INTERVIEWER: Today is May 3, 2010. I am Karen Arenson. We're talking with professor Woodie C. Flowers the Pappalardo Professor of Mechanical Engineering emeritus at MIT, and father of the wildly popular robotic design competition that started in the Introduction to Design Class 2.70 and is now 2.007. Students are given kits of parts and work in teams to make small robots that go up against each other in a lively playoff at the end of the semester. It quickly became a major phenomenon at MIT, a kind of NCAA basketball championship, but in mechanical engineering.

It has inspired similar competitions around the country and around the world. Students not only have fun, but many credit the class with changing their views of engineering and their life. Professor Flowers won one of the coveted MacVicar Faculty fellowships for his innovative teaching, and is an aggressive advocate of the need to transform education. Woodie, thank you for talking with us today.

FLOWERS: It's great to be here.

INTERVIEWER: Once upon a time young children, and especially boys, grew up tinkering. They built ham radios, they worked on car engines. Did you like to build things when you were growing up?

FLOWERS: I was really lucky. I grew up in a very small town in Louisiana, and both my mother and father were great mentors. My father was the creative mentor. He was a terrible businessman because we were always very very broke; we never owned a house. But his shop was a welding and general repair shop. So dad built things all the time and I worked with him all the time. And everything that dad did was a little different. Part of his ego was doing things that people didn't quite expect. I didn't realize it at the time but later in life I think I figured out that he had a peer review system. Because he would go around town telling people I'm going to take a framit and a widget and make them into the thing- a- ma- jig. And the people in town would say "Abe, you crazy SOB, you can't do that." And then he would go do it and take great pride in peer reviewing it and having everybody say, "Wow, that's really Abe; you did it." So I believe that was one of the seeds for me doing things differently.

And once when I was junior in high school, beginning of my junior year, my uncle gave me a 1947 Dodge four-door sedan, big hulky, black ugly thing. And I drove it home holding both hands on the steering wheel because if I turned it loose it would go straight into the ditch. So I told dad that it's not really worth much to me like that, so I think I want to make a hotrod out of it. And in the way he managed that sort of thing he thought for a minute and said, "Well okay Scooter, if you want to do that I'll help you, but if you start it you gotta finish it." And so that was the commitment, and that's kind of the level of agreement that we had, and so I did.

And there were times when I felt like giving up, but that vehicle, that hotrod roadster, by the time I finished almost nothing of the original car was left. Part of the frame had been shortened a lot, but most everything else was different. It had a big v8 engine and it was a hillbilly hotrod because I couldn't afford chrome. But it was crazy fast and I'm surprised that I was able to use it without killing myself. But learning in that process, I think I learned probably as much engineering as I did in engineering school, because there was a lot of things to do with very limited resources.

INTERVIEWER: Did it spill over into studying science and math in school? Did you find any need to do those or any interest in those subjects?

FLOWERS: My sister was valedictorian of everything that she ever was part of including her college class. So I was the little brother of the academic star. Because of that there was some pressure. Parents never said a word, but self-imposed pressure, but a feeling of insecurity. So I worked hard comparatively. But in the small town in Louisiana in my senior year, I didn't take any books home except for when I was writing a research paper on the abominable snowman, which was kind of fun, but you could do okay; you could make A's without really working that hard.

So in the last part of my senior year, when my social studies teacher noticed that I could not fully extend my left arm because when I'd fallen out of the tree in the second grade and broke it all up, it wasn't exactly set to perfection. So my social studies teacher in the vernacular of the time and place said boy we've got to get you declared a cripple. So he sent me to a hospital 40 miles away and the orthopedic surgeon looked at my elbow and said this boy need some rehabilitation, wrote a letter to the state. State gave me a rehabilitation scholarship. So everybody said college? Opportunity can't turn down. Because we could not afford to send me to college.

And I was going to get a job in oil field and buy a Corvette. Aspirations. So I went off to school and my sister did a good job of helping me balance a feeling that I could probably do it, but knowing that I had to really work hard to make it happen. So worked really hard. And then the next year transferred to an engineering school because mechanical engineering is kind of obvious thing for me to do. And everybody said well you did okay at that other school but this is an engineering school and Louisiana Tech is really hard.

So I was again balancing insecurity and I worked really hard. And by the time I was about to graduate, I was thinking I can buy a Corvette and get a job. And I'm back to interviewing in the oil field and other friends were getting job offers. It seemed really great and then my department head call me in and Dr. Thigpin said, "Have you applied to graduate school?" And I said what? He said, "You should." And I did, and somehow I got accepted to MIT. Everybody said opportunity you can't turn down. Off to MIT.

And I arrived here, and you can guess what the story was. You did okay at Louisiana Tech but this is the big time; this is really going to be hard. So I was balancing and I worked really hard. And as I was finishing my Master's degree, Bob Mann called me in and said have you signed up for the qualifier's exam? And I said what? He said you should. And I did, and somehow I passed the qualifier's exam. And everybody said PhD at MIT, et cetera. Same thing happened with regard to becoming a faculty member. There was a slot and the senior faculty said if you want to take the job then we'll make a decision over the weekend. So everybody said faculty at MIT. And that kept happening; I never got a Corvette -- I drive a truck.

INTERVIEWER: When you were growing clearly some of your mechanical tinkering came from your family. Were your friends doing things like that? Did they come into the shop with you, or were you pretty much separate from them?

FLOWERS: Some did. One of my very good friends had a very souped up car that I actually used once to elope my best friend. We had to get to Marshall, Texas and back in an eight-hour period. So having this moonshine running car, which is literally what it was, made that possible. It was a dramatic trip.

But I also was an odd mix because I was a boy scout; I was an eagle scout. By the time I was 12 or something early -- I can't remember when you make the transition -- but I was an eagle as a boy scout before became an explorer. And I collected butterflies and did science fair projects, and so there was a strange mix. And I played football -- not very well -- but I played football. And I think that was a good thing for me because I didn't fit in a particular slot, and I've always enjoyed that feeling.

INTERVIEWER: Did you ever think of becoming an entomologist?

FLOWERS: A little, but not nearly as much. I like things that go clunk and bang.

INTERVIEWER: Do young children today do as much clunking and banging as children your generation did?

FLOWERS: Not as much. One of the reasons that I spend a huge amount of time with FIRST, for expression of recognition of science and technology, is because it provides an opportunity for our kids to get involved with hands-on things. And I believe at an academic level, Wilson's book *The Hand,* is a very elegant argument that says this and this evolve together, and they work together and they help each other. I believe that.

There's also a recent book *The Last Child in the Woods* which talks about the fact that most of the things that I've learned a lot from are illegal now. The model rockets that we did -- because my father had a welding shop -- our rockets were metal and big and heavy, and we couldn't find the materials to make the fuels that you read about in the magazine. But we discovered, kind of accidentally, one of the formulas was sulphur 25 percent powdered zinc and 75 percent sulfur. We couldn't find powdered zinc.

But one of my friends worked in the oil field and his father had paint cans that were this much paint, and then another can was powdered lead; really heavy stuff. Terrible to handle but I inhaled a lot of it. We mixed 50/50 -- powdered lead and sulfur -- and it wouldn't burn, it wouldn't burn. It would just make this terrible gas that was terrible to inhale. And I got frustrated and struck a match and stuck it in. And I came out of my little workshop behind our house -- all white -- and so we had rocket fuel.

We then made rockets that were big. And when we carried them to the launch pad they were really heavy. So our rockets didn't do like ST rockets; ours were more Saturn 5 things. This huge billowing thing happened and it took off. And there again, I was lucky that we didn't do something that injured someone in that process. That's the only time in high school I've ever been called into the principal's office because the rumor went around town that those guys are doing these rockets and they don't even know where there coming down. And we didn't. They would go far enough that we'd never see them again.

INTERVIEWER: Do you ever have students these days who simply don't know where to start in making a robot from a motor and a bunch of gears and springs and pieces of plastic and wooden metal because they come in and they've just never done that? Or do the ones who come into mechanical engineering tend to have done things like this in some way?

FLOWERS: Have to be careful and not talk about hands-on experience and kids today in three-hour chunk. But one quick story that kind of makes the point. Students have lived in a virtual world. Students at MIT are incredibly smart. They jump through every hoop that's been held up in front of them, so it's not their fault but just society has directed them in different ways.

