KELLER CENTER ENGINEERING DEANS PANEL

Princeton University 2009

(edited transcript)

H. Vincent Poor: Welcome to the continuing celebration of the inauguration of the Keller Center. This next hour and a half, we're going to hear from five very distinguished educators in engineering. We have Linda Abriola, who is the dean of engineering at Tufts University, and Dave Munson, who is the dean of engineering at the University of Michigan. Dave and Linda are both graduate alumni of Princeton. We also have Jim Plummer, dean of engineering at Stanford University; Subra Suresh, dean of engineering at MIT; Kyle Vanderlick, dean of engineering at Yale. Kyle is also –

Dean Vanderlick: Faculty alumni!

Dean Poor: Faculty alumni, former chair of chemical engineering at Princeton. Kyle taught me a lot about the Princeton administration when I first became dean, so we're very delighted to have you here, and thank you for coming. Looking forward to what you have to say. So let me say a little bit about the format. I have five questions, which I'll read to you in a second. We've divided up the questions so that two deans will be providing primary commentary for each question, and then others of course can add comments as they like to the discussion. It's fairly informal, so that will take about an

hour, and then we'll open it up to questions from the audience and discussion from the audience.

The five questions are not really questions, they're issues. The first issue, very appropriate for today's setting is "Engineering in a Liberal Arts Setting." The second question is "Engineering and Globalization." The third is "Interdisciplinary Teaching" -- in particular, the suitability of existing academic structures for that. The fourth is "Integrating Research and Teaching" -- how do we bring the excitement of research to our students? The final topic is "Engineering and Entrepreneurship."

These five topics are all things that are very much at the heart of what the Keller Center is involved with. Why don't we kick things right off and go and talk a bit about engineering in a liberal arts setting. How do we teach liberal arts students engineering, and how do we teach engineering students the societal issues facing them and relating to what they're doing? Linda and Dave have agreed to be the formal speakers on this issue. Linda, we'll start with you.

Dean Abriola: Okay, well I'm delighted to be here. It's been a long time since I walked around the campus. In fact, 25 years. A lot has changed -- this was a parking lot when I was here! But it's beautiful and it's

great to be back, and some of the places still are there like A&B used to be my favorite place to eat, and that's still around, and Landau's, and Hewlett's. Anyway, was walking down memory lane last night. So I've been asked to address the liberal arts, engineering in a liberal arts setting. I'm dean at Tufts, and Tufts in many respects has a similar profile to Princeton. It's an engineering school that's really embedded in a liberal arts college which is within a research intensive institution so that there are a number of professional schools as well. So this allows us, I think, already to attract students who are interested in combining engineering and other disciplines in liberal arts.

Our students typically have very broad talents, and that's an advantage, so my comments here are going to address things that are going on at Tufts and ideas that we have, but I'm not sure how exportable they are to different environments. We're very closely tied with arts and sciences. The engineering population is about 15% of the student body. The buildings are actually all integrated, unlike how Princeton's evolving, we are very much closely knit with the sciences, and we're close to the liberal arts as well, because we're relatively small, so our students tend to take double majors, which are very, very common; double majors are encouraged. We have a 0 net attrition in engineering, so as many

students come from the liberal arts into engineering as leave, and I think it's part of our willingness to fashion degree programs. We're not always wedded to the ABET curricula, if our students want to experiment, we allow them to do so when we have a number of different options for them. So while we have a number of ABET curricula, if our students want to experiment, we allow them to do so, we have a number of different options for them, so while we have a number of ABET accredited degrees, we're not limited by those, and I think that's important when you start to look at these issues. The other thing that I think you need to do in this kind of setting is build on the strengths of the institution. So for instance, as you have the Woodrow Wilson school, we have the Fletcher school of diplomacy, and International Relations is the largest undergraduate major at Tufts, which is across departments, so we get a student body that is very interested in the global picture. We're trying to build on that by giving them experiences, giving them opportunities.

Another example is that we have a nutrition school, and so we have a lot of opportunities to wed the engineering with public health, and we have a lot of interesting programs, so you have to look for those kinds of opportunities and encourage your students to explore them. We also offer, and I think that's true here as well,

we offer what we call half credit, but they're essentially half courses, in sexy topics: building skyscrapers, gourmet engineering; and they're open to, and they count for distribution requirements for the liberal arts students, so they're encouraged to take those as part of their curriculum, so we do have a lot of flow back and forth, but it's been less successful than I thought in attracting students. They tend to come knowing they want to do engineering, and I haven't found a lot of liberal arts students coming to engineering because of those courses. They tend to take them more in their senior year, so it's an imperfect model, I think, at this point. And I think the other thing that's really important is to let creativity flourish. We have an ex-college, which creates courses outside of the curriculum, and a number of courses have been created in the ex-college by faculty that are partnering that end up then coming into the curriculum, and it's an interesting model. I don't know if many schools have that. We're blessed by the culture at Tufts, which tends to be, the faculty governing body is joined, arts and sciences and engineering are joined together, so faculty governance is together, tenure and promotion is together, there are many joint appointments, and so that culture encourages that sort of education, and we do have administrative support from above for these kind of activities. I think the impediments are, on the liberal arts side, I still think there is a lack of appreciation for

technological literacy. I still think that we have a ways to go to communicate the importance of this, and as Norm Augustine said this morning, it's so important, and I think, in this case, our students are our best spokespeople. When they take classes in these other disciplines, and they get engaged in the problem, the students start to appreciate what they're bringing to bear, and I think they're the best advertisement for the importance of technological literacy. And I think the other thing is, there have to be fiscal incentives for this kind of experimentation, and unless you establish those incentives, I don't think it's sustainable, and that's one of the things I face as dean. So those are my comments.

Dean Munson: First of all, as Linda said, it's wonderful to be back. I hadn't been back for a number of years. I did notice that the Nassau Inn is still here, Hoagie Haven is still here, and so I guess the world is okay. But seriously, it's a thrill to be back here and meet a lot of folks that I haven't seen for a while. Earlier in my faculty career, I was really pretty interested in establishing something at the intersection between engineering and the arts. I see a lot of connection there, and I'll address that in a second, and it was about two decades ago or so, maybe a little bit less, maybe a decade and a half ago, there were a number of liberal arts schools in New England that were going out of business, and I thought, "Darn, this is a time to be entrepreneurial! If I could just find somebody with a lot of money,

I could establish some sort of institute for engineering and the arts." Well, that didn't happen. At the time I was a faculty member at Illinois, but six years ago, I moved to the University of Michigan, and it turns out there that engineering is sort of segregated from the rest of campus, if you will, we're up on the north campus, but we have neighbors. The other people we share the north campus with are every single arts unit, and so it's music, theater, dance, architecture, and art and design, and so with me as dean, our faculty don't have a choice. Engineering *is* working with the arts! We're going to do that, and we *are* doing that, and I'd like to talk about that just a little bit. What I see among our student body is the vast majority who enter engineering, those kids are musicians, artists, etc., that's just a fact if you look at their records, and so there's no reason that we ought to shut that down when they start engineering.

