I wanted to pose is, how have all of our educational institutions at the university level managed to maintain their stature and their quality despite the fact that lower-- lower level institutions like high school and below have been so sub par? And can we implement some of these characteristics at these other levels? Yeah, that's all.

AUDIENCE: I think some of the answer to that comes from just the inequality across I through 12 schools. The US does have some fantastic schools, it's just who has access to them, and that tends to favor certain groups over others, and so instead of being able to tap into the full potential talent pool that we have, we're getting the ones who happen to live in a neighborhood that goes to a good school, or they have a nice magnet school in their county. So I think you could also pose the question, how much better could American universities be if they had their full talent pool to choose from?

AUDIENCE: That's fair.

AUDIENCE: Yeah, I like that point a lot, because there are-- I mean, we definitely have institutions-- higher parable learning institutions, universities-- in the United States that are extremely famous, extremely well known, and extremely well respected. You all are at one. But there, if you look-- that doesn't mean that every single university in the United States is internationally respected.

There's this huge spectrum of the level of education or the quality of education that you can get at the university level, and I think you're exactly right-- that's the same for K through 12. It's just there's a huge span. You just don't necessarily hear about the really bad university level educations. [INAUDIBLE]

AUDIENCE: OK. So--

AUDIENCE: [INAUDIBLE]

AUDIENCE: So following up on that, then, I've heard that one of the main reasons that we-- that, at least for the K through 12 system, people are-- or governments-- are unable to support the schools that are doing very well and punish the ones that are doing poorly. Is there a way that we

could implement this without jeopardizing the educations of the people who are already in these systems? Because schools can't be treated exactly like a free market, because in a free market, the worst case is you buy a Zune instead of an iPhone or iPod and well, OK, that kind of sucks.

But it doesn't suck nearly as much as it does for the kid who has to go through a year with a bad teacher, and sure, maybe the teacher gets fired after, but that's still a year that this kid has lost, and that sets them behind, and those-- that impact can last for the rest of this person's life. So-- that was a really long question, I'm sorry. So to phrase that more simply, how can we implement some sort of free market style without that inherent impact on a kid's life?

AUDIENCE: Well, I think just to reorganize the question and some decision making, why are you assuming it's the teacher's fault that, in a central city school, they don't do well, right? Usually it's people who really, really care, but the students aren't ready to learn. Because like-- I forget the quote, but it's combined as like a parachute that needs to be opened to receive information. So I think it's a more complex issue, is the point I'm trying to make.

AUDIENCE: Yeah.

AUDIENCE: [INAUDIBLE] the first time I've looked into this, because there's a special class called by Tom Malone, and I think we're going to be talking about the future of war next week where he talks a lot about, now we're in a distributed kind of network system. And we kind of get through hierarchy systems. And so like in that class, we posited like, you know like YouTube has all the videos and is created by a ton of people.

We talked about like what if somebody made like a YouTube for education, where the best teachers would get the most views. And you could quantify that and pay them really high salaries, right? So you'd get like NBA, and NBA player salaries for doing really great content and a lot of people would access it. And pretty much the whole population would be taught by the best teachers in the country or in the world.

And then you'd have the personal touch, like Khan Academy, where it's like online for some subjects or like [INAUDIBLE] in a really good way. And then in the actual class system, you are going through the kind of like the issues and figuring out what your errors are so you can learn better. So I think that's an interesting incentive.

The thing though is like I think this is more of the dynamics of the market but the gatekeepers problem than it is like an education problem or even like the pipeline issues. If our incentive system is to get the best people to the school and not care what happens after, that's kind of like a screwed up system, right? It's like if your whole-- yeah. Like we're not focusing on making the best students in the world. We're focusing on finding the smartest people up to that point that they become students at our university.

And our reputation is based on getting the smartest people up to here. So it doesn't matter if you have a screwed up economy. There's always going to be a really top 1%. Like, it doesn't matter, because like most of the people at the school will come from all different kinds of backgrounds. And they will never say, most likely it was because of their school.

Like if they come from a poor background, they're going to say, you know, I just went online, or went to the library, or I learned from the best people in their books. That was even like a response.

WILLIAM BONVILLIAN: Well, you introduced the online idea. And we're going to jump on that kind at the end of the class. So we should come back to that Martin.

AUDIENCE: Which I definitely think is an interesting idea. I think it's easy to frame the access. All you need is an internet connection and basically everyone has a cell phone.

AUDIENCE: You know, we'll get to is later.

WILLIAM BONVILLIAN: And there are pros and cons on this too.

AUDIENCE: It's also overdone, right? There's like a ton of businesses and a ton of organizations I've seen try to do it. And like why haven't they figured it out. It's probably like a policy, incentives, power issue.