In our senior design course, one of the really elegant students who happened to be the leader of her group -- they had divided up some task and she had accepted the one of finding out whether a piece of reinforcement steel rebar could be bent into a tight loop and serve as a bearing. She came into lab and I was there early, and she had a slightly bent piece of rebar. It had been heated -- you could tell that it had been hot, and she was going to report that she really can't do that; it just kind of doesn't work.

I said we got a few minutes. Why don't we go out in the lab and try some stuff. So we went out in the lab and I found another big steel bar and I found the biggest vice I could find. And I cranked down the rebar against the piece of steel that I was going to wrap it around. And I took a four-pound sledgehammer and I climbed up on top of the bench and I was going wham, wham.

My father had a blacksmith pit, so that was familiar to me. So I wrapped it around, made a fine bearing. And as I finish kind of the last blow, I looked up and three of the best students in the class -- really sharp people -- were standing there with their jaw open. I wasn't behaving like a professor, and they'd never seen anyone hit a piece of steel hard enough to just mold it. So that visceral understanding of the behavior of mechanics is really important. And it doesn't fall out of the sky and it certainly doesn't come out of a textbook; comes through real interaction. I believe I had been so lucky because when I encountered Castiglione's theorem about deflection of materials, it kind of made sense. And I have a basis for saying you know, that's about right, or not.

INTERVIEWER: So what happens if there isn't a Woodie Flowers in the lab?

FLOWERS: I believe it's very important that we rebalance education. I'm not saying go back in anyway; I'm saying let's readjust. Because the beautiful news is that we have these incredibly powerful tools that are analytical tools that are so easy to use; they get really good answers. But they can also be just a magnitude because of us typing error, and if you don't recognize that, that's dangerous. So that powerful tool should be augmented by the wisdom that comes from understanding things in a way that helps you recognize -- ugh, that's not even close.

INTERVIEWER: Well just to take that example that you were given, if you don't have that person who's grown up with a blacksmith shop in the backyard or nearby, how do you recreate that experience? Even if you set aside some hands-on type labs, if you don't have that people who've had that experience to be the mentors, teachers, advisors, are the students going to manage to replicate that type of experience? If it's doable.

FLOWERS: This may be a big out of the box assertion but I don't think it's the responsibility of just the universities to educate people. We have in this country, and we better not lose, a connection to people who do have that visceral understanding that you just conveyed. So I'm personally devoted to the notion that it's not about lecturing at, it's about working with. And mentorship and/or apprenticeship are things that are really sophisticated; things that we should worship. And

MIT graduates, for example, have an obligation to give back, and they know a lot of that stuff. So whatever we do, we need a system that does pull out of society those resources and make sure that that stuff happens. And I believe that we can find the room or the space or the time or the resources to do that by exporting the training piece of education. The codified learned calculus stuff shouldn't be done with two people working together, that can be done with a screen. And learning to think using calculus is something that you do with another person.

So the model of education that I believe in is the one that MIT does so beautifully through UROP and through design courses in mechanical engineering and through the doctoral student/professor relationship; that is a beautiful educational. And in that model, for example, the supervisor might say go learn the code to run this program, to do this analysis. Go train yourself. And in a career, you better know how to go train yourself. But in our education system up until the graduate school, we have this notion that we have to kind of lead students step by step through training process. We filter for students who actually accept passive learning. What we really want is the best students are the ones that say I need to know that. I'll go learn that stuff and then I'll come back and find this opportunity to work with an expert and become more educated.

INTERVIEWER: But do you think there are enough people in our society with the practical resources, so-to-speak, to keep in the system or build into the system somehow, such that it gets passed along; the kinds of skills you're talking.

FLOWERS: And I think we have to return. It's an old fashioned notion that agriculture, mining, and manufacturing are the only sources of real wealth. Economists kind of chuckle and don't want to ask questions about that. But I believe that as we look at what's happening in the world economy, we do begin to see that all currencies is potentially a ponzi scheme. And if there's nothing to back it, if you can't exchange it for something at some point, it's value is diluted.

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believe in the last few years we've seen a major part of the economy that was just associated with the world; there was a nonproductive activity that drew a heavy tax from the system. Here again, I'm not saying we should go back, but I believe innovative new products that actually involved touching things and understanding complex systems Et cetera, will be the source of whatever real wealth we are able to get. INTERVIEWER: Let's go back to the design contest itself and how it was born, how it evolved and you're roll in it. You weren't even a professor yet.

FLOWERS: That's right. In about 1970, I became the engineering projects laboratory coordinator. Actually I was an instructor, which at that time was a faculty position. So my faculty appointment record goes back further than usual. INTERVIEWER: And you had your doctorate already or no?

FLOWERS: I did not have a doctorate. It was an oddity the way the records were kept at that time, I guess. But, in that role, the engineering projects laboratory was an innovation that was primarily driven by professor Robert W. Mann, and it was part of the mechanical engineering department. We put out an annual report and we gave seminars and things like that. I was to help make that all happen. But in addition, I was used as a kind of glorified teaching assistant in the design course.

And the first year I was involved, Herb Richardson, who later became the department head of mechanical engineering, was in charge of the first design course. It had a different number then from 2.70 then but it became 2.70, and he had heard about Xerox Corporation doing something called giving employees something called a creativity kit to stimulate their creative juices. So we did that. So we had a brown bag of stuff. And we gave it to the students and said make something useful. And it was an odd mix of pieces boss wood, paper clips and things of that sort.

My officemate, Don Margolis, and I were both helping with the course then, and we made the observation that the students really struggled with deciding what to make. That part of the exercise was really really difficult. And I think ultimately I believe that one of the most sophisticated things a designer ever does is decide what to design. If you want to learn about you and the design process, it's probably a good idea to say here's what you're designing and here's some stuff to do it. So constrain the problem and as you become a more sophisticated designer, you just peel off constraints. And then the final very wise designer has no constraints and decides what problem to tackle.

But what we suggested, what Don Margolis and I suggested, is next year let's give them the kit of materials but let's define the problem. And so I was involved to get the next year of this course the next year. And we said build a machine that will move down a 30-degree slope three feet in three minutes. And the criterion for excellence is how close to three minutes you get, so their building clocks. And that was in the first 2.70 competition, and it was good. When you look at the pictures of it that's a fascinating machine.

INTERVIEWER: Why did you make a contest? In other words you could just said design a machine that does X that moves down a slope, and then simply say it does or it does it well, it doesn't do it.

FLOWERS: I can't pretend that I remember the mental process, but I can tell you what I think about that. Students always compete. We always want to know how well other people are doing. If you say we're going to use this as a criterion, and by the way, that's not what your grade is about, but whether or not you do something purposeful is what you're grade is about. And by the way, if you help each other you'll probably learn a lot.

So early on with some of the ways that we structured things, we laid the groundwork for what I later started calling gracious professionalism, which is an umbrella term that had to do with competing like crazy but treating each other nicely and helping each other in the process. It turns out that really works. We do we humans like that. And in particular if the competition -- it doesn't have to be like reality TV today. You're not trying to focus on the tear forming in somebody's eye because they've been ridiculed. It was humiliation free, gracious competition. And you'd also have the right to say to your instructor look, I don't want to make a clock, I want to make this thing that goes zipping down, stops, and then celebrates.

So as long as you did something that was interesting and did it well, then you could do well in the course. So competition doesn't have to be malicious competition, it can be gracious competition, and that's the way that was set up and got started. And students at MIT embraced that notion, by the way, and as the years progressed it became more and more the tradition.

INTERVIEWER: Do you like contests yourself?

FLOWERS: I don't know. I'm not sure.

INTERVIEWER: How many students, roughly, were in this course?

FLOWERS: In the first one there were probably 24, something like that.

INTERVIEWER: Not very many.

FLOWERS: Not very many. At its peak 220 or 230 people would show up on the first day, and I think we probably have given as many as 200 grades.

INTERVIEWER: Did you have idea when you were staring out that it would become so popular?

FLOWERS: Absolutely not. I was just doing what seemed like the right thing to do. And I stumbled into -- I love designing things and to go to sleep at night I pick something to design and work on it because that's kind of my meditation. It also turned out that I guess my fascination with design was a bit infectious, and I liked getting other people hooked. And that ended up -- I talk about teaching but I don't think it's really teaching, I think it's helping other people learn. And saying that you're teaching implies a push, and I think a pull is a better way to think about it.