I also see a complete parallel between engineering and the arts. On both sides, there's a strong element of creativity, and that's probably the side we think about the most, but there's also a strong element of refinement. A musician may be somebody who is improvising in jazz, but more likely, that musician is learning how to play Bach or Beethoven better and better and better, and it's their own interpretation, but still, better and better and better, and

that really describes an engineer in terms of optimization and trying to do things in the best way for your employer, or for society. So I think those parallels are there. On the engineering side, if you look at the products that engineers create, whether it's an iPod or an automobile, a lot of times the value added there, the really distinguishing characteristic is not on the technological side. I say that as an electrical engineer. You look at an iPod, why does an iPod sell? Is it because it has a better mp3 decoding algorithm? No, they're all pretty much the same. Better chips, better integrated circuits? No, they're all pretty much the same. And you really have to admit, it's the way it looks, it's the way it feels, it's the materials it's made out of, it's sort of the pizzazz, it's the easy download from iTunes and all of that. Well, so that has a lot more to do with design, and maybe the design ought to have a lot more to do with engineering. The same thing is true of automobiles. Really, the automotive "manufacturers" now are just system integrators, and you can buy a transmission from anybody, you can buy batteries from anybody, you can buy the electronics from anybody, etc, etc, and I think there's increasingly a lot of customization being done in terms of the consumer options there.

So I see a lot of connection between engineering and the arts, I think we have students who start in our institutions in engineering

with an enormous amount of creativity, and what we used to do in our engineering curricula was do our best job at stamping that out. It was homework, homework, homework, and the homework's necessary, but it's not enough. So the question is what to do, and I won't address this completely in my couple minutes here, but at Michigan, we've got plenty of students who double major, and we've just instituted a number of minors, and now it's possible for any student in engineering to get a minor in art and design, minor in music, minor in architecture. We're also doing some co-teaching. We've got engineering faculty helping teach some of the courses in architecture, for example. We've got a course on creativity we're teaching this semester, it's got two faculty from engineering, two from art, two from music, and two from architecture, and students from all over campus in that course, so it's a multi-section course. Huge student project component there. Speaking of student projects, we're working very hard on multidisciplinary design projects, great big imaginative things. So not the traditional senior capstone design experience in engineering, but something way bigger. We have scads of these, and I think this is the trend at all leading engineering institutions, including this one. Just as an example, we have a group of students that decided they wanted to bring the internet to the entire continent of Africa. Well, that's pretty ambitious, and how would

you do it? Africa doesn't have much infrastructure, and I should be a little cautious there, Africa's not completely homogeneous. Obviously, a lot of countries and a lot of differences there. But the students, for their project, designed a satellite ground station, and then the idea was this would be solar-powered, because there wouldn't be electricity in the village where this thing resided, and then if there were just one laptop computer and this internet ground station for that village, it perhaps could be transformative. But the students did more than design it, they actually built a bunch of demos, they actually flew over to Africa, they actually installed it, and the stuff is all operating now, and now the students are looking for corporate sponsors. The next thing they'll have to do is get the price down, because the price is around $4,000 for one of these stations, they need to get it down around $1,000 or so, and then they think that can really spread across many countries over there. But that's just one example of dozens that I could comment on, and I think these kinds of things are giving our students real world experience, and by the way, there are a lot of these projects that involve students from outside of engineering with engineering students, and for me, there's nothing that I prefer to see. At least at my place, we're making joint faculty hires between engineering and the arts units, and so the fellow who was recently hired as a professor of campanology, he's the person that instructs the

program on how to play the carillon. We actually have a couple of carillons. And he's got a partial appointment in engineering, it's not a zero time appointment, it's a real appointment, and he's going to be teaching courses on the physics of bells and that sort of thing. We have another offer out right now to a faculty member who will be joint between computer science and music and is at the intersection there in performing arts technology. We're also doing a lot of fun things together between the engineering students and the art students. I won't describe those things right now, but we claim we're having more fun than anybody else on campus.

Dean Poor: Engineers always do. Anybody else make any brief comments on this topic?

Dean Suresh: Before joining MIT as a faculty member, I was a faculty member for 10 years at Brown University in engineering, and that, if I could describe an experience that's very different from my current experience of being an engineering faculty member, department head, or dean in a place like MIT, Brown and MIT probably span the ends of a very broad spectrum. One of the things I realized at MIT is the ability of students in the arts, the ability of engineering students in the arts, it's just incredible. There are no, I don't know the official numbers, but something on the order of about 65% of the undergraduate students have well beyond the average ability in music in playing one or more instruments, and I feel that given the

time pressures and the infrastructures that we have, that potential is not fully tapped yet. There's so much more we could do, not just in an engineering based school, but also across the country, and that's just one observation that I would like to make. The second observation, going back to David's point, is that the Media Lab at MIT was set up as sort of an interface between engineering and products going into the marketplace, and a lot of the things that happen in the Media Lab are what engineers do in departments like electrical engineering and computer science, or robotics and so forth in mechanical engineering, but at the same time, you also have elements from other units that are brought into it. And that can pervade, not just one particular center or lab, but across a campus, there are many, many models one can think of for something like the computer setting.

Dean Plummer: Actually, if I could just build on that, one of the experiments we tried at Stanford four or five years ago was something we called the D-School, or the Design Institute. It was founded by one of our faculty who was also one of the founders of IDEO, which is a world class design firm, but the concept was that historically, senior design projects when many of us were in school would – I'm a double-E, so a senior design project was get 5 double-E's together, and we'll all work on programming a microprocessor on a motherboard or something, it's a double-E-ish kind of product,

and that's not how it is in the real world. If you design something in the real world, then yes there are technical issues, but there also are human factors issues and there are very important business issues as well. So the concept -- and I think this is what's happening at Michigan and MIT and other places – is a new kind of senior capstone design project [where students] create a team of people drawn from business, from the liberal arts, the humanities and the engineering school, and they work together on a project. The one you cited about the project in Africa is a great example that this kind of thing is happening everywhere, and it gives the student a very different kind of real world design project, and more importantly, I think, it's one of the few ways I've found to get students outside of engineering into an engineering environment, because they'll come in as domain experts, you know, and engineers don't know much typically about human factors, they don't often know much about business, so the business students or the humanists who come into these teams are the domain experts and the team is put together, so they're not like outsiders, they're really part, a critical part, of a team, and that's, to me, the key to getting all these different disciplines together: have each player think that they are the expert in what they do, and they're coming together to do something that not any of them could do separately,

so I think that that's actually a good way to think about how to bring liberal arts into engineering and vice versa.

Dean Vanderlick: The point I was going to make, and everybody touched on it, was the importance of design that's coming into engineering education at all levels: through the graduate program, that's what the D-School I think focuses most on, but in particular, building design experiences all the way down into the freshman curriculum, which gives a chance to expose engineering to non-engineering majors and to get engineering majors psyched up about the discipline. We're all thinking about new ways to do this, and I think the focus on design, especially, is what's going to separate engineering programs from the science programming and is going to be incredibly important to the discipline.

Dean Plummer: Thank you. Outstanding points. Let's move on, we can come back to this later when we take questions, so this is perhaps at the center of the discussion is this relationship between engineering and the liberal arts, but let's also talk about globalization, so the next topic is engineering and globalization, and Jim and Subra are the designated speakers on that, and Jim, we'll start with you.