AUDIENCE: Yes, I think, just thinking about it from like also an international perspective, I think a problem in the US is also like the whole respect thing for teachers. Like I think especially at the middle school or the high school, like the public education system, maybe there's not as much respect for being a teacher. Whereas like maybe in Sweden, or like China, like being a professor, a teacher is really well respected and considered a really prestigious job.

So I think that's like some systemic issue that's also kind of preventing maybe the top talent

from going into teaching, not necessarily at the higher education level. I think there is a lot of really intelligent academics in that space. But definitely, towards the beginning where children are like really starting out their educational careers, and that's the fundamental.

And also from what I know like in Europe, they start kind of specializing pretty early on in like high school into what kind of track they want to pursue later on. So I feel like that could be an interesting way that they're kind of promoting, for example, engineering or math or STEM related technical expertise. Like they're really fostering that from early stage. So that really helps and sets up the students to advance later on.

Whereas like a lot of students here they get like kind of basic introduction to everything. But then once they get to engineering classes, some people aren't very prepared.

AUDIENCE: Actually regarding the first part of what you said about the teachers and trying to incentivize the best talent in our country to become a teacher, that's actually my second question. I was going to ask, well, how could we incentivize them outside of pay? Because I've heard that the US education system is at an all time high for paying, for the amount of money that we spend per student in the classroom.

So clearly just throwing money at this problem is not enough. So what can we do? Is there a way we can either change the culture or some other aspect?

AUDIENCE: Yeah, I think one of the problems with the US system is that it's kind of punitive. Where there's like mass or firing, sorry, mass firing things, whereas teachers that are not like performing up to a grade just be like let go. And that's kind of bad on the students because there's a lot of turnover.

But I think in other, we can maybe borrow from another model where other cities, I think what comes to mind is Shanghai has this program where a lot of teachers or professors that are not performing as well are partnered with an educator that has more experience or has better understanding of how to reach the students. And they have this kind of like collaborative model, where they bring up the teachers instead of trying to just fire them or like dock their pay or something. Which I think is probably something that would be ultimately better for like the students in general as well.

WILLIAM BONVILLIAN: So Max, why don't we move on now to Grover.

AUDIENCE: Oh, yeah, sure. That most anybody is going to be closing points here.

AUDIENCE: I just want to bring up the point that was made in one of the papers, I forget if it's this one, about having access to looking at like seeing engineers. Yeah, like, if you're in a community where you've never got to interact with engineers or somebody who does STEM, you're going to see it a certain way, especially since when you look at the subject, it's so dry in the classroom versus what you actually end up doing.

I think that's also a big component, especially once you structure who you want to become, right? Because at that age, you're trying to figure out where you want to be a role model. Yeah, like an example, Steve Jobs got to work when he was 12 at HP. And he said that was the thing that led him to work on tech, because his whole background, his dad was a mechanic.

It also made him realize what a good company was, because he saw how the employees are treated and it made them see, oh, this is why having the right company culture matters. That's a lesson he learned at 12 that led him to change how he saw his life.

AUDIENCE: I think on my end in terms of Augustine, there is a point he made about American exceptionalism and our focus on finding spectacular talent, not just on good talent. And so, I remember a few weeks ago, I mentioned the quote where the good becomes the enemy of the great. And maybe in the education system, the great is the enemy of the good.

And perhaps we're sort of not doing a good enough job of supporting people who do a fine job at pursuing engineering and science because we're focused on finding the innovators, the Edisons, the Jobs, the Gates of the world. So to create a support infrastructure, people who might do a fine job at carrying out their functions I think is ultimately the task of the education system at the lower level. And then at the university level of cultivating that talent to really create spectacular innovation.

AUDIENCE: Yeah, to add on to that point, I think, yeah, they definitely prefer the Edisons, but I think that was more in the paper already talked about breakthrough ideas. I think this paper was more about, we have a pipeline issue that we need these kind of employees so that these fields stay in the US. And they weren't looking for Edisons. They were looking for niche, like you know, you want to discipline and can move ahead and get that job.

WILLIAM So let's shift over to Romer.

BONVILLIAN:

AUDIENCE: Sure. you're just like, oh,--

WILLIAM BONVILLIAN: Well, we're leading into it. So we might as well. That's your pipeline boy.

AUDIENCE: Yeah. Yeah, so regarding the pipeline, Romer decided to focus mostly on the undergraduate and graduate institutions and trying to figure out how you can increase the supply of the talented scientists and engineers that exist in the American innovation system. So one of the questions that I saw was posed pretty interesting, someone was asking what metrics or measures could you use to actually evaluate these new scientists and engineers as they're coming into these fields and how can you train them to come into, to be prepared to go into either industry or academia.