INTERVIEWER: Do you still go to sleep thinking about designing something?

FLOWERS: Absolutely. Absolutely.

INTERVIEWER: What are some of the ones you've thought about recently?

FLOWERS: Last night -- my wife and I, are going on a nature photography trip to Costa Rica and I'm trying some new ways to do macro photography, and I want versatile arms that hold two strobes out to the side of the camera, et cetera. So, that mechanism is evolving in my head and I have a mockup, and I've learned, so.

INTERVIEWER: Do you ever find you're not falling asleep because you're getting so excited about the design progressing?

FLOWERS: Most of the time when I don't fall asleep it's because I lose track of design and start looking at the list of things that I should be doing.

INTERVIEWER: What do you think made the course so popular and the contest?

FLOWERS: Well, I worked hard at the course. It seems obvious that if you are responsible for -- I feel very strongly about creativity, perhaps because of my father's influence. But once you take a job, the chances that you will have to reinforce your own creative self-image is pretty slim. Because the stakes get to be really high, so you pick conservative's path. While you're a student you have a safe opportunity to learn about your ability to be creative. And people have often asked me well, do you think you can teach creativity? I don't want to be part of that debate. I don't care what the answer to that question is. I do firmly believe that you can create an environment in which people can learn about their own creativity, and you can certainly teach people to double or triple or quadruple the number of ideas they can have in a short time.

So you can get people out of the "you must find the answer" into the "let's think about lots of ways to do this" and then winnow down. So, one of the things that I think was wonderful about the course 2.70 was that a lot of people came to understand that they could do something that they didn't think they could do. And a lot of, in particular, women in the course had never built a thing. And when you build a thing that will over there kind of do what you told it to do, I believe there's a feeling of attachment of birthing or something if you've created something in a completely unambiguous way.

Some of the other things that were part of the course were -- Bill Verplank was a fellow graduate student at the time and Bill had spent time at Stanford and helped with their visual thinking course. And he taught me about some of the things that they've been teaching, so I pulled from Bill some of that stuff and modified it and brought it into the course.

INTERVIEWER: Is that best?

FLOWERS: Well, sketching for one, I had a 10 or 12-lecture series on sketching. Most people don't think they can draw; that's almost always wrong. One can learn to sketch remarkably effectively in a remarkably short time. So one of the things that was great to me was to be able to watch students -- one of the assignments I would often give them was draw your room. And I would give them a way to do it; one point perspective way to do the converges, all that stuff kind of falls out. It's incredibly out of rhythmic.

I had a minor in art. I took drawing from art instructors. They don't do what I would do. I didn't say draw what you see or feel, I said do this construction, and then after that you can start being an artist. But they would draw their room and be really proud of it, and they would send it to their parents. I did this. So in several ways students were able to do things that they never been able to do before and they were tangible things that they could talk to other people about. In some cases I think I could help them learn to see.

When one of the exercises, for example, was I would say draw a grasshopper. And by the way, in the course, even when there were 200 people, when they came to "lecture" they knew that I was going to be down front doing things with the blackboard and stuff. But they also knew that they were all going to be doing things too. So outside the room, if there were five stacks of white paper, they took one out of each stack because they knew there were going to be five things they were going to do to hand in. And they handed in stuff at the end, so there's always involvement. So I would say draw a grasshopper. And you can watch students go [SLAPPING SOUND] -- I don't know what a grasshopper looks like. And so they would draw Jiminy Cricket was the dominant thing. And then I would go to the blackboard and I would draw a grasshopper, which I would have carefully rehearsed, and I would say I'm going to draw a grasshopper. And I have a huge advantage because I've looked at a grasshopper recently and I know, for example, that the thorax is shaped roughly like this, and the overall shape is roughly this, and they have six legs, and their eyes are actually above the antenna, it's not below.

So I would talk through every line that I put on the board. Then the next time they came to class the first thing I would say was drawn a grasshopper. Huge improve in grasshoppers. So I would then say look, you did better this time because if you were studying Robert Frost's portrait, you would carefully read the portrait. If you're going to use things in design you must look at the thing. And then quite often I would then follow up, but.

We handed out kits. They had motors in the kits. Everybody now draw your motor to scale, putting all the details that are there. Phenomenal correlation between people who had look carefully at their motor and knew contacts were here, and the shaft was here, and it's about this long in diameter. If they had seen it and could render it, they were empowered to use it. If they hadn't then I'd say go pick up your motor and talk yourself through every bit of it. Look at everything in your kit because if you know it in that way, you will be able to use it much more effectively.

INTERVIEWER: Did the mechanical engineering department or MIT or you ever try to measure how much better, if at all, the students who had come through this design course were in their other courses afterwards? In other words, did it play into their other classwork after they took this class?

FLOWERS: Not in a methodical way. It would be a really interesting study, I'm sure. But first approximation, if you just looked at people's ability to sketch something, it was a big difference. If you ask them about their ability to drill a hole where they thought it oughta be, it would be a big difference. There were lots of skills that one could assess.

INTERVIEWER: Right. It depends what payoff you're trying to capture. Did the contest run smoothly from the beginning? Did you run into any obstacles?

FLOWERS: It was generally -- I'm proud of the way it ran. I think that I'm somewhat of a fanatic about details like that, and I think that we were making a deal. One part of the deal, by the way, is that if you did this economically not solid, but interesting assessment -- I would always put on the blackboard at the beginning of the class how much the students had paid to take the class. And that's not quite right. I just take the portion of what it cost to be at MIT for a year, and that number would end up being $300,000 or $400,000; a lot money. So I would say that's a lot of money. You guys have paid a bundle to do this. So, here's the deal, we're going to try hard to make it worth it, but you should stop trying hard to take advantage of it.

Another thing occasionally I would do is as students came in class I would give them a ticket that had a price on it for that "lecture" that day. And it was what you'd pay, and that number would be $45 or some number like that. I don't think it's fair to a large group of students who have given a chunk of their life and some of their parents' money to not try to make sure that stuff works. And making a big mistake in the way a design competition is stated is a serious mistake. And I would try really hard to, when I was trying to fashion these things, to make sure it was a whole group of criteria.

One distinction I'd like to make -- in the beginning when we first started doing this and people's faculty at other the schools would ask about -- quite often people would say you know I have this great idea and I don't know whether it's possible, but I gave it to the students as a creative exercise. I'd say that's pedagogically criminal. Why would you ever do that? You've got a very small chance in making sure that people regard themselves as creative and you're going to potentially give them something that can't be done?

So we would try very hard to fashion competitions in which you would never sort the class into what's able to and not able to. You always wanted gradations of success and an idea where everyone was able to do it -- some better than others. You also want to try very hard to make sure that there is not one killer way to do it. That's horrendously complex because if everybody recognizes that and they try to make this really complex thing and it doesn't work, that's not good for their image either.

So we tried to do what I call ambivalent scaling so that the faculty, staff, working on the course, would be ambivalent about whether you'd like to make an arm that reaches or a car that runs over. So you'd try to make the trade offs very subtle and difficult. I actually tried to make sure that the competition was not fair. Because if you set out to say this is a fair competition -- we're going to find out who's best -- that's not the right environment for a creative exercise. So there were always lots of places for egos to hide -- yeah did okay but you know, I happen to run up against the guy who had the right -- and it was all right. And that was the spirit.

And I really loved seeing 19 year old males give each other hug after a round of competition in which one had beaten another. And I think that spirit is a major part of what made the course complex. So, fun, hardest fun they've ever had. Worked really hard long hours, complicated things, lots of thoughts about strategy, et cetera, but the competition itself was more of a celebration than a competition. So it was a big party that celebrated what had happened up to that point.

And things like one year a student was trying to make their poxy dry really quickly, and they put it in the oven. And so when their name came up they put a pile ashes down on the starting plate. Because we said the deadline is completely unevading. When I first started working with the course, by the way, the course would give about half incompletes. Students would have these design projects they wouldn't finish. I said wait a minute let's do this thing and end it. And the number of incompletes went to essentially zero because it was over then, and you couldn't go back and revisit.

INTERVIEWER: So they got some credit for their ashes?

INTERVIEWER: Sure. Sure. By the way part of the in the design courses we typically have more information about what students have done then you ever did in electrical course that had three grades and a final. You've got lots of contact over time. You've actually become familiar with how students make decisions.