Dean Plummer: Well, I'll just take a couple minutes to maybe, as best I can, define the problem or maybe define the opportunity. I'm not sure, it's probably both. So the best way to think about this, many of you maybe read Tom Friedman's book on the flat world, and that's an

element of this, you know, to be competitive in the future, we need to be more innovative, more entrepreneurial to create the new things rather than trying to build more of the old things, so our students need to be educated with that in mind, I think, and prepared when they leave our institutions to go out and create the new opportunities for this country to be competitive in what is increasingly a flat world. Another way to think about this is that, whatever our students do when they graduate, they are going to be global citizens, and it's likely the case that most of our students during their careers will live and work in different parts of the world, and so in some respects, we're not doing them a very good service if we don't try and give them some exposure and experience with different kinds of cultures and different kinds of people around the world as part of their education, and another way to think about it perhaps is all this concern about outsourcing of jobs, and that's an element of globalization as well. The numbers of engineers that are being trained in India and China and so on.

So what are engineering schools doing? I'll try and just make some general statements. I think every university here is doing things in this general domain, and there are many, many different examples, but they tend to fall in a variety of buckets, I think. A number of

institutions are providing summer research opportunities for students overseas. We have a program like that in China. Other institutions do. Sometimes, when I talk to faculty about globalization, they say, "Why are you worried about that? Half of our graduate students come from around the world, and all our U.S. born students, all they have to do is go to school and they'll be globalized because they'll be surrounded by students from around the world." I don't agree with that, but that is a view that some people have. But in any case, I think we do need to continue to bring the best and the brightest students from around the world to our graduate programs, and that does provide an element of exposing our students to different cultures. Some universities have and are thinking about and are building overseas campuses of one kind or another, and these are interesting experiments, and there are a variety of such overseas campuses. Stanford has 12 of them in various parts of the world, but they're like little enclaves where Stanford students go along with Stanford faculty, and yes, they're exposed to the culture, but it's almost like they're in a Stanford classroom, and I'm not sure that's the best model. Other institutions are building partnerships with universities in Singapore, and Subra, I'm sure, will talk about that, [unintelligible] in Europe, and so on, so there are these kinds of partnerships being built. Some institutions are helping developing countries build

world class universities. Probably the best examples today are in the middle east where we're heavily involved with Kaust in Saudi Arabia, other universities in that region, Abu Dhabi, and the goal there is to actually build a world class institution that can become a center of gravity for high quality education in those regions of the world. Another really interesting piece of this whole picture is distance education. The truth is, today, that you can deliver a high quality education anywhere in the world anytime of the day or night, and you, the power of the internet, all these communications technologies that all of us have worked on developing have created the opportunity to make education remotely, make remote education much more practical and viable than it's ever been in the past. Now exactly what we do with that, I think is not clear. We're, everyone's doing lots of experiments, and MIT's got the open courseware project, we put up 10 of our introductory courses free on the internet a year ago, and they're being downloaded all over the world, so there's lots of stuff going on in distance education, which is also part of the globalization picture. So to me, our goals in this area ought to be to provide an education for our students, which prepare them to work in a global world, and secondly to provide an education for our students which allows them to be the innovators and the entrepreneurs that are going to provide the future growth job opportunities for this country, and

those are two key elements of how we should think about, I think, what we're doing in the globalization area.

Dean Suresh: So I want to touch on, just to amplify what Jim said, I want to touch on four aspects of globalization in the context of an American University, especially for schools of engineering. The first and foremost is with respect to undergraduate education. Even though, for example, the numbers that I know very well, in the school of engineering at MIT, which is about 40% of the faculty at MIT, 375 faculty members, 43% of the faculty are foreign born, so it's a highly international group. Roughly 40% of the graduate students are foreign students. But only 8% of our undergraduate students are foreign born, come from foreign countries. So it's the undergraduates more than anyone else who need the greater global experience, and that's a challenge that a number of models that we have, the most successful program that has been in existence at MIT for 25 years is a program called Mystic, where every year, large numbers of students, and the numbers are growing, they go abroad, preferably to a non-English speaking country, more and more students want to go to developing countries where they engage on a project, usually it's a technical solution, not necessarily high tech, but a technical solution that has an impact on the local community. So last summer, about 260 students went to Africa, India, China, Middle

East to do a variety of programs. That's one model. Institutionally, there have been different kinds of models of engagement.... Then [there are] advisory roles, many of us do this, and partnership is much more significant, and there are a lot of challenges in doing this, which we want to assist. In institutions like Princeton, protecting the brand name is a key issue, and as a result an international engagement has to be taken very, very carefully, and where do we engage and where do we not engage, at the same time, let the faculty do what they want to do, it's a very delicate balance. One of the principles that we have employed in our international engagement most recently, MIT's first research center outside of Cambridge, Massachusetts, which just before becoming dean, I had the good fortune to help set up, there, our operating principle's the following: to set up a research facility in Singapore that MIT faculty will engage in, and many of them will lead under the following conditions: if we can do in Singapore what we can do in Cambridge, Massachusetts, don't do it in Singapore, do it in Cambridge, Massachusetts. There has to be a unique value added, intellectual value added. So we've developed four programs so far, and those four programs uniquely bring in something that they can not do in Cambridge. This makes it very attractive for the faculty to engage in, so that's one of the principles. The last point I would like to make is, especially for leading American institutions, I feel,

given that the 21st century is going to see greater rise of Asia with 45% of world population, which is increasing, and the number of engineers is significantly greater there than what we are going to see here, it's partly an opportunity, but also an obligation to make sure that the future of engineering evolves there in such a way that we play a part in, at the same time, we play a part in ensuring the quality that affects all of us, so the questions of how to define the quality, how to ensure that they meet well established standards that have been existing in the west, so these are all challenges, and later on in the discussion, we can go into specific examples.

Dean Vanderlick: I would say globalization is one of the top, if not the top theme of the Yale University experience. What makes it easier for us, and Linda alluded to this, is to have flexible degree programs, not just ABET accredited degrees, but also non-ABET accredited degrees, or even AB degrees, they give all kinds of different flexibility to students as per their wishes for not only dual majors, but to participate in an experience abroad. Vince said this morning, it's not like thermodynamics, or I think Norm said it this morning, it's not like thermodynamics is any different in Melbourne or France than it is here, but it's the cultural experience of being in a different place that matters. There's another topic here that I think we really haven't touched on that relates to education is that education extends, of course, beyond the undergraduate experience

and throughout the graduate experience that is so important to all of our programs, and the graduate experience in engineering at the Ph.D. level has certainly been, I think, very static for however many years, you know, students come in, they stay in the lab for 4+ years, and then many of them go, the vast majority go on to take industrial careers, and they get involved in business and the like, and I don't know what percentage it is, let's just call it 10-20%, go on to become clones of their advisors into academia, so we're thinking hard about how do we, how do we give educational experiences and leadership experiences to Ph.D. students as part of their educational experience and globalization opportunities, I think, are going to factor into that as well. I think it was Vince who said that it's a little harder at Princeton to get students to go abroad because the experience is so nice here at Princeton, it's so nice to be here at New Haven, I think we have a little less problem in offering a trip to France, but anyway –

Dean Abriola: There is another model too, at Tufts, we have something called Institute for Global Leadership, which is sort of an extra-departmental institute that is well funded, and every year, they select a topic, so one year it's megacities, another year it's oil and water, and I sent a letter, invitational letter out to all the students at the engineering school and encourage them to participate, and there are various levels of participation. You can actually take a

pretty intensive course load around this topic, or you can participate in seminars, and many of our students have participated. There are a lot of people who are coming in from the globe lecturing on these topics, and then they're sending groups of students out, and it's been very successful, and our students have benefited from that. That's another sort of model that one could use.