AUDIENCE: I mean, the first thing that comes to mind is like professional engineer exams that exist already. That's kind of like the standard.

AUDIENCE: Those aren't required, are they?

AUDIENCE: No, not usually. Well some companies will require you to get them. It's generally just like a--

AUDIENCE: It's a nice little--

AUDIENCE: Thing you can check. But like, I don't think it's very like, before I came to MIT, I'd never even heard of it. So I don't know if that's something that carries a ton of weight. But I don't know. I don't really like the idea of using standardized tests as a measure of competency. But I mean if you're trying to talk about a large group of people there is no feasible way to do it other than that.

If you want to talk about all the engineers that are entering the workforce, like, unfortunately, numbers are kind of like the only way to do it.

AUDIENCE: Yeah, you can't [INAUDIBLE] recommendation letters. Just like everyone can find someone that likes them. Yes.

AUDIENCE: Might there be a reason why such extensive licensing exams exist in the medical field and not in the engineering or life sciences fields?

AUDIENCE: I mean, it's because it's probably easy to mess up costs a lot of money if you mess up. So you don't want people to mess up. But it's pretty easy to mess up in engineering.

AUDIENCE: Yeah.

AUDIENCE: Yeah, but people don't die and don't get lawsuits.

[INTERPOSING VOICES]

AUDIENCE: I mean, to the personal engineering exams, to what extent does accreditation of universities already attempt to fill that role that you know, if you're accepted into and graduate from an accredited engineering program, you already have that check mark, that like, OK.

AUDIENCE: Yeah. So the PE exam is basically just a feather in your cap. It doesn't really-- or I don't know, a little stamp on your resume. Doesn't really--

AUDIENCE: But is there a fault with the way that we give that accreditation to things right now? Is it becoming more meaningless? If we're graduating maybe an engineer from one school that is far more capable than another school that has the same like stand?

AUDIENCE: I mean, you could make the same argument with like any profession, right? Like, to go into Stephanie as example of medicine. So if you have someone who comes from the Harvard vs. name somewhere you don't like, Harvard. Yeah, then you can see a difference in quality.

WILLIAM BONVILLIAN: Let me raise a question, [INAUDIBLE]. It's harder for you folks at MIT to see this because it's obviously predominantly science and engineering. But let me ask Sanam and Steph, how much do you see the great inflation in a classic, you know, high quality, liberal arts school between social science, humanities kinds of majors and science and engineering majors? And Lily, you came from one of those institutions. Please join in. Is this real? Is the problem that Romer is seeing here, is this a real issue?

AUDIENCE: [INAUDIBLE] econ major at Wellesley College.

AUDIENCE: Not at Wellesley, there is a definite sense of grade inflation there.

AUDIENCE: It is not a sense. It is a policy.

AUDIENCE: Yes, it's a policy. It's an actual policy. Instituted, grade inflation. But in terms of the disparity between the humanities, social sciences and STEM fields, I think there is definitely-- generally,

there's the idea that like the STEM fields are more difficult. So recently we had this policy where the first semester of your college year shadow graded, so you're not actually given grades.

And that kind of resulted in a lot of people entering the STEM fields [INAUDIBLE]. And that was something that obviously the humanities professors and social sciences were very against. Because if the students coming in were automatically going to anything outside of their department, they kind of ended up staying there because the faculty are great. So they would continue in that program. So that was kind of an imbalance that occurred in the recent years.

WILLIAM BONVILLIAN: So in a way, exactly what Romer's talking about. Interesting. Lily, what was your point?

AUDIENCE: I was a science major. And I made A's in every single class I took outside of my own major. And not As.

WILLIAM BONVILLIAN: What were you thinking, Lily?

[LAUGHING]

AUDIENCE: We started-- I wanted to do science. We started out with almost 600 students in the first semester chemistry course. And by the second semester chemistry, so this is chemistry majors, biology majors, and engineering majors, all have to take that. They also have to take a second semester of chemistry. And there were probably less than 400 by the second semester. So it was a huge weed out class.

AUDIENCE: How many were there in the beginning?

AUDIENCE: Over 600, just over six.

WILLIAM BONVILLIAN: Most schools have notorious weed out classes that essentially frustrate the ambitions of a lot of students, particularly in the premed area. Obviously notorious, shall we say organic chemistry is the [INAUDIBLE]. So this is a dilemma when you've got a societal need and you've got the institutions that are supposed to deliver your talent base just operating off a completely different set of incentives than what the society may be.

That's the core of Romer's argument here. And another part of his argument is, the numbers

are not that far off. In other words, if we just got the people who wanted to major in science, engineering, and mathematics to stay in the field, you know, lots of the numbers problems get a heck of a lot better. But that 40% or more dropout rate out of those fields that typically occurs at the undergraduate level is highly problematic.