INTERVIEWER: Because you're in the lab with them or because they --

FLOWERS: Working with. Working with.

INTERVIEWER: -- And it seemed like there were two different pieces of the design itself you were presenting them with. One was the go up a slope or down a slope that's 30 degrees and it does whatever. But then you called them things like the mouse trap or the watergator or the volcano. How did you and your colleagues figure out what you wanted these things to do and then come up with a name?

FLOWERS: When I was designing the competitions and naming them, several of my colleagues decided that I came up with a name and then tried to fit or find a contest-- because for me they were always a pun of some kind. A couple moments of truth was about a teeter totter, well a couple moments. The thing of the mountain was a thing that went to the top of the mountain and a tug of war. But the thing that goes into thinking about a competition are dear to my heart. Because night before last I went to sleep trying to think about next year's first robotic competition. And there are hard problems. You try to do all those things that I mentioned earlier, possible, possible in many ways, possible in ways that allow you to see gradations different than last year. Maybe allow some analysis but is not dominated by; a real mix of things, and it's a good creative exercise to keep the professor honest.

INTERVIEWER: And then you have to figure out what parts are necessary and do throw in extra parts?

FLOWERS: Well, when we first started doing 2.70 the rule was that everything had to come out of the kit. And to be kind of wise one year we put a peanut in the kit and we thought what will they do with that? One of the students very quickly figured out that peanut oil is a great lubricant. So he squeezed the peanut, got the oil and lubricated parts of the thing.

Things got a bit looser later with regard to what's used in the kit, and now it's really quite wonderful because rather than cutting out intricate parts with scalpels and coping saws, they can use laser cutters and waterjet cutters and really elegant things. I think that's great. I think that the rapid prototyping world has pulled all of that stuff much further along.

INTERVIEWER: Does that make it even harder for them or --

FLOWERS: No I think it allows them -- there was a time when manual skill was really really dominant issue in the competition. A lot of people would have really good ideas but they couldn't quite get the. The people that did well were the ones that had a good strategy, the good idea, and had the execution skills to make it happen. Now some machines and computers can help you with the acute using skill. Still means you have to have good strategy, good ideas, et cetera.

INTERVIEWER: So do you and your assistants or colleagues take these kids and then sort of go up against each other before the class starts to see --

FLOWERS: I haven't been associate with that course in quite a long time. But a relevant story -- the first year, the 30 degrees slope -- I at that time had keys to the student shop, so I stayed up all night the night before the contest and built one myself. I still have it. It was a classical clock. It had an escapement and in order to make the escapement work, there was a small paper clip in the kit. And I needed a very effective bearing in the escapement. So I drilled an axial hole down the center of the paper clip wire and put this little fine piece of piano wire that was in it through that to make a bearing. So I did this. And doing that on the old student shop where surplus lays was quite a challenge.

But, when I tested my machine, it really worked and it was tunable and it was a torsional pendulum. After the students finished their competition and John Purbrick won with three runs that were within a couple of seconds of three minutes each time; quite amazing. I put my machine up there and I was going to show how did the instructor do. It went sliding down the ramp because we had sand in the kit as ballast. The ramp was covered with sand by the end of the competition. My machine wouldn't stay. When I adjusted it, it was a nice clean ramp and I think that was the perfect outcome, because the instructor's machine didn't work. And that was exactly the way it should have been. But it is really important that when you design a competition that you run the movie in your head and as many ways as you possibly can, and you have to be fairly close to right.

INTERVIEWER: But just in your head? In other words, you didn't do trial runs with the kit before you handed the out?

FLOWERS: Try to do some critical experiments. You must know what's important. It's not fair to the group to miss a big thing.

INTERVIEWER: Were you ever truly surprised by any results that students came up with?

FLOWERS: Sure. Sure. You'd be horribly disappointed if you weren't surprised by some the results. It'd be really sad if you got surprised by something that negated the competition, for example, if there was a big hole.

INTERVIEWER: Did that ever happen?

FLOWERS: No. We made some mistakes but never, never a killer mistake. And there was always a supreme court that would adjudicate questions about rules sometimes, and you want to really not change things; you want to leave things as they were stated. Because people start down a path and if you change a rule that is really unfair. One of the years, one of the things that we thought about that turned out to be really effective was that there were two machines on opposite ends and they were grabbing a peg and putting it in a whole -- it was a square peg and a round hole. One of the machines that ended up being quite outstanding started by firing a little projectile that knocked the other peg out of the grasp of the opponent. So we thought maybe somebody will do that but it would be really hard. But this guy did it really well, over and over. It was good.

INTERVIEWER: Do you have any idea how many other colleges or schools do something similar at this point?

FLOWERS: There was a time when it seemed like they were just everywhere, and they're still variance in lots of places. One of the things that was quite amazing for me was that after -- back up and tell you about it's important to put into context how 2.70 became well known. When I took over the course I had been a helper in the course and then became a faculty member and was teaching sections, but I would still be very much involved in designing the competition.

When I became instructor in charge, one of the first things I did was ban media coverage because quite often the local TV stations would send a crew. They'd show up with someone who didn't know or didn't care about what was really happening. They would be invasive in getting some shots. It would go back and there would be fifteen seconds on the local evening news, and the anchor and the co- anchor would both chuckle knowingly about those nerds at MIT. What are they up to next? That was a lose, lose, lose. No one had any idea what was really going on, and it was just making fun of.

So I said just stop. I asked the news office don't tell them that we're doing it. So after I'd done it for a while, more people had come to know about it. And there'd be fire code problems with the number of people in the room where we had the competition because there were too many people there. So folks from *Discover: The World of Science* came and said we'd like to cover the competition and I said no thank you. They were kind of shocked. I said we just don't need that kind of publicity. So they went back and then the proprietors of the company that was a producing company for *Discover: The World of Science* came and sat down, and we had a long conversation. They said we want to do a 14 minute piece that's really serious about the pedagogic theory behind this stuff; we want to understand what you're doing. I said okay. Write a letter to the students, tell them what you want to do, I'll let them vote and they can decide. They voted to say yes. And Joe Blatt was a producer of that first segment, and he did an outstanding job. It was just a beautiful job about 2.70. So that started a series of those and then that was --

INTERVIEWER:

About what year, roughly? Mid- '70s?

FLOWERS: -- No, that's probably mid- '80s. *Discover: The World of Science* ended and *Scientific American Frontiers* was the following program and that was the reason I was a host of *Scientific American* iFrontiers/i for the first three years of that program, because we got to know each other a lot. And Japanese version of PBS took all of those programs and put them together into either a one hour or two hour -- a big special. That was a really popular program in Japan.

I went to Tokyo several times to be guest at competitions that were run by Mytech Corporation and others. People would recognize me on the street in Tokyo as the guy from MIT who does those. So in the United States there were many versions, but in the rest of the world some were really ubiquitous, and a major part of Japanese education got focused on that stuff for awhile. Obviously Japan is still really dedicated to the idea of robotics competition. What does it take to win a contest? How much is design savvy and knowledge? How much is luck?

FLOWERS: All the above. As I said earlier we really tried to make sure that luck was important in winning, because it depended on who your opponents were, things of that sort. But it's a great lesson in you had to do a whole series of things right. One of the things that students often thought at the beginning was the person that had the great idea was going to be the winner and so some students would try to keep their great idea a secret. We would say that's fine, you don't have to disclosure your idea. You would need to talk your instructor about it, instructor would keep it quiet.

First time you had a brainstorming session they would quite typically hear that 15 other people class at the same idea, so it wasn't really worth it. But picking the right great idea is really important skill, so picking a strategy had to be well done. The strategy that you picked had the match your ability to pull it off. So if you had a great idea but you couldn't put it together, that didn't get you it. So the people who win were the ones who got check marks in all the boxes, and happened to be lucky. And that's okay.

INTERVIEWER: And this was all in ten or twelve weeks? how long did they --

FLOWERS: No, that was actually when I was doing the course it was half a semester, so it was six or seven weeks.

INTERVIEWER: -- Did you ever think gee whiz what could we do if this were four two semester exercise?

FLOWERS: I think it becomes a different kind of exercise and the senior design course -- one of the things about 2.70, 2.007, which I think is --

INTERVIEWER: The current version.