Dean Munson: Just a couple things, Vince. What I tell our students the first time I see them as freshmen is, when they're out there on their first job and their boss comes and says, Paul or Susan, I need you to go to Shanghai on Monday, I don't want them to go, oh my goodness, what do I do, I've never done this kind of thing before! You need to have done it beforehand. So we're trying to get absolutely as many of our students as possible to have a real serious experience overseas, and like a number of places, we have international minors, all kinds of deluxe things they can do, and then we've got other things they can do like summer jobs overseas, and we facilitate that sort of thing. The other thing I wanted to say is putting our administrative hats on, because we're all deans, and probably it's about once a week, we have either a university from overseas or even representatives from a country overseas saying, gee, Dave, or Jim, or Linda, or whomever, we'd really like to establish serious partnership with your institution. Well obviously,

we're not going to be arranging these things at the rate of one per week. So we almost always say no, and I think it's really important for any university that's thinking about these things to have your list of what you're looking for. If you're not going to get that out of it, you don't do it, and at Michigan, we think of our partnerships in one of two categories: either minor partnerships that require very little on our side. It's more of a goodwill gesture, maybe exchange of a few students and a few researchers, but no big deal, and then on the other side, the real major strategic partnerships where over a period of years, we're trying to get something very significant out of it, we have very few of those latter partnerships.

One that we do have is with Shanghai Shaotung University in Shanghai where we established a joint institute, and it's a major thing. There are many hundreds of students there, we send lots of Michigan students there, but we had our list. We knew what we wanted to get out of it, which was a convenient landing place for large numbers of our students, we're taking large numbers of students from Shanghai that transfer into our curricula at the junior level, they're spectacular students, and we want to keep them as Ph.D. students. We knew what the Chinese government wanted. They wanted our faculty over there teaching some courses and really establishing a different style of education in the classroom,

so no longer the style that professors at the chalkboard, writes things down, students copy it all, professor assigns even homework problems, students work both evens and odds and then get As on their tests, because that's just not enough. That might be a necessary part of the education, but it's not enough. All the teaming part and group activities and interaction with the instructors, that's the American style, that's what the Chinese wanted to see, so we were happy to provide that in exchange for the things that we're getting, and in our case, the Chinese government is really footing almost the entire bill, and I think if you check around in a lot of these partnerships, it is the government on the other side that is footing the bill or industry or somebody, but I think it's really important before one establishes a major partnership to have your list of exactly what you think you want to get out of it and make sure that happens.

Dean Poor: Again, we'll have a chance for questions later at the end. Let's move on, and this next topic is one that relates to the first topic quite a bit, engineering in a liberal arts setting. This has to do with interdisciplinary teaching, and in particular, the suitability of existing academic structures. The designated speakers for this are Kyle and Linda.

Dean Vanderlick: I'd be happy to start. So I think there's absolutely no question that students, faculty, everyone across the board believes that

interdisciplinary work, interdisciplinary teaching is where a lot of the action is, where the excitement is, and there's a lot of momentum and certainly, you know, effort and energy into directing our attention to thinking about teaching opportunities, research opportunities, and so on. The question is, how to do it. It's very, you have to try things, I think there's experimental, an experimental nature to this, you can't be afraid to try things. At Yale, for example, we created a department of biomedical engineering in the last decade, and we decided to create it as a partnership with the medical school, so there are faculty appointed in the medical school that are part of that as well as our own faculty within engineering, if you wish, that are part of that. Having a school of forestry and environmental studies on the Yale campus allows us to partner with them, so we have a joint faculty member in our chemical/environmental engineering department and the school of forestry and environmental studies. Being small, Yale has about 65 faculty in engineering, I think we're the smallest school of engineering at the table, and as many undergraduates who graduate each year, so also the smallest student and faculty ratio. We have but no choice to leverage all the strengths of the Yale campus, and that means interdisciplinary work with the life sciences, with computer science which is not in the school of engineering, with the school of forestry, and more forward looking

things, like with our school of music, with our school of drama, and different opportunities with the arts which are so important at Yale. I don't know if it was teed up this way, I don't think so, but I think I would like to actually turn the mic to Vince, because when I was at Princeton, not that long ago, I think some of the most interesting experiments were going on here in terms of interdisciplinary teaching, especially at the freshman level with a new course in engineering and the modern world and an integrated program tying together physics, calculus, and biology, and I thought it would be nice for folks to hear how those things are coming along.

Dean Poor: Sure. Thank you. [laughter] There's a lot going on! Although we have a larger engineering school than Yale, it's still relatively small compared to some of the other schools that are represented here, so we have also been almost by necessity quite interdisciplinary here at Princeton. Two ways that this has played out -- one is the freshman level, where we have worked to develop courses that cover all branches of engineering in a more general context, even than in engineering. We have, for example, courses in the civil environmental department, the names I think are something like engineering and the modern world, and we have another one called structures and society, and these look at engineering problems in very general contexts. Now the structures

in society course is very much focused on civil engineering, but the engineering in the modern world course, which is taken by many, many students from the humanities as well as engineering students looks at a number of technologies and how they fit into, or how they developed, both as businesses, in terms of business context, how they fit into the societal context, what the societal conditions that sort of fostered the development of those technologies, how they affected society and so forth. We start with the telegraph, we talk about the telephone, so these are electrical technologies, we have many other technologies, transportation, airplanes, so forth. So this is one type of interdisciplinary teaching that we have been doing for quite a long time here at Princeton. And it has worked very well, partly because there have been people who have been really passionate about it, partly because the university has put resources into it, and partly because it's been extremely successful, so it hasn't been very hard to argue for more resources for these kinds of courses. You know, again, interdisciplinarity also has gone up into the higher curricula. We don't have here, for example, a department of materials as I know MIT does, Subra. Here, materials is an interdisciplinary subject, it goes across chemical engineering, mechanical, and aerospace engineering, civil and environmental engineering, and electrical engineering, so four of our six departments are very heavily involved in materials. Almost

all the courses that we offer in this area, graduate and undergraduate, are taught by interdisciplinary teams, or in an interdisciplinary fashion. So again, partly because of our size and the nature of the way things have been organized at Princeton, we've been forced into doing things in an interdisciplinary way. It's been very fortunate for our students. I think they see a side of things that they might not ordinarily see if they were in one of these stovepipe departments that Norm referred to earlier. Thank you for giving me the chance to say that, Kyle, and maybe I'll turn it over –

Dean Abriola: So similarly, size-wise, we're very small at Tufts, so we have to build across disciplines, so that's very much a theme of the engineering school, and we chose some themes such as bioengineering, engineering for sustainability, innovation and education as themes to rally around, and we've been hiring faculty who fit into those general areas across all departments, and it's been very successful. One of the things that I found about a small school is the collegiality is very high, and there's a collaborative spirit that was a little bit more difficult to engender at Michigan when I was there for many years. So what we find is people have personal relationships with each other, the faculty know each other, they see each other every day on campus, so that helps, so I had, I took a little different tack on this, I had a few different

models that we've used for this sort of thing. One thing has been mentioned before which is the project-based learning, and I think in the interdisciplinary area, this is a key model that works extremely well. There's the cross-departmental, cross-university sort of senior design project, there's thematic types of projects like robotics or there was an NSF sponsored project called bringing engineers into new disciplines, which was partnering with the nutrition school and the medical school to look at bringing engineers into things like developing a diabetes, a monitor for diabetics, for them to regulate their intake of food, and those sorts of things which brought our engineering students in contact with others. We also have a theme at Tufts which is active citizenship. We have the largest number of graduates going into the Peace Corps upon graduation – the largest number, not the largest percentage, in the country. And so there's an ethos there, and many of our students are involved in social, community projects as part of the design, and we have a virtual college which is called the Tisch College of Citizenship and Public Policy, which funds these sorts of activities and gives fellowships, summer scholarships to students to do projects in the community, and that's a way to bring students together, and problem focus is a key thing in these sorts of models. Another interesting model is, I brought a group of faculty together, work in bioengineering and challenge them to come up