AUDIENCE: Yes.

AUDIENCE: I think they've been waiting longer if you want to.

AUDIENCE: Oh, I couldn't see your hands.

AUDIENCE: Yeah, so I started to wonder about a couple of these choke points, like where actually people are starting to drop out of these science and engineering fields. I know we identified kind of these weed out classes. And I think kind of looking from like who declares, who ends up finishing, I think you could probably, as a whole identify kind of gradient deflation in a couple of these classes is like very complicated, kind of weed out classes as reasons why people start to kind of leave the field and migrate out.

And I think it might be indicative to sort of each institution kind of where these dropout points are. But I think en masse, you can kind of take these like first year classes as kind of places where students start to fall off. And then, is it actually-- so is it part of kind of this college exploratory process, like kind of figuring out what you want to do? It's like how you phrase it.

As like, you started as a chemistry major. But maybe you end up gravitating towards social science because you don't really like the way that weed out class is structured? Or is it part of this indicative problem that we have, where like we can't graduate and sustain the people who are actually interested in these fields? And so I wonder if like, you know, just because you know, we're not graduating enough, is it because these classes are actually structured in a way that prevents people graduating?

Or is it like part of this-- kind of the way that we brand your college experience is like you're supposed to be able to explore and kind of transition in and out, especially in that first year and experience things. And my second point was like, there's a little bit of a difference I would say in kind of STEM fields, even in that first year. Because I know a lot of colleges offer the opportunity to use high school classes to sort of test out of those first year, maybe even those weed out classes.

And then, it's sort of an added bonus as well, because you end up testing out of these classes,

so you use up less semesters to finish your degree. And so I know that can be like a big reason and incentive for students to sort of choose other universities, because they're like, oh, I'll only be in this school for three years if I go to maybe the state school over here, rather than staying in school for four years at a different university.

And like, is there a way to identify sort of the relative quality of education in kind of testing out of that first year of engineering classes and then finishing in three versus going for four. Because I feel like if you can graduate a whole bunch of people, maybe in that three year time span without like a marginal decrease in quality of education, we can start looking more to those programs as well.

WILLIAM BONVILLIAN: Max, how about a close up point on the Romer.

AUDIENCE: So evidently, Romer is evidence that the education problem is unbelievably complicated. Throwing money at the issue has not been sufficient to actually solve it. And there are issues with the quality, as was being talked about, the weed out courses that exist, grade inflation and deflation, standardizing. So, such an issue will take-- it's going to take a very long time to solve.

But all of the issues that he has pointed out, they are definitely solvable. I'd say the main barrier between us and now and a future where these issues are solved would be the-- would be just politics, just trying to get people to agree to these different programs that would focus more on the education and less on the incentives of those teaching.

WILLIAM BONVILLIAN: I think part of what's interesting about Romer's argument is that he takes the theory that we've got a talent supply, set of talent supply issues, and then he attempts to figure out what are the more specific barriers to that supply, and then do an institutional analysis of why these barriers are in effect created at the higher education system. And then interestingly, he attempts to take three or four public policy fixes that could actually address these.

And I do think that both his article and the Step Program from the National Science Foundation created based on the legislation that he recommended that Congress passed, and that NSF implemented. It was never implemented with the funding scale that was really needed to make a significant difference. But it started to send a different set of signals about supply of science and technology talent to the university system and did I think have an effect over time.

But these issues are obviously still with us. So let me move quickly from Romer to our next reading with Richard Freeman. And he kind of takes us to the next level of the supply problem. Richard Freeman is a quite famous labor economist at the school up the street. And he's famous for his wide range and variety of hats. As you can see, he has a wonderful collection.

So he looks at a different problem. You know does globalization threaten the-- and its movement in science and engineering, threaten US economic leadership? And you know, his-- I'll kind of summarize his four key points here. You know, the underlying issue is that changes in the global job market for science and engineering, science and entering workers, S&E workers are eroding US dominance in science and engineering, which in turn diminishes a strong comparative advantage that the US historically held since the end of World War II as we've been talking about in the past.

And he makes four underlying points in kind of looking at this dimension. In other words, we have Augustine's critique of K through 12. We have Romer's critique of the higher education system. And then Richard Freeman kind of tells us what the economic implications are of failing to maintain that leadership base in science and engineering talent. So his point is that the share of the world science and engineering graduates in the US is in decline. And look, others are understanding this model and moving to fill it.