FLOWERS: -- The current version is nice and not is that, when you first design something, it's really nice to have the luxury of working alone. You get to make all the decisions the way you want to make them, and that's a responsibility but it's an incredible luxury. You find out about yourself as a designer. In our curriculum in mechanical engineering, when you hit the senior design course, the opposite extreme happens. In that case a problem too big, a time to short, a budget too small, and a team too large, and those teams are like 20 students.

And we'd make sure the problem is big enough that it must be distributed, so MIT students, in general, have been very good at policing their own trademark. They've had control over how they're being evaluated -- their quiz, their homework.

All of a sudden they're depending on a large group of people, and I think that's a really really important part of engineering. And it brings out some interesting things such as I was saying that it's really nice to be able to render quickly and sketch and get other people understand your ideas. The extreme of that is a well-rendered bad idea is a horrible disservice to your colleagues. Because if you convince them that this thing is wonderful because it looks beautiful and then you find out it was a bad idea, that's not good. Likewise, if you have a great idea and you just described it by waving your hands, you've lost. So in a team, the complexities of the design process explodes. It's much more subtle sophisticated human interactive and thus a senior-level activity.

INTERVIEWER: When you started each student did his or her own project or did they work in teams at all?

FLOWERS: 2.70 has always been, for me, a design-it- yourself activity, and the senior design course has been both. But in the last 15 or so years -- right now, Dave Wallace is running the course and doing an absolute fabulous job of doing this thing where, as I said earlier, the most sophisticated thing a designer ever does is decide what to design. The first half of the semester this group of 20 people are deciding what to design, and a lot of students struggle with that. It's like why don't you just tell us what to do? That misses the point.

Understanding what constitutes a product opportunity is a big deal. Engineers must take more responsibility for that. It's not that the marketing department should tell the engineering department what to do. Engineers owe it to society to be more involved in that process.

INTERVIEWER: Have your or anyone else followed the careers of the contest winners, and are there any interesting patterns that you have?

FLOWERS: Well sure. There's a whole bunch of folks who have come -- see the people that come through those courses are the people who come through mechanical engineering. Mechanical engineering has an amazing group of graduates. I would love to claim credit for all the outstanding people who have come through mechanical engineering but that would not be fair. But there is a very long list of very impressive people. And even if you'd look back at they PBS coverage of the 2.70 contest you'll find lots of people who are now quite well known.

INTERVIEWER: Have any products come out of it salable or commercial?

FLOWERS: Well, designing a robot to accomplish a particular task doesn't usually generate product idea, but the senior design course has generated some products. One of them is a thing called Kinkajou which is a battery operated LED projector for adult education in places where they don't have electricity. That product I think is moving along. I haven't heard about it in a while. There is Atlas Corporation that builds a cinder, a wench that lifts people up quickly, and I think that has roots in an almost identical in [INAUDIBLE]

INTERVIEWER: Let's go back to your own education. What was your college experience like and did you ever have any class like 2.70 while you were going through college?

FLOWERS: Didn't have anything like 2.70, but I was lucky because I was able to pull some of that stuff out of Louisiana Tech in a quite natural way. My engineer's day project at Louisiana Tech became somewhat infamous, and I was lucky that I didn't kill someone in the process of those engineer's day project.

But one year, for example, I built a magneform device, which was a way of putting a lot of current through a small coil and producing a repulsive force between two conductors, and it was used as a manufacturing technique. I was working for Louisiana Power and Light at the time and I borrowed 300 and 250 cable R capacitors for that, which was a stack roughly eight feet by eight feet by eight feet.

And it was being very frustrating because I had found in the department a pair of ignitrons which were huge mercury vapor switches that had water jackets and great big pig tails, and it was wonderful big stuff. I kept trying to dump the energy stored in the capacitors through the coil and caused something to happen, and wouldn't happen, wouldn't happen. I got frustrated, so I used the biggest DC supply available at Louisiana Tech, connected it, charged the capacitors, and then put the full output of that same DC source across the igniter, the trigger in the ignitron. I had a quarter inch copper coil, about three loops. And there was a quarter laying on top to see whether I was reducing any repulsive force. When I hit the switch the quarter knocked a piece of concrete down to the ceiling, so I had made it a gun. So that year I was making ashtrays with this thing.

Another year I found a turbo charger from the B25 bomber that had been donated to Louisiana Tech a combustion chamber from an Ellis Chalmers gassed turbine and a fuel nozzle from a Messerschmitt airplane, and I decided I'd make a gas turbine. But I couldn't spin it up fast. I kept escalating this fuel and starter war, and I ended up with a two inch steam line coming into the turbine, and it would get up to about 20,000 RPM which was really really loud. Then I would light the combustion chamber.

I finally ended up with gasoline that was pressurized in a freon barrel. I would light it up and it would go up to about 25,000 RPM. I would shut the steam off, and it would almost sustain as a self-sustaining gas turbine engine, but it would gradually slow down. The day of engineers' day I had a whole bunch of people around watching what I was doing. I brought this thing up and I had a control panel that I'd built and underneath control panel was the freon barrel that had pressurized air over gasoline. I couldn't hear anything. I was pointing and the combustion chamber was glowing red; it was just an amazing scene. I felt the control panel start to move and for some reason that I'll never understand, I knew what had gone wrong because I had two identical valves, one for air pressure and one for gas flow. I'd turn the wrong valve; I was putting more pressure.

So I very quickly turned off things, made some excuses, got people to scattered away. My knees started to shake because I knew what I'd done. I had a fire and I had a nearly exploding barrel of gasoline, so I would have killed probably 40 or 50 people. So that was one of my lessons in think, think, and do the human factors. I had done the Three Mile Island thing. I had two knobs that were very different and I'd grabbed the wrong knob -- so that was a great lesson. But anyway, I really enjoyed learning by building big things.

INTERVIEWER: Did your teachers, your faculty there have any clues as to sort of what you were doing and how you did it as you went through the years there?

FLOWERS: I think so. They were a wonderfully gracious supportive group. I --

[INTERPOSING VOICES]

FLOWERS: -- Got their attention several times. I was an agent of change. At the time of the Tau Beta Pi initiation the Engineering Honorary Society was an all night test that was all fake. You took this all night exam and you really studied for it, and it was really hard, and it was just awful. And then you came in for the grading session and there was your senior faculty sitting with lights in your eyes. And there was your test out in front with a big red X on it. This was a humiliation thing. It was a hazing thing. So when I became a member of Tau Beta Pi and became president we stopped that; we ended it. I went into a long discussion, and so we just stopped it. We had gotten to know each other in situations like that. My department head Jack Thigpin was the one who suggested I go to graduate school and offered me a lot of guidance.

INTERVIEWER: Besides earning your diploma, what do you think was most important to you educationally about your college experience? You were doing hands on building and designing before you got to college, and you obviously did more while you were going to college.

FLOWERS: But I learned a lot about better ways to do everything I was doing. I was doing stuff while I learned as a college student enabled. It also broaden scope. I was involved in student government, and that was also a great education. I learned kind of about both sides of the campus life, and got to know some of the administrators.

INTERVIEWER: Did you go right to graduate school from --

FLOWERS: I did. I did. I had from Louisiana Tech one summer working as corrosion control engineer in Hawkfield field in Southern Arkansas for Humble Oil; absolutely wonderful education. And then to graduate school. I finished my first semester and rushed to Louisiana Tech to marry Margaret who was finishing her master's degree, and then we came back for the semester. My arrival at MIT was interesting in a whole bunch of ways.

INTERVIEWER: This was what year?

FLOWERS: This was 1966. Harvard Square was the center of the hippie culture and protest, et cetera. From a small town in Louisiana I arrived at Harvard Square, and I had a room a block and a half off Harvard Square. So I was like a deer in headlights. It was just kind of an amazing cultural shift.

They took my chest x- ray standard screening for tuberculosis, and a sharp-eyed radiologist picked up a scar in my aorta. Turned out when I was a junior in high school I'd been in the backseat of a car that was in a horrible accident. I was lucky enough to survive. Broke lots of things because of the way I absorbed energy, just tearing stuff up. But luckily they didn't discover that the deceleration had ballooned my aorta at the time, so my aorta looked like a 75 year old person with arteriosclerosis. So the advice was those things usually rupture now or later, so you probably ought to get fixed.