with one syllabus of a course to give students fundamentals of biological systems, and they actually did it, and we're going to launch that course next year, and I couldn't believe they came to agreement, and we have teaching assistance from every department engaged in developing, case studies now for this class, and it's going to be taught with, one person has to champion such a thing, but having engagement from all departments, I think it's great, and a different model, the provost came up with the idea of having a university seminar which was going to bring graduates and undergraduates and multiple schools together, and there was a competition, and faculty had to submit proposals, and the first one that was funded was water and diplomacy, and that course was run last year, and the Fletcher school, which is a school of diplomacy, co-taught it with one of our engineering faculty, Shafiq Islam, and they had students, they had undergrads, they had grad students taking this, and they had students separated for part of the course to give them some fundamentals in the other areas, and then they brought them together, and they've also launched something called Aquapedia now which all the case studies from the class on all the aspects of water and solutions and war related to water and conflict and all that, all these case studies are going to be put up on the web, and it's going to be a living document that's going to keep being developed, so it's very exciting, it's very labor cost intensive

for the provost to support this, there were a lot of tools that had to be developed, web tools, video conferencing, all these kinds of things, so I don't know how, it'll be taught once more, I don't know if it will continue beyond that, that's one of, the sustainability is an issue, I guess. The other thing that we have across school majors, which kind of relates to liberal arts, like we have a very strong program in Engineering Psychology, which is a partnership between Psychology and Engineering, sort of human factors, those sorts of things can bring people together, and then summer scholars programs, where you fund students to do research in the lab of a faculty member in another discipline, you know, really brings the students into exposing them to other disciplines, and I guess the last thing is, we haven't talked too much about extracurricular opportunities, but these abound in today's society. The Engineers Without Borders, I found it interesting that the president of Engineers Without Borders at Tufts was a political scientist last year, so we're bringing students in from all disciplines because, again, it's the problem focus, and this, next year we're going to be on the mall building a solar house as part of a solar decathlon, and we're partnering with the Boston Architectural College, and I was amazed to see all of the non-engineers engaged in this, the urban environmental planners, and it was quite interesting, and their approach is quite different based on the group

of students that's assembled, so I think there, in my mind, all kinds of models out there, and there's no one size fits all, and the only issue I see is making sure that the faculty have the time to pursue their vision and the resources to pursue their vision.

Dean Poor: It's always resources! Anyone else?

Dean Munson: I would just say, depending on the budget model that's used at a particular university, it can make it difficult to arrange for faculty from multiple departments, multiple schools or colleges in a university to co-teach. Everybody wants to know kind of how they're going to get credited and what it'll count for, and it's not that the faculty member's being selfish, but most faculty members don't want these things to overload, and so I would admit, in some cases, we handle this on a case by case basis, and there's probably work to be done.

Dean Suresh: One of the major issues for large engineering schools, Michigan or Stanford or MIT which may not be the same issue for schools with say, less than 100 faculty members, is how do you bring down the walls of engineering departments, the stovepipes that Norm talked about this morning, so there are a couple of experiments that are going on, and one experiment in that direction is the following. We asked the department heads every year, what areas would you like to hire, to see in your department? There are nine departments, and we get answers to that. And we asked them, what areas do you

think the school should be hiring, and then you put all of this information together, you find that more than five departments at a time typically ask for the same area, so that gives us a tremendous opportunity to, over time try to bring down the barrier, so here is an experiment we are going starting this year, so I have a large number of faculty searchers that are in areas in departments that are important to them, but more than five departments want the same area, so we interview faculty members, but the search committee consists of members from all five departments. They hire the best candidate, we ask the candidate what department do you want to be in, and the candidates can change their department over time. And not only that, because this is an area where we would hire for multiple years in a row, and we hire the candidate, we tell him or her that if you come here, next year you'll be part of the search, and you get to hire your successor, or the person that'll join your group, because it's a great recruitment way for us, so we'll see how this process works. We don't know how it will work.

Dean Munson: I guess one other thing I'd mention, this doesn't pertain directly to Princeton, but it does to some other places. There's places that have major medical centers, have an additional, just enormous opportunity for education, and it crosses heavily over into engineering, so I look at my operation, I've got about 340, 350

tenure track faculty. The medical center's got 2,000. Maybe I've got, I don't know, 500 staff or something like that. They've got 10,000, and so we are very heavily involved with them, not just in research, but also in education, we've got many, many students doing projects on health system operations and things like that, so for schools that have major medical centers, they ought to use those and leverage those to the fullest extent possible.

Dean Poor: Okay, next topic is integrating research and teaching. We had a little discussion of that this morning, and the questions for Norm's talk, and you know, the idea here is that the main principle here is how do we bring the excitement of research to the classroom, and here the designated speakers are Subra and Kyle. Subra, you're on.

Dean Suresh: I want to talk about three to four different examples, the typical thing that most universities do, especially research universities, too, is to have undergraduate students right from freshman year engage in research in the lab of a faculty member, so we have a program that's almost in its 50th year now called UROP: Undergraduate Research Opportunities Program, and the data from the program are quite interesting. It's completely voluntary, it can be either for pay, which is about $10/hour, no more than 10 hours a week, or for credit, 85% of the undergraduate students voluntarily participate in this, and something like 20% publish a significant journal article in an archival journal before they get their

undergraduate degree, so that's a program that's for research and not for classroom. Something that's related to research at the undergraduate level and for the classroom, possibly, is a relatively new model. This also pertains to innovation.

About eight years ago, we started an experiment in the school of engineering called the Deshpande Center for Technological Innovation. The concept is simple. Faculty are highly entrepreneurial, they go start companies, they patent intellectual property and so forth. But how do we give them a little bit of extra incentive over and above what they already do so that the process of translation from the lab to the marketplace is much faster? At the same time, how do we give an opportunity for our undergraduate and graduate students to participate in this entrepreneurial activity? So the way this works is to have a transparent call for proposals which is university-wide, twice a year, get all the input, and you give the faculty members a very small amount of money, about $50,000 a year for one year to see if the technology has a way to make it to the marketplace. During that year, we have faculty and alumni and industry friends and mentors who, if the faculty members want, can provide advice. These are people with a lot of experience in starting companies, and they've failed many times in the marketplace, which is often

very helpful, and related to that is an educational activity. We put teams together. Half the team members are from the school of engineering, and half the team members are from the school of management. In some areas like energy, we bring in people from humanities, technology and policy, taxation issues, economics, and so forth, and this is a very good educational opportunity. Just to give you an idea on the numbers, in seven years, we've sponsored 95 projects involving all five schools at MIT, 200 faculty and students have participated in this, we've spent $7 million, it has attracted $155 million in venture capital funding, and it has spun off 20 companies in a span of 7 years.