Second, that the job market has worsened for younger workers in science and engineering fields relative to many other high level occupations, which in turn discourages US students in those fields. Now he's writing this at the time when a startling proportion of MIT students and other science and engineering graduates in other schools were going into the financial sector, financial services, and consulting. Some of that since he wrote has turned around.

In other words, there has been an emergence at MIT of interest in startups and entrepreneurship, to the tune that some 20% to 25% of those of you when you graduate, your graduating classmates will go into those fields in a way that community moved out of financial services post 2008 crash and moved over to what may be a really important kind of career shift in terms of the country's future. But that hadn't occurred yet by the time he's writing this.

So in other words, the extremely high pay available to those entering financial services and consulting drained talent out of the system is his point within the US. And then, you know, countries like China and India found that they could compete with the US in high tech by starting to train substantial numbers of science and engineering specialists. In other words,

they could leapfrog, right, and in effect go to substantial parts of their economy being quite high tech, even while they were working on bringing up what's in effect a developing world economy in the meantime.

So they hit on this model. And it's a really important model. But that in turn had an effect on kind of US dominance in this field. I mean, it's not a bad thing for the world to get better, but it doesn't have an effect on the US comparative advantage.

So to ease the adjustment to a less dominant position in science and engineering with the corresponding economic ramifications for US economic growth and competitiveness, the US is going to have to develop, he argues, new labor market and R&D policies that start to try to change the science and engineering talent numbers. So we're going to have to step into the marketplace. And you know, this is where Romer's thinking would come to bear.

So let me let me move to Goldin and Katz and they further talk about the societal ramifications for what we're doing in higher education, right? We've talked a bit about this before. And they also teach up the street. And their book, *The Race Between Education and Technology* was really a quite important one. I think it's held up well since it came out in 2009. But I had you read a short version, a Milken Institute review piece that came out before they put their book out. But I do recommend the book to you.

The gap between wages of educated and less well educated workers has been growing since 1980, and this expanding wage inequality has characterized the US since that time. So we're becoming a much more polarized society and the lines are drawn on education lines, right? And this is, we've talked about this before, but this is David Otter's barbell problem, that our society is increasingly looking like a barbell.

And we've got on one bell, a growing and successful upper middle class that has the education and is able to use that education to capture that wealth, a thinning middle, and a growing lower end services economy that's less well-paid and less well off, to which substantial portions of the middle are now being shunted. And we can start to see this polarization in our economy in pretty sharp terms.

And that's what Katz and Goldin are writing about. The wage inequality narrowed in the United States significantly from about 1910 through the 1950s. Then it stabilized until about the 1980s. And then it's grown since that time. Why? And they argue-- I'll attempt to just paint you a quick picture.

But they argue that there is a race between education and technology, and that what happened in the US was that there is an ever-growing curve of technology knowledge since the Industrial Revolution. And we've talked about this previously, but I'll reiterate it. That an economy requires, in other words, it requires an ever-growing level of technological sophistication.

And the genius of the US system was to create mass higher education, which we did, first through the Land Grant Act. Of course that created MIT. That was the big enabler for MIT. It had initial funding in 1861. Its graduating class marched off to the Civil War. There was no revenue base.

In 1862, Congress passed the Land Grant College Act and suddenly there was a revenue stream to make up for the loss of talent, loss of the tuition base. So that saved MIT. But created public higher education really across the country in every state at the time extended to new ones. So we created that system of mass higher education, really through the Land Grant College Act in 1862. No other country had done anything like that.

So we created a talent base that stayed ahead of the technological curve, right? And that's what you want. You want your talent base to stay ahead of the increased sophistication of technology in the economy, so that that talent base can keep moving that curve up, right? And that they benefit each other.

And then, what Katz and Goldin point out, is that in the mid '70s, we level that off.

AUDIENCE: Was there something that caused it in particular? Let me get to that in a minute, Martin. But we do need to come back to that. I don't think we fully understand the dimensions of what was happening at that point. But there are some thoughts.

So what happened was that the people that continue to ride this curve, they stayed up with the technology curve. Those that fell off fell behind the curve and their incomes correspondingly suffered. That's the case that they're making. and that these people got left off the curve and couldn't keep riding up to take advantage of the economic gains.

So you've got a smaller number of people you know, riding this curve up. They get the gains. Whereas in this period of time between 1910 and 1950, everybody at least, a very large part of the population was riding that curve and able to benefit. So that's the great creation of this

mass middle class in the United States.

And the data tends to bear this out. So that's their essential equation here on what happened. Again, they argue that technological advance is the key to growth. We know that from this class. And that the ebb and flow of wage equality and inequality is very much related to the skill set you've got to keep riding that technological curve.