Because I was here and because I'd been an employee of Humble and they wanted me to come back to work for them, DeBakey's team in Houston and Jerry Austin's team at Mass General were kind of fighting over me to do the surgery. So I picked Austin's team at Mass General. He's a graduate of our department, by the way. So I had open-heart surgery right after the end of my first semester, so there was a lot going on. My team was, from the beginning, an incredibly intense place to be.

INTERVIEWER: Any other recollections you have of your first impressions of MIT and what it was like, and even how it compared as university to what you were use to?

FLOWERS: Dramatically different in a whole bunch of ways. But the students that I met -- again, I arrived with, I think, a good balance between thinking I could make it and being really aware that the level of performance had been bumped up, and this was a highly competitive group. And I met a bunch of really great colleagues. And we worked together, studying together, and my period as a graduate student was really really a wonderful time in life. Margaret and I learned a lot, had a great life together.

One of the amazing things that happened was I became involved with the art group at MIT and met Auto Pena. Auto introduced me to his wife, at the time, Nan -- now Nan Rosenthal. She had written a doctoral thesis on the Moholy-Nagy light space modulator, which the original is down at the Heart Bush Russian Museum. She asked me to look at it and say can it be fixed, because they don't run it, because it's a dangerous machine. It was the grandfather of kinetic sculpture; a rotating thing with lots of moving parts.

I concluded that it was dangerous to itself because it had been renovated badly, and because the original design had some serious flaws. Moholy's wife was still alive at that point. She heard about my comments by hearing Nan's stuff. So as a graduate student I got a commission to build two replicas of the Moholy-Nagy sculpture; deliver one to Dennis to the Benali in 1970, and one for Howard Wise Gallery in New York for here. I felt weird about that because I have some pride as an artist myself.

My name is not on any of the replicas but they work, and it was challenging to try to make something that looked like the original, but would really work because there was some serious mechanical flaws. And the original is dangerous. It would hurt someone if they got their hands in it. That was a great experience and it happened because I was at MIT and connected to this amazing community. So MIT has been a fantastic amplifier for almost everything that I've ever been involved in. It directs things to you, and it makes whatever you do matter more.

INTERVIEWER: How different is the MIT of today from the MIT that you arrived at in the mid -'60s?

FLOWERS: Well, I think MIT is always different; it involves, it goes through cycles. I was here during the time when there were murals all the way down the hall. I remember when I was writing one of my thesis, I had to stop because the tear gas was burning my eyes. I'd stepped out on the roof of building three and five which you could do at that time, and walked over and watch the Cambridge radicals and the Cambridge police throwing tear gas back and forth at one another. That day my wife, who was teaching in Lexington, could not get back into Cambridge because Cambridge was cordoned off. So, obviously things were different then.

There was a 30 minute documentary on the 2.70 contest the year we did the tug of war and it's called tugger mugger, and it was done by Bestor Cram and Steve Ascher in delightful 16 mm film. If you just watch that it is so clear that so many things -- attitudes, language, were very very different. Then after that was a wave of more conservative, focused on getting a career. Now we're going through, I think, young people are trying to teach us adults that we need to save the world, and we're listening too little, I think. So it evolves.

INTERVIEWER: How much is MIT the same?

FLOWERS: MIT is still a hardcore meritocracy, and I think that makes it delightful in many ways. Because of FIRST -- FIRST now involves 200,000 young people a year. So I if I'm out in the FIRST Robotics Competition world, I meet lots of high school kids. And anytime one of them has been admitted to MIT, people say hey go see Woodie. So I meet lots of people that are headed this way.

My standard comment to them is MIT is either a steamroller or a candy store; you have to pick, and the default is steamroller. Because if you sort of let MIT wash over you and you struggle against it, it's a heavy big thing. But if you kind of get grounded and make some good grades, and buy yourself the freedom to learn because you want to learn, it's the best candy store you can find anywhere. You'll be surrounded by people who are curious about everything, so you can find a group of people who want to work with you to do anything you want to do. MIT has thesis projects, and you're off and working with graduate students and all kinds of clubs. It's a fantastic place for an entrepreneurial learner.

INTERVIEWER: How much do you think the MIT admissions process is about identifying students who will in fact be able to use it as a candy store as opposed to being rolled over by it?

FLOWERS: I think they do pretty well. I believe that our culture is still too focused on symbolic manipulation and some of the kinds of things that are very concentrated on a particular kind of mental activity. I think there's a whole bunch of kids out there that are customizing motorcycles who would be unbelievably good engineers, if they could get over the symbolic manipulation hurdle of calculus or something like that.

So I think we miss some fantastic opportunities because we still have a minimum level of grades. I still in fact remember in faculty meetings we have the impression that our grades are accurate, and I don't think they really are. They're probably a good measure of a particular kind of activity. But I think the MIT system does really pretty well. In one of the things in a very careful study that just finished in the last year, we know that 10 percent of the MIT freshman class are FIRST alumni. So they've been involved as high school students in this robotic competition, which is very much like 2.70 on steroids. They've done hands on stuff. They've worked in teams. They've been entrepreneurial, et cetera. So I think the fact that MIT is paying careful attention, that's really good news.

INTERVIEWER: Do you think that is expanding the mechanical engineering department or enrollment undergraduate because there is this funnel now?

FLOWERS: I know that we've done professionally-done studies in FIRST that says if you give young people an opportunity to do this stuff, they double their chances that they're going be involved in science and technology and triple a chance that they're going to become engineer. So I know that is working. I also know that in mechanical engineering the more versatile parts of mechanical engineering Course 2-A is very popular because the old classifications that were kind of narrow really don't apply now.

So if you know something about biology and systems and mechanics, you're in a very good position to go be innovative. I think we've done a pretty good job of remaining versatile. I would like to see us have more emphasis on leadership and on ethics, and some of the very important professionalism issues.

One of the things that I'm really proud of is that this notion of gracious professionalism came out of our beginning design course where you not only have a high bar of being a professional, you do it in a way that creates the smallest number of victims and maximum number of beneficiaries.

INTERVIEWER: When did you first think of making a career out of teaching and remaining in academe, and did you think of going any place besides MIT?

FLOWERS: While I was starting to write my doctoral thesis, I hadn't thought about getting a job yet. Our department had a slot that according to the senior professor that explained this to me -- Monday that slot's going to go away unless we have a name associated with it. We want to hire you if you will take the job let us know by Monday, and we'll hold it so long as you graduate fairly quickly. So Margaret and I had a serious conversation about do I want to be a professor. So we decided that yeah let's do this because it would be really interesting. She had gotten into the computer industry. She had an exciting job. She was winning all kind of corporate awards for her performance. So this place was interesting and we were enjoying life. But we decided look go ahead and take the job, but agreement -- not going to try to get tenure, right?

INTERVIEWER: They said that to you?

FLOWERS: No, Margaret and I decided it's okay, I'm going to be myself, but I'm not going to get in this tenure rat race. When I joined the faculty the department head was Ascher Shapiro. Ascher was a nice man. In my meeting with him in which he welcomed me to the faculty, he said Woodie of course you do understand that since you're in design you have almost no chance of getting tenure? That was his well-meaning welcome to the department. So I didn't try to get tenure until I got close enough that it didn't make sense not to sprint. So I gave up on my commitment.

Herb Richardson who was department head at the time called me in and gave me a bit of a tongue lashing and said, "Woodie, you've gotta do this; you've gotta go and become famous." That's exactly what he said. So I wrote some more papers and packed up my zero case with artificial leg parts in it and stuff, and traveled around and gave seminars at a whole bunch of universities.

INTERVIEWER: For a year or two?

FLOWERS: For about a year and a half or so, and jump through all those hoops. Being a faculty member at MIT is a seven-day a week job. That's a bittersweet experience. There are times you do a lot of things that you're not really anxious to do, and the things that you have to do that are not pleasant get pushed off into the weekends and stuff.

Not long ago as a professor emeritus, I arrived here on a Sunday morning to do something in my office. As I walked down the hall on a Sunday morning, I had this kind of whoa feeling because it was delightful. Because I remembered what that felt like when I would do it early on a Sunday morning and know that I had to spend the whole day there, and if I were really lucky I'd get to go home and do something with Margaret, but I had to get ready for Monday. In this case I knew I was going to be in the office a couple of hours and then I was going to go spend time with Margaret.