The third example in linking education and research at the undergraduate level is the new program which is an international version of the undergraduate research program called IROP, where again, we strategically take our global partners and our industrial collaborators from abroad and send our students, not only do we send them over there, but we, when they come back, they work on campus in the lab of a professor, and then we also engage graduate students who could be teaching assistants in this. In fact, sometimes even senior undergraduate students who could be teaching assistants in these classes so they get the educational experience, they get the overseas experience, and they get the

research experience. And the last example that I want to mention is a program that I started about a year ago, it's a very ambitious program for a period of 10 years with a $20 million gift and overall $40 million investment, it's called the Bernie Gordon Program for Engineering Leadership, and the objective is the following: how do we, in an increasingly software based virtual world, how do we import the real excitement of engineering to undergraduate students for hands-on project based learning. It's easy to do for small groups of people, but it's very difficult to do for large groups of people, so we have something called Opportunities For All, which is for all MIT students, not necessarily engineering students, Opportunities For Many, and Opportunities For Few. We start at Opportunities For All, and then you move your way up the pyramid, and it's highly competitive, but this is the first year that we've launched this, and I can discuss this in detail later if there is interest, so these are examples of activities that are relatively new and that we've been experimenting with.

Dean Vanderlick: I'd say we at Yale have a special challenge just in getting students to come to Yale who want to study engineering. We're only graduating 70 students per year in engineering. Engineering and sciences at Yale, more generally, at least 400 to 500 students in every entering class professes on their application an interest in majoring in science and engineering, and I can tell you that we

don't graduate 400 students every year with degrees in science or engineering. So clearly, we want to get kids interested in research, especially at the beginning, because if you don't get on the engineering train at the first station, it's obviously very hard to get on at the second.

So one of the things that we started some years ago at Princeton – Yale rather [laughter] -- was a freshman course called Perspectives in Science, which when I got there, I insisted they call it Perspectives in Science and Engineering, where they have different faculty from across science and engineering come in, one per week. It's more than just giving a talk about research in their area. There's a whole team of people involved, faculty in charge of the course, a whole cadre of graduate students, so it's a discussion about research in that area led by the faculty member, but there's homework crafted around it, a project crafted around it, so it's more than a seminar, and this exposes students to all the different exciting research going on at Yale -- connects them, you know, makes the faculty real people to them, interestingly, the student enrollment is limited to the course, so some of the best and brightest students in science and engineering are offered a chance to take the course, maybe enrollment is from 40 to 50. It's a real privilege to be able to take this course, and I think it's been a real

help in retention issues and just getting excitement about engineering into their minds. I'd say, from the Yale perspective, I've been pushing hard to make sure that we talk about engineering as distinct from science, because it is. Engineering is not a part of science, but a partner to science. In fact, I think I pretty much earned from a marketing value my first salary at Yale when I said, you know, if you spell Yale backwards, it's E-L-A-Y, that's "Engineering and the Liberal Arts is for You," Yale is the place! [laughter] But in all seriousness, major research universities, if they don't capitalize on research experiences in their full vigor to enrich the educational curriculum, they're just wasting their most valuable natural resource.

Dean Poor: Thank you. You spell Princeton backwards, it's "Not Ecnirp." [laughter] Anybody else want to comment on this topic? Okay, so we have one more topic, and then we'll open it up to the audience for questions, and the last one is a topic that all engineers are very interested in, and this is engineering and entrepreneurship, and Dave and Jim are the designated speakers. Dave, do you want to go first?

Dean Munson: I think Jim should go first since he's from the Bay area.

Dean Plummer: All right. So everyone says, to be competitive in the world that we're going to live in in this century, we need to be innovative, we need to be entrepreneurial. That's going to be our competitive

advantage. So when we think about this, it seems to be we first ought to define what it is we think entrepreneurship actually is, and to me, one of the best definitions I heard of entrepreneurship actually came from one of our students who answered that question, and what she said was entrepreneurship is a mindset. It's simply recognizing that things can be better than they are, and that I can be part of making them better. It's not necessarily by starting companies, it can be, but it's not necessarily about starting companies, it's not necessarily about doing this or that, it's just believing that things can be better and that you can be part of making them better. The second characteristic of entrepreneurship I think is really important is it's been described many times as a full contact sport. It is not something that is easily taught in a classroom through traditional lectures, I believe the same thing's true of innovation. Innovation is a full contact sport. It is not something that you can have someone take a class like this and me or somebody else stand up at a blackboard and give you a lecture about entrepreneurship or innovation. So if we want our students to have these characteristics, and I think we really do, then how do we teach them to be innovative, and how do we teach them to be entrepreneurial. So many universities, us included, do have, in fact, a set of courses and seminars and lectures and that kind of stuff that provide the fundamentals of how to think about how to be

innovative and so on, and those are good, they're necessary, probably, but they're clearly not sufficient, so what are the key elements, and in my experience, and the things we've done, students learn how to be entrepreneurial, and they learn how to be innovative by actually doing it, and let me just give you one simple example. There was a worldwide contest which was run a couple years ago, and these contests now happen every six months on a regular basis, the person was organized out of our technology ventures program at Stanford where teams of students said, various universities around the world are given a project, and the project is usually, it's usually a weekend project, so it's over a 2-day period, so outside of normal classes and everything else, and the kinds of projects are like the following: the very first one, which was two years ago, each of the student teams in 7 countries around the world was given a pad of post-its, and they were told, in the next two days, they had to create the most value that they could out of a pad of post-its. Now if any of you are interested, send me an email, I'll send you a site to a video of what happened in this contest, it's unbelievable what these students did. Some of them ended up making thousands of dollars for charity through various things, others of them created things out of post-its that they sold or used to solve social problems, it's just unbelievable what they did! And to a person, they came out of this competition being a

whole lot more innovative and a whole lot more entrepreneurial than any of them thought they were. So to me, that kind of example is illustrative of the fact that it really is a full contact sport, it really is something that you learn by doing, and so we need to provide those kinds of opportunities for our students, and generally, they will be outside normal classes.

I guess another important factor in this whole area, to me, is that unlike 10 years ago, when I talk with undergraduate, entering undergraduate students today and ask them what it is they want to do with their careers or what it is they want to do with their lives, you know, 10 years ago in the late 90s was all, well I'm going to be a computer science major and I'm going to get a bachelor's degree and I'm going to write a business plan and I'm going to take it up Sandhill Road, and I'm going to get $10 million, and then I'm going to do an IPO, and then I'm going to retire, and this would all happen by the time you're 22, and in a few cases, it actually did happen, but in most, it didn't. Today, when you ask them this, they say, "I want to do something with my career and my life that has an impact. I want to do something that makes a difference," and when you ask them, "What do you mean by that?" they say, "I want to work on global scale projects, I want to work on alternative energy, I want to work on human health issues, I

want to work on the environmental issues," and so on. So wrapping the experiences that we give them to help them learn how to be entrepreneurial and innovative around these kinds of global scale problems is a match that I think has tremendous power and tremendous implications for getting young people excited about engineering, so I am a real believer in entrepreneurship and innovation, I think you can teach this. I don't think, and some people think you either have it in your genes or you don't, maybe that's partly true, but I think you can teach these things, and I think young people can become much better at them than they think they ever could be, and we need to set up structures and things in our curricula and outside our curricula that will give students such experiences.

Dean Munson: I had Jim go first because I just wanted to say "ditto!" [laughter] I'll say just a little bit more, but Jim is absolutely right about sort of his definition of entrepreneurialism, it's all about creativity and innovation, it's not that every student needs a start up or wants a start up, and Jim is also right about learning by doing. Trying to become an entrepreneur by just taking formal coursework and reading a few books would be like trying to play basketball by reading a book. You might know some rules, but you really have to do it, and so for a university that wants to be successful in this area, you need curriculum, yes, but you also need programs.