Now look, if anything the growth in that technological curve has just gotten steeper with the development of all these information technologies. You know heaven forbid, a next generation if you don't have coding skills, right? With the entry of significant amount of artificial intelligence in the economy. If you're going to stay up, you really need that skill base. Otherwise you're going to get left behind.

So, you know, that's essentially their picture of what's been going on here. Let me-- that stagnation of education levels around '73 or so coincides with the period of economic challenge from Japan that we talked about in the second manufacturing class. That's the period where the Rust Belt gets created. So the US had been on an ever rising economic curve.

Suddenly its growth rate fell to the 2% range from its historic 3% range and its productivity rate strides growth as we've talked about, its productivity rate fell to the 1% range. So that means there's less real wealth in the economy. And that may, Martin, in answer to your question, that may have had something to do with our ability to keep financing ever-growing education.

Remember that the public universities provide 80% of higher education. That's the key component of the system. You know, places like MIT are all very well and good, but that's a 20% share. The core talent base are getting trained in public universities. And other things have been happening to those public universities.

So they're competing at the state level for funding with two major factors. One is Medicaid, which the states bear a very large portion of and the other is prisons. Because we have a massive prison growth. And the annual cost of prisoners is much higher than putting people in higher education. You begin to wonder where your priorities are when you think about that.

So there have been increased pressure on state budgets that correspond with that '73 to like 1990 and 1991, kind of economic decline period that may account for it. Now the Obama administration understood this curve well. And Obama was fluent with Katz and Goldin's work.

And they made a major effort to increase Pell grants and increase the availability of higher education funding.

So interestingly, there was an improvement in the last decade in some of these numbers. Some of that was driven by the fact that jobs are a disaster in 2007 and 2008. So people tended to spend that time if they could afford it in higher education locations. So that was some of that going on. But overall, the Administration made an attempt to try and get those numbers turned around and they're a bit better.

And the public universities themselves understood their mission and realized that they're going to have to increase their employment base in order to accomplish this. All right, so that's Katz and Goldin. I mean there's other important points there, but that's key.

And then I want to do-- you know, we've talked about higher education as though it's the only way here. But I wanted to introduce some controversy into the debate. So William Baumol, very noted economist, taught at Princeton, more recent years have been teaching at NYU, you know, a remarkable analyst. And he's written in many different kind of economics fields.

Baumol does this NBER, National Bureau of Economic Research kind of work paper that just nails the whole system. So I thought we'd introduce a little controversy in today's class by putting his piece in front of us. He argues that breakthrough innovation comes from independent inventors and entrepreneurs, that large firms concentrate on incremental innovation.

We've talked about this bit before. And this conclusion is what is startling. Education for the mastery of science knowledge aids incremental advance, doesn't necessarily prepare you for doing the breakthrough, entrepreneurial side. So his point then, is that kind of standard science education may actually impede breakthrough thinking. And that large firm R&D requires scientists and engineers that are educated in the established fields and the established analytical methods and that successful innovators and entrepreneurs often lack that standard preparation.

And that that may get them out of the box of incremental advance into kind of new territories. And he points out that we don't have a system and we don't understand breakthrough learning. How do we educate for innovation? We have no real clue on how to do that. And that procedures for incremental learning do seem to work. But we don't know how to educate for the innovation side-- of the innovation system, who's got what.

He points out the Proctor & Gamble with 7,500 scientists, 1,250 PhDs, I mean, these kinds of totals start to dwarf the size of faculties at MIT and Harvard and Stanford and so forth. You know, with 22 research centers, P&G has in 12 different nations, that's a pretty amazing talent base. What are they up to?

Remember that when you look at R&D combined, industry spans about 70% of the total spending on R&D. Of course, we know that that's D, not R, right? But industry has got about a 70% share. The federal government, about 30% share, that's R. So that gives us an idea of the different size of the establishments in the R&D side.

So we know that industry employs some 64% of scientists and engineers, right? So industry has got that talent base. And he notes that critical breakthrough historical innovator figures like Watt, Whitney, Fulton, Morris, Edison, the Wright brothers, Wozniak, Jobs, Gates, Dell, have no college degrees, and frankly, limited scientific training.

AUDIENCE: Wait, Jobs had a college degree.

WILLIAM BONVILLIAN: Yes, he had a college degree. No, he didn't finish Reed.

AUDIENCE: No, he left in the first year.

WILLIAM BONVILLIAN: Yeah, he left. He left after a year or two.

AUDIENCE: I thought he went somewhere else.

AUDIENCE: He stayed. He stayed with Reed and just dropped in on classes, but it wouldn't count as getting a degree.

WILLIAM BONVILLIAN: He was studying things like calligraphy that actually turned out to be incredibly important for him.

AUDIENCE: I mean, that's the quote example, he went a lot of classes [INAUDIBLE].