So being at MIT is a substantial time commitment, but if you're trying to get tenure I believe you'd do a different set of things. So what I had done because we decided to do it that way was I was going to do what I thought ought to be done, and then at the last minute I would remap my effort and said, okay, I give up; I'll play the game. It's my impression that my tenure case just barely made it, but it did. It became the case that not trying was more expensive than just letting it go, so.

INTERVIEWER: Is that to say that this was a trade off between your having thrown yourself into teaching and focusing on the 2.70 and the competition, and you were deciding to rebalance between teaching and research and the more traditional research and publishing?

FLOWERS: The trade off between how you spend your time as an educator versus how you spend your time as a researcher is always complex. And it was simpler some years ago. You were expected to have 50 percent of your salary covered by outside sources, and that takes a lot of time. It's not quite that simple now, and MIT has shifted, so that there is what might be called dual path process. But it's not dual. You can be tall and short this way, but you can't be zero.

I'm glad I picked to the path that I did; I feel very satisfied. I think the relationship between me and MIT is a little bit like a parent child where the child misbehaves a little bit. I made department heads a little anxious from time to time about whether I was toeing the line.

INTERVIEWER: In particular ways?

FLOWERS: Well, the need to spend more time in the publication world and in professional societies, I didn't give as many conference presentations and stuff. The American Society of Mechanical Engineering has been really wonderful to me, but I chaired one committee in ASME when I was assistant professor and have not since. So I've picked other things to invest in. I was for about ten years an overseer at the Museum of Fine Arts as representative from MIT. That probably didn't show up in my tenure discussion.

INTERVIEWER: Although the chairman was from MIT for a while, yes, Howard Johnson?

FLOWERS: Yes.

INTERVIEWER: And I guess MIT administrators and leaders have remained in that leadership.

INTERVIEWER: You've also been given awards at MIT for the type of things you've done. One was the MacVicar Teaching Fellow Award.

FLOWERS: The first one was a Goodwin Medal which was just absolutely wonderful when I was a graduate; blew me away.

INTERVIEWER: And that was given for --

FLOWERS: Involvement in the beginning design course in 2.70.

INTERVIEWER: -- And the Goodwin Medal was given by the graduate counsel or by the --

[INAUDIBLE]

FLOWERS: It's a --

INTERVIEWER: -- Or teaching excellence, yes?

FLOWERS: -- Teaching excellence, based a lot on student recommendations. But since I have helped with the judging process for many other Goodwin Medal winners, I'm very proud of that. That was a very competitive award. And at that time it was given at graduation.

INTERVIEWER: Was that before you had tenure?

FLOWERS: Oh yes, I was a graduate student, I wasn't even a faculty member yet. I was technically a faculty member, but I was an instructor not a professor.

INTERVIEWER: And Pappalardo came along. You were given a name chair at a certain point too.

FLOWERS: That's right. I won the Baker Award which is a wonderful student initiated Institute-wide teaching award, so I've been very very blessed. The students have been incredibly kind to me as have my colleagues.

INTERVIEWER: In some parts of academe, being singled out as a good teacher is seen as a kind of kiss of death, that it will sort of highlight your focus on teaching and maybe therefore raise questions about gee whiz are you spending enough time on research and publication. Was that an issue after you became tenured?

FLOWERS: Not as much of an issue but still I had to try to make sure that I carried my load. One of the times that that was noticeable was when I was being host of Scientific American Frontiers it is obvious that it was not acceptable to say to my colleagues I don't have time to be on that committee because I'm hosting a television show. I would not have made it very far. So hosting that show and being a consultant and being a full-time tenured faculty member was stressful.

INTERVIEWER: That was what, late '80s- early '90s?

FLOWERS: Late '80s- early '90s -- 1990 to '93.

INTERVIEWER: Did you get involved at all in helping? Were there any efforts to say to other faculty at MIT, here are ways to make you better teachers and Professor Flowers is one of the people who knows how to do it? Any kind of activities along those lines?

FLOWERS: I participated in several committees and workshops and things where we tried to address that problem. We as a community are fairly sensitive about that question. If you've decided that you were going to require a pedagogy instruction certification at MIT or something, there would be an earthquake. So the things that have happened I think we do have some institutionalized help now, but it's a sensitive issue. And in particular, some of the things that I would love to see happen more is focus on professionalism and focus on things like ethics.

I wrote the foreword to Caroline Whitbeck's book on engineering ethics; very nice book. She argues that resolving ethically complex situations are very much like design problems, so obviously I like that approach. But the opening line of the foreword is I want to die proud of having been an engineer, and I believe that. I don't think that professionalism or professional behavior or ethical behavior drops out of just being educated. I think you have to think about it. You have to put yourself in positions where you address those issues and know how to deal with them, and I think we should do that more carefully.

INTERVIEWER: Do you feel that the time you devote to being a good teacher did take away, in some way, from research you could have been doing? Is there necessarily a trade off?

FLOWERS: I think there is a trade off for sure. For me, going back to this notion about I don't think teaching is quite the right word for me, I think helping learn feels better, and that takes time. You can't pick up your notes from last year and go in and go over that material. Or in today's language, you don't download the slides and go through that power point presentation. If you are designing new things for students to do when they are with you every time you do it, that takes a lot of time, and it's not something that happens at your desk. You have to go do things. You have to go be in life. You have to go buy a prize for this thing. You have to go gather them. You have to put together kits for them to use. So there's a lot of different kinds of activities.

INTERVIEWER: A few years ago you said that this was a black swan time for education. What did you mean by that?

FLOWERS: Well, I think there's a whole series of black swan events that are little things that have huge impact. And I think the world economy shift has created a situation in which, I believe, well-trained people will be a commodity. People that are well-trained and well-educated will have comparative advantage.

So there's been a big shift that makes it much more important for young people to prepare themselves in different ways to become part of the workforce. Right now in the United States the unemployment rate is about 10 percent. I don't believe that there is a path to reducing that other than education. I believe creating new real wealth will come only from innovation. We have no advantage in natural resources. We can't trade mining agriculture or manufact -- well we can trade manufacturing for real wealth. But in the developed world we consume two or three times what the rest of people on the planet do. We can't keep doing that unless we produce two or three times what the rest of the people do.

So the downshift that's occurring is going to be either severe or not as severe depending upon how productive we can be. And I don't believe -- for every student in the developed world who really understands calculus and really can do symbolic manipulation analysis very well and even think creatively, there is 100 somewhere else in the world. And in many cases they will have the same level of training as kids in the developed world. So the marginal value of contribution will be determined by how innovative and creative and professional, et cetera; all higher level things.

So all that stuff, to me, adds together to make me believe that it's now time to redefine liberal education and create the liberal education for the 21st century. The liberal education for the 21st century -- there was a time when a liberally-educated person knew a lot about humans and what they've done in the last 100 years, and it was dominated by white males. The nerds were the ones who knew about the universe and natural law. I believe we need to move both toward the middle. And I believe the liberally-educated person for the 21st century knows a lot about the universe and knows enough about humans and human behavior to be effective.

INTERVIEWER: In the same speech, I think a couple years ago, you expressed some dismay that some of the mechanical engineering students at MIT could not explain why a light bulb didn't light up when connected to a wire and a battery. What was that about?

FLOWERS: It is frightening. Our system produces a particular kind of understanding, and the students here have done a really good job of making their way through that system, and got check marks in all the boxes. I believe the issue of lighting a bulb with a single piece of wire and a battery would be different if there had been two pieces of wires because it would look more like a circuit diagram. So the abstraction to reality transfer had not happened enough, wasn't fluid enough to be natural. Connecting abstract learning to the real world is really important.

A very closely related set of issues is that my colleague, Warren Seering, supervised thesis by Kristin Wolf, an undergraduate thesis, and she surveyed graduates to about 10 years out. She asked them about what they're doing, what they're using of what they learned at MIT. Correlations is not one to one. Clearly they learned that way to think while they were at MIT. But a lot of the analytical things that were covered in their undergraduate career they don't do now. They do another group of things that have to do with communication and professionalism, et cetera. I believe that by doing the analytical stuff in the context of the profession is a win win, because everyone will retain more and be better able to step right in and start doing engineering as a graduate.

INTERVIEWER: And yet another study there was some effort to see what students really understood. Something about measuring whether they could talk about the units that different things would be measured in. Could you talk a little about that?