Another comment I'll make, and I'll try not to upset too many people in the audience who might be from the business community, but I think at a lot of schools, we've too long left entrepreneurship to the B-schools, and in my place, we have had a longstanding relationship with our business school, it's a terrific relationship, and we have had joint entrepreneurial programs with them for a very long time, but those programs were attracting mostly engineering students and industrial and operations engineering, because their curriculum was already kind of halfway vectored to that of a business school. We found it necessary about a year and a half just to start our own programs, not as a substitute for, but in addition to what we were doing with the business school, and within a year, we had a student entrepreneurship group of 800 student members, and now it's bigger than that, and we've even invited students from all across students in the engineering entrepreneurial programs, so we've got plenty of students from business in our programs, and I think that's okay, because in almost every case that I've witnessed, at least in my corner of the world, the idea for the company came from an engineer. They needed business expertise, they needed help from the business side, but the ideas came from engineers. We've got lots of engineering students who are fully capable of doing a whole business piece, and so if that's what they're capable of and that's

what they want to do, then I think we ought to facilitate that. Some specific things we do, actually, we've got, in my case, about 5,000 alums that are in the Bay area, California, and quite a number of the famous companies out there were started by Michigan alums, and in many cases, they picked up a masters degree at Stanford before going on to the start-up world, but we get our kids as connected as we can with those alums, and in fact, we take a plane load of our students out every spring break instead of those kids going to Florida, or students going to Florida, we take them to the Bay area, and they spend a week with our alums getting an entrepreneurial boot camp. I was with them a few weeks ago, and my students pitched 30 different companies to the alums, and so that was a great experience, and we also do some things that get campus wide attention. Last fall, the student organization at Michigan in entrepreneurship, they launched a competition called 1,000 Pitches, and they were actually looking for ideas for more than 1,000 companies. It's pretty ambitious to try to come up with that many ideas in just a few week period, but they did it, and every submission was a video submission, so it was the students talking about their idea, and what have you, and then as you can imagine, these were judged, and there was a big dinner and that sort of thing, but a whole bunch of these things are turning into companies, and a bunch of them are not, but that's fine, the

students were dreaming, they were creating, they were thinking about possibility. The last thing I'll, well I guess two other things. One is that, in addition to entrepreneurship, I've got a number of my alums clamoring that we in engineering offer something that might be called a mini-MBA. There would be two to three courses covering topics like corporate finance, accounting, marketing, and some others, and I've got so many alums giving me exactly the same list, I'm starting to believe that maybe we should do this, we probably will do something like this, but we won't do it alone. We'll get the business faculty to teach a lot of this for us. But what I'm seeing is engineering crossing over more heavily than ever before into the business world. The last thing I'll mention is coming from the state of Michigan where the economy is probably the poorest among any state in the country, we have a huge economic imperative at my university to transform the economy of the state of Michigan, and so we're taking that very seriously, so in addition to our entrepreneurial activities, we do a lot of recruiting of firms to Ann Arbor and that sort of thing, and this all mixes together very well, so we're doing more with industry than we ever have, and the entrepreneurship is just one piece of that.

Dean Poor: I don't want to cut this discussion off too prematurely, but I'm looking at the clock, and I want to be sure that we get a chance for the audience to ask questions and take comments, so why don't we

move to that phase now, and let me open it up to you, anyone who has any questions or what have you. This one right here:

Audience: Question about marrying two ideas, one is the teams of interdisciplinary students, and the other is the financial partnerships, but in fact, before I get to that, I just want to say something about problem solving. It's often been said that engineering's about problem solving, and we want people to do that. In my experience, aerospace and then Wall Street, and now microprofits, the benefit of problem solving wasn't the solution, often, it was the process. So my idea, and I haven't heard any quite touch on this, is maybe have three students from the University of Michigan, three students from the engineering school at MIT, three students from one in Germany, and they form a team, and you give them a problem, and I see the interview of those students afterwards, on the plus side, it's a big success, the kids initially say, yeah the guys from Germany came up with, I never would have thought of it that way, they thought of the problem entirely differently than the way we did, or you interview the students afterwards and say it was a bust, and the kids come in and say, well, those guys in the United States, they didn't think this was important at all. That may be worthy of our attention, appreciating what's not important in other parts of the world. You've touched on a number of new ideas, including the competition, but I think it

was seven teams overall at the same university, and I would suggest –

Dean Plummer: It's actually a really interesting idea, and we've tried that experiment, actually, where we had a year long design course, actually in our mechanical engineering department where there were teams at Stanford, and there were two other teams in Europe, not one in Asia because of the language difficulties, and the results were mixed, some of them were spectacularly successful, some of them were a bust, but it was an interesting thing to do, and it had many of the attributes that you described in terms of benefiting students.

Dean Suresh: Along the lines of what you just mentioned, the Lemelson Foundation is funding a program to have students from American universities in track with students from one particular IIOT, Indian Institute of Technology in Madras, to go to do a project jointly in different villages in South India, and I don't know how successful that program is, but I just heard about it a few months ago.

Dean Plummer: Frank?

Frank: Just on that, we're doing that with Tokoshimo in Japan with the University of Colorado, with mixed results, and one of the big problems is scheduling. It's not with the back and forth to have the students talking to each other, the back and forth schedule is the

semester schedule or the exam schedule is so different that that turns out to be a real difficulty in doing …

Dean Poor: Take another question from here.

Audience: I'm very fascinated, of course, with a lot of the buzzwords that we always here and the American politicians, you know, change is necessary, and a lot of the politicians say, innovation is going to solve all our problems, even though they don't know what they're talking about in terms of innovation. We talk about leadership, we talk about wisdom, we talk about innovation and so on, these are all good things, but the overall work, or the overall contributions that are being made in industry are not simply done by entrepreneurs or by leaders or by just innovators. Something we all shoot for, maybe a fancy word for it would be a team player, and people, I always liked [unintelligible] said, an idea is great, but only if you work on it. Working on the idea is, we do not just need a leader, a number of leaders, but we need a leader then a team. We are not teaching, probably, our students how they can change sometimes rather than being a leader, because they're being assigned to a product team, or to just a development team, there can only be one leader.If they're all leaders, then they'll never get to the point where they make the product that they can sell for a profit. It's not as fancy or as sexy to say "I'm a team member," or

"I'm a follower," but we should do that, and I have seen that as an example in the course that I'm teaching, concentrate mainly on the process of innovation rather than just the idea. You start with a case study, and I design, like I said, I write the class [unintelligible] and all the students come to me and say this is the first time in my life where I had to work as a team where I had to put together a schedule, who's going to do what at what time so that we actually get to a result, namely on December 4, they have to present their case study. How do we get this in there somehow?

Dean Munson: I think it is in there, at least in my place, we start that right away at the freshman level. We have student teams doing exactly the kind of things you're talking about, and then we also, outside of the regular curriculum have some very large student projects, we have a large solar car student team, it's more than 100 students, and yeah, there is one leader, and it's a student, and there's a whole organization they build, they set the schedule, and they build a completely new car every two years, they race it in North America, they race it in Australia, etc. They have to raise $2 million for each of these cars, they do all that themselves, and it's not just engineers, it's engineers and business kids, and people that can predict the weather, etc, so at least at my place, students are getting a lot of this. I will say that this is more recent. 10-20 years ago, it wasn't that way.