WILLIAM BONVILLIAN: Right. And he spent a year in India.

AUDIENCE: Yeah, he did a lot of interesting things.

WILLIAM BONVILLIAN: So Baumol's point is progress requires-- we shouldn't underestimate this. It's not that one side is bad. Progress requires both breakthrough radical advance and incremental advance. And an example, which I've used before with you all, you know, if you're flying across the Atlantic Ocean, the Wright brothers, you know, motorized kite is a terrific, radical break through advance. But I'd rather take the 787, product of 10 decades worth of incremental advances when I go across the ocean. So both are really important here. You've got to do both pieces.

But, a disproportionate share of the breakthroughs do seem to come from kind of independent inventors or entrepreneurs. And large firms tend to specialize on the incremental, in part because they want to break up their own business models, right? They've got established business models. They want to contribute to those business models rather than wreck their existing business model. So that's part of the economic motivation here.

But education for incremental advance may well be different as Baumol points out, than education for the novel advance. And incremental improvement may well require a much greater mastery of demanding science and technology information than the novel idea. So both are essential.

But then he posts the critical question, how do you educate for the original and novel idea generation? So we've got three new stories on the table here. And let's start off discussion, and then we'll take a break in a bit. First, we've got Richard Freeman.

AUDIENCE: Yes. I wanted to make some strides actually on a point to that Baumol made in our conversation of three months since Baumol was the one who cited P&G as an innovative research and development firm with a lot of PhDs. One of you posed the question about Freeman. This paper lauds the relationship in the United States between firms and university research.

For multi-national companies, what incentives do they have to promote US innovation leadership, even when they may be based in the US when they operate in so many different countries? So at the heart of this question is, why do we need to invest in America if it is that the private sector is not investing and has no rational self interest to invest in us from an economic perspective? That is the implication of this question.

AUDIENCE: I don't think it's like-- I think that we look at it one dimensionally. You have to look at it, like,

think about it like an individual, right? Like you're going to be a baby. There's a whole gestation period. Then there's a time period where you're trying to grow as an individual. And then there's one when you're ready to get to it, right? And like you're very useful.

So for industry like, they can't really handle this whole gestation period, you know, one to 18 years old period. But they can handle it after, when you're ready to go and do a little ramp up skills. But to do a whole thing is pretty difficult.

AUDIENCE: That's an interesting answer.

WILLIAM BONVILLIAN: I'd add too that the US has an extremely decentralized labor market. So there is a huge disincentive for employers in the United States to offer training. Because they offer training, which can be quite expensive, investing in you, that in turn equips you to move on. So often another employer will buy you out for a lower margin with the educational costs.

But the employer who invested in your education won't be able to match that increment. So why should they invest in employees if the talent is going to go elsewhere? And countries like Germany have a much more established set of apprenticeship rules and much more heavily unionized, 80% unionized in the manufacturing sector. They have been able to create an apprenticeship system that's much more enduring and employer tied.

That creates tremendous encouragement for employers to provide lots of skills training to its employees. Indeed, it's really a part of the German education system. We have never really been able, because we have such a decentralized and almost laissez faire labor market, we've never been able to create significant incentives for employers to provide education. It's a deep structural problem in our system.

And you know it's one we're going to probably have to figure out how to deal with. We have created a whole system of community colleges. But the burden is on the employee to go back and get that education. We make that pretty inexpensive.

AUDIENCE: Going back here about the gatekeeper thing. Couldn't we just bribe them?

WILLIAM BONVILLIAN: Bribe the employees?

AUDIENCE: Yeah. Oh, no.

WILLIAM BONVILLIAN: Bribe the employers?

AUDIENCE: Yeah.

WILLIAM BONVILLIAN: Right, we could.

AUDIENCE: The education, how much is it?

WILLIAM BONVILLIAN: I'm sure it's not cheap, right?

AUDIENCE: Damn it.

WILLIAM BONVILLIAN: But in other words, could we create an incentive for employers to provide the education system, even if they weren't able to retain their workers. And what would that cost? So maybe the feds would pick up that cost. So in a way, the community college system is a way of the government picking up that

Cost and share it with the employee. Because employers can't take the risk mitigating. I kind of jumped into the discussion here. I want to give it back to you, Steph. Get me out of this.

AUDIENCE: I think that's-- who posed this question? Yeah, I think you're right. I mean it really gets at the heart of all three readings. And I think, in particular, let me see if I can parse for a quote here from one of the readings. Actually it was in Freeman's reading, when he quoted Derek Bok, who is the founder-- I think--

WILLIAM BONVILLIAN: President of Harvard.

AUDIENCE: President of Harvard. And now the graduate school of education at Harvard has a center for innovative learning named after Derek Bok. And he claimed towards the end of the piece, or rather he was cited towards the end of the piece as saying that other countries are facilitating our enterprise model.

And if, I think it's really meritous of consideration, that if our education system is not supporting the production of scientists and engineers, and firms are you know sort of ready and happy to get employees from other countries or to move to other countries, that we're effectively

shooting ourself in a foot, by participating in free market principles for education. Because we can't provide the labor force and we can't support the labor force and we can't support incentives financially.

So at the end of the day, we're preventing ourselves on all fronts from innovating, which I think is a really important consideration that merits sort of being honest with ourselves, as not only a society, but also as you know a political economy.

AUDIENCE: Something throughout all the readings that I have not understood. How is it that we're spending so much on education, like so much money per student, yet teachers are not getting any of it and the students don't have very high quality educations. Where's the money going?

AUDIENCE: Yeah, Max, I think that was addressed by Norman Augustine's piece very slightly when he talked about the appropriation of funds and where spending goes. Specifically Augustine cited that 61% of education budgets in schools tend to go to education spending sort of broadly. And that it actually tends to trend downward for a lot of school districts who focus on other extracurricular activities like sports.

And I think he made that very brief note about the role of American culture in those funding priorities. And I think that also was a consideration of mine in reading this piece in conjunction with the Freeman piece. Like, what is the role that our own vision of ourselves and how we want to educate our children informs our policy decisions and spending down the line.

And you brought the point earlier that how is it that we don't have-- or that we have too many jobs that we don't have enough jobs but have too many PhDs, but then not have enough PhDs. And I think that the point that Bill was trying to make is that we have too many PhDs who are trying to go into academia, but not enough PhDs who are prepared for industry and not enough PhDs generally to go into industry. Does that clear things up a little?

AUDIENCE: That clears things up a lot.

AUDIENCE: OK.

WILLIAM BONVILLIAN: Yeah, I think I'd add an additional point there. And this is a complex one that you are free to disagree with. But, when we created the higher education system in the US, obviously it occurred over the process of centuries. And when the federal government, during and following World War II, came into a very significant support role for that system in addition to

the states, that was already a quite competitive system.

And as someone who has spent substantial amount of time with MIT's top administrators, I can tell you that MIT and other universities do exactly the same thing, they watched their university competitors like hawks. They know exactly what they're up to. They know exactly what they're spending on what.

They know exactly what their competition models are. They're looking very hard at how MIT will compete all the time. It is an extremely competitive model. It drives a tremendous search for talent at the faculty level as well as the student level. And that talent base is very well compensated. And that is a core way by which you compete for talent in a competitive system.

We don't really have a competitive system in the K-12 public education system. It's essentially a monopoly-based socialist model frankly. And you know part of the entry of charter school legislation was to introduce a competitive model into the K through 12 system. Now there's a big debate as to how well that's worked. But I think it's fair to say overall, it's added a significant dose of competition into that system. And

You could look at competition in health care. And you could competition and you know other large government supported systems too. But you know, when we came out of World War II, we created a socialist model for caring for veterans in federally owned hospitals.

And we fit into what was already a competitive space by supporting students, who in turn were given funding and they could go. They could take the money with them. Didn't go to the universities to fund them. So it's introduction of more competitive models here may have something to do with improvements in higher education. At least that was the concept behind introducing charter schools.

AUDIENCE: Could I ask you a followup? I know that other countries have normal schools which are schools meant to train--

WILLIAM BONVILLIAN: Yeah, other countries have socialist models and make them work. But we're just not as good at that.

AUDIENCE: What prevented the United States from developing normal schools or incorporating normal schools into their model?

WILLIAM I don't want to claim to be an expert on the creation of normal schools. But in the 19th century,

BONVILLIAN: the US did create both the institutions for mass higher education, i.e. the public universities, and high school education in a very short period of time. And communities were essentially realizing that they had to upgrade the skills for an industrial economy as their population shifted from farming to working in manufacturing firms primarily.

And they understood the need for upgraded skill sets. And there was an effort across the country to create high schools. Now some regions, particularly New England, had them. But the rest of the country, including the American South, is pretty quick to replicate a high school model as a fix for a needed skill set. So that is a massive social policy that was done in a remarkably short period of decades across the country. So the country is capable of making really major changes. I don't think I answered your question.

AUDIENCE: That's OK. I just certainly think it's important to consider the-- as it was highlighted I think in several of the readings, the role of teachers, one, moving forward in the future, two, how teachers are currently being educated, three, teachers are being compensated and sustained within the model. They seem to be sort of an undercurrent of what we're talking about, but not something that any of the readings are willing to address specifically, and perhaps strategically for political reasons.