FLOWERS: Ben Linder did a doctoral thesis under my supervision. I was very lucky to talk Ben into working with me. He did a survey of six of the top 12 mechanical engineering schools in the country, seniors. The problem was to estimate the energy stored in a nine-volt transistor battery. The data was astounding. For one, 20 percent of data had to be thrown out because mechanical engineering seniors in the best schools of the United States had used the units of power to answer a question about energy. The difference between power and energy is a big deal. But if you look at textbooks, quite often there are no units, there are equations that don't have units, so you fall into that trap.

But the data -- students estimating energy -- covered 12 orders of magnitude; 12. That is a very very large spread. The good news was that the middle was kind of about right, but the spread was so broad, and the bell-shaped curve --

-- So our students had no idea whether a nonvolt transistor battery is equivalent to what it takes to turn a page in a book or whether it's a barrel of oil. If you don't have an idea of what the numbers are about and you don't have an idea of what the units are, you can't think very carefully about the output of wonderfully powerful analytical tools that are completely opaque. You just type in like this and you get out answers, and you don't know what happened back there.

So you need anchors, you need calibration points, you need ways to model the important question to ask about what's going on here. If you put your snout to the spout where the gospel comes out and do not doubt treatment of an engineering tool, you're dangerous to society.

INTERVIEWER: And after you had these findings did you or your department or the engineering school make any changes: Did it bring about any kind of gee whiz moment?

FLOWERS: I've tried to make sure that everyone that I talk to knows about Warren's data and Ben Linder's study. Ben also asked our seniors to just write down the units of the things that we have "taught them." The average response is that our seniors know the units of half the things that we've covered. I think that warrants attention. I think we probably should do more to make sure that doesn't happen anymore.

INTERVIEWER: So if you could wave a wand and reshape the educational experience in your department or at MIT generally, what would you change? In other words, do you have a fully-formed vision or is it more general principal?

FLOWERS: I have a dream.

INTERVIEWER: okay

FLOWERS: It's a somewhat complex dream, but the major part of it is that I believe that we should stop lecturing and stop writing text books and outsourced training to highly produced new media materials. Avatar costs $500 million. It was 1,000 people in four years. Every one of those the best in the world; super at what they do. We've never done anything like that in education.

So if you look back at 1994 I have data -- 600,000 college freshmen took calculus, 45 percent failed -- 250,000 failed. To say that $2,000 is a reasonable cost for a semester for a student is very conservative, but the $2,000 per semester for a student, that 250,000 is $0.5 billion. So every year we have our recurring cost lost, associated with one course -- calculus -- that blocks a whole bunch of people who probably should get into science and technology but don't. It cost $0.5 billion; we can fix that, I believe. Not all of it, but we could cut it in half, at least.

So imagine that we had a set of materials that were put together by the best people in the world -- pedagogics, specialists, sociologists -- yeah, somebody to make sure that calculus is right. But we know that, it's written down; that's all pretty well done. We could create a system that any kid anywhere could have access too. The people that could pay should, the people who can't pay you can make reasonable efforts to make that free for them.

But if you had 100,000 users -- only 100,000 users -- and every day the folks look at the results of how that stuff is being used -- it's all connected, it would get better every day. For the first time in the history of humankind we could have compound growth on the quality of training material. Whomever does that first will rule. That thing for calculus and for difference of equations and for biology and for a whole group of commodity courses, could change the complexion of a major part of education; the training piece of education for the planet. As a diplomatic tool it could be incredibly powerful.

I believe we should do that so that you don't lecture to people about codified material. You tell students if you're a good student go train yourself, because that's the only way you're going to keep up for the rest of your career. Obviously when you're in kindergarten this model doesn't work, but as you become high school and college students you better be able to do that stuff on your own. And then you spend time with mentors in apprenticeship mode, professors, and teachers to become educated on how to use the stuff.

So the standard comment is learning calculus in training, learning to think using calculus as education. They're very different things. Still too much, in our university system in particular, the freshman year is training. We need to take that residential experience and concentrate on things like UROP and thesis involvement and design project.

INTERVIEWER: What's the cost of that half of the education half? In other words you've talked about the economics of the training portion and creating Avatar calculus in 3D, whatever. But the other side, is that doable?

FLOWERS: I think it is. I think we can't afford not to do it. Even if it's twice as expensive it's worth it because otherwise, I don't see how we're going to get to the other side. I don't see the 10 percent unemployment going down unless we create people who can be much more productive. And I don't think that productivity is going to come from competitive productivity. It is not going to be advanced by being well-trained.

INTERVIEWER: Are there schools that offer a curriculum like this or a set of experiences like this?

FLOWERS: Not as much as I think they should because no one's done the big piece. The big piece to me is go big or go home. Having the web filled by things produced by pedagogic hobbyist is not going to solve the problem. So we need to get the right group of people together who can do the really excellent version of that stuff and then if that happens, places like MIT and Olin, for example, would be great places to be.

INTERVIEWER: So it would be hard to try this with say a small group of students, 30 or 50 freshmen, because you need the big investment to create an appropriate training -- the calculus and physics?

FLOWERS: Just as if you had $100 million to invest in movies, you would not invest in 100 $100 million movies, you would do one $100 million movie. We're not going to get over this hump until we change the model. Right now the textbook companies are saying we're going to scan our textbooks into things like the iPad, and we're going to offer the professors an opportunity to do some video to go along with that. We professors don't know anything about high-value production stuff. We need to have really qualified people helping. If Disney writes the story of calculus, it'll be riveting. If Pixar does the animations to go with that, it'll be riveting, et cetera.

INTERVIEWER: How closely does the only Olin College of Engineering come in? I know you've been involved with them and that they have more hands on experience, but how do they handle the training?

FLOWERS: I was involved quite a lot early on. I haven't been involved much in several years. But I think they do a very good job of trying to make sure that the students get involved in doing things immediately. For example, they have a freshman course in user oriented design which means engineers from the beginning learning about customers and what they might need. I think that inverts the typical process.

Most engineering schools still do the capstone design course and very often that course doesn't involve deciding what to design, so Olin's doing that from the beginning. But they still have this burden of there is this cup to drink, so they still have to find room for that in the curriculum. I believe that kids could learn that codified stuff while they were in a service project in the developing world learning about themselves. Right now in entirely too many colleges, the freshman year is trying to learn how you can finish early enough on Thursday so you can get drunk three nights in a row rather than two. Even the military does a better job of enforcing mature behavior than the university system does. I think we need to make some bold moves about how to do that and giving kids an opportunity to learn about themselves serving others rather than partying all the time and be a constructive move.

INTERVIEWER: The design competitions have gotten a great deal of attention, but another thread in your work as an engineer and as an educator has been projects that help people. Could you tell us about some of that work?

FLOWERS: I was lucky because my research citizenship offer, when I was at Louisiana Tech, came from professor Robert W. Mann. And he was a pioneer in getting engineering involved in helping humans with maladies. So my first project with him was a sound source ball for blind children to play, and I did that and really enjoyed it and worked with kids at Perkins School. They were able to play with this ball because they could hear it. It was an interesting design problem and execution problem, but I chose not to use that as a Master's thesis; did another thesis. And then as my doctorate work for him I developed a human interactive simulator for studying various kinds of prosthesis for above the knee amputee. So this was essentially a robot lower leg that you could wear, and you could make that leg behave like any leg you'd like to study. That was a different way to do that sort of research.

I learned a lot in that process and with colleague Derek Rowell we develop the first microcomputer- controlled artificial leg. It was really interesting that an amputee found it quite handy to be able to retune their life. So it became fairly clear -- I think our research got ahead of technology in that we knew what we wanted to do, but that first computer was this big. Now things are happening nicely. Hugh Herr's work at the media lab is -- he was a Master's student with me for a while working on his own ideas. But the power density and the control fidelity is getting better, and I think replacing human limbs with electromechanical things is becoming closer to a meaningful thing. It's still a very hard problem. If I do a one-leg sit up or support my body on one leg, the moments that occur around my knee mean that this thing that took bacon and eggs for breakfast is lifting one end of a Volkswagen; the forces are just huge. Not only that, it can move like that. So as an actuator the human muscle system is really really amazing. So when you start trying to mimic that it gets tough. In the research that we did I decided, I think it is true, that if I lost a leg above the knee in particular, I think