Audience: I'm curious, many of you touched on the crossover between engineering education and business education. Probably the center of that is in Congress, and I tell you that I see a lot of engineers graduate and there is no corporation too large or too small. They're assigned to a design team, but it's much more than aesthetics, so they figure out the usability, the market segmentation, the cost, the market impact, they're in product management before they know it, then they're in product planning, then they're in product marketing. So my question, I guess, for undergraduate education is, what focus is there on incorporating the training … and management of the production ability of products related to the corporate work as opposed to simply technology?

Dean Plummer: Maybe I can take a cut at that. A number of universities, Stanford included, have specific programs in product design that have many of those attributes, but they don't, or at least historically have not reached out and impacted the broader group of undergraduate students. So I think in a number of places, ours included, one of the goals we've had is to take those kinds of experiences that a subset of students have had and to make opportunities for a broader set of our students to have that kind of an experience. The example I described earlier of the D-School and are bringing together these interdisciplinary teams and working on a problem, these problems

very often have the kinds of attributes you described. You know, there's an industrial mentor, there's a real goal and objective, they have to really worry about creating something which has a decent business plan, which has performance reliability and engineering sense and so on, but it comes from bringing these different kinds of people together and wrapping them around a project which in and of itself requires those kinds of characteristics in the project. But it's a challenge to do that. These kinds of things are very intensive in terms of faculty time in terms of how you structure them and so on, so it's, to find a model which is scalable to large numbers of students is a challenge. Many of these experiments you can do with half a dozen students or a dozen students. To do it with 500 students, you know, is quite a different story, and to figure on a model which is scalable, why us?

Audience: I'm very inspired by all of the great programs and initiatives that you have shared with us. At the same time, I'm very intimidated by the fact that this is supposed to, at least for the undergraduates, have to happen in 4 years. To cram everything in here, and so I'd like to hear from you a response to Dr. Augustine's thought this morning that this perhaps is not a four-year education, and what are your thoughts about preparing good engineering students for this nation, and for the world, in more than four years so that they can have some social life and grow up during those years of 18 to

22, and have this great global experience and collaboration and innovation and hands on experience and basic science and basic engineering and design and so on and so forth. So I'd like to hear from some of you as to what this four year, or more than four years?

Dean Poor: Any takers?

Dean Munson: I've got a pretty strong opinion on this, and it's grounded in the fact that an engineer is not just one thing, not just one type of person. We've got students who graduate who go on to do extremely technical work, other students who go to medical school, other students who go into marketing, students go into business, students to do all kinds of things. I think there is room in those four years for a lot of what we've said, and it's not that every student needs to do every last thing we've mentioned, and there are some students that will take a more technological version, and there's some students that will take a less technological version. Now, if you wanted all the technical depth, plus all the other things we're talking about, yeah, then you're talking about a masters' degree, and we have a masters' degree, so that works fine. The other thing is, in a lot of cases, you can kill multiple birds with one stone, and so we work hard at my place at arranging summer jobs for students overseas. Good, they get the international experience, they also get to earn some money, they also get to learn something

technologically, and a number of these things sometimes can be combined, but we're not just trying to train one kind of person, we're not insisting that everybody have exactly the same kind of experience and check off every single box among these things we've mentioned.

Dean Suresh: As somebody who took five years to do his undergraduate degree, maybe I'm well qualified to comment on that. At that time, I thought it was a complete waste of my time in one of the IAT's, and then a few years later, after I graduated, the IAT's went to a four-year curriculum. I think the real stumbling block for us, and a lot of students go for a five-year program, volunteer for a five-year program, but the stumbling block there is not the unwillingness on the academic end or on the part of the students, it's the cost of undergraduate education. I think until we, especially in private institutions, address that in a serious way, that is going to be an issue.

Dean Poor: Can I make one quick comment on this? I don't think of this in terms of four-year problem or a five-year problem. I think of it as a career problem, because I really believe that engineering education needs to be a lifelong commitment and a lifelong experience. And so the concept, I agree almost completely with what Norm said this morning, that all these things are important for students and so on, but what I don't agree is they all have to be

crammed in four years or even five years. I think we need to educate young people who are lifelong learners. Look at the way people learn nowadays. They don't go to libraries anymore, they search in Google for something, and you, it's amazing what you can find, what you can learn through online learning, and that's only going to get better, so I think in many respects, our students need to have the fundamentals, obviously, but the fundamentals include some of these other things we were talking about, not just throw in academics, etc, etc, but they most importantly need to have the ability and a commitment to be lifelong learners. So as they need to learn new things, they will know how to do so, and they will be good at doing it, and so I think of this as a career problem, not as a four-year or five-year problem.

Dean Poor: Question up there at the top.

Audience: I came from Thailand three months ago from the Institute of Process Engineering, the Chinese Academy of Sciences, and I agree with various introduction of the Chinese government's attitude to the education in the universities, but the thing in the institute is a little bit different from those universities. With the record development of Chinese economy, there are a lot of opportunities we obtained to establish a very good relationship with the companies, and this relationship offers us a very good opportunity to confer our engineering innovations to the market,

and we have a lot of chance for our Ph.D. students to practice, so we have a chance to realize the project based training. But the problem is that, how can you prove those students, their engineering research innovation have ability? I would like to have your suggestions if you have some good suggestions, it would be very high appreciated.

Dean Poor: Takers?

Dean Munson: Based on my visits in Shanghai, what I tend to see there is the university research is high quality, but it is more like what used to be done in American industry. A lot of the research, at least what I've seen, is not what I would call basic research, and I think that the Chinese government really wants to foster more basic research, and to do that, they probably obviously need to fund basic research, but they may need people that have been trained in slightly different ways, and I think that's going to be a process, and that's going to happen over time, so there's no question, earlier I was commenting mostly on what the Chinese government wanted to get out of this sort of educationally at the undergraduate level, but they're absolutely looking to change the research operation there, and I think that will happen. In the case of the joint institute that we have in Shanghai, they're hiring their own faculty, and this is a different type of faculty member than may exist at some other

Chinese institutions, these are people that are being hired to do basic research.

Audience: Do you have some experience that improves the student's research ability during the practical process, [unintelligible] the technology to the market during this process, improve the students' research ability. Do you have such examples?

Dean Munson: Well, I have examples here in the U.S., but I'm not familiar with what is or is not happening in China in that area, yeah.

Dean Poor: Maybe I can just amplify on a couple of comments various panelists have had relevant to this question and the earlier question. You know, we can't really teach everything in the universe that engineers need to know. At the very least, there's a period of apprenticeship after you leave the academy. If you're going to become a researcher, you become a graduate student and be an apprentice to a researcher. You're going to be a design engineer, you go into a company in design, and you learn from other engineers. You just don't learn these kind of things from books or from professors, really, unless maybe doing research. If you want to be an entrepreneur, you've got to get your hands dirty. So I think a lot of these questions are, how do we do this in the academy, but I think ultimately, it really is, as Jim said, a lifelong process. You get out there, you learn from people who are already doing this, masters in the field. It's very much like the medieval

guild, if you will, where people are learning from people who did it, and I think we can't do everything in the university, and many of these things are things that we can foster, we can encourage our students to get out there, but at some point, we have to rely on the whole engineering enterprise, the whole community to bring along the new generation. It's not just about what happens in places like this.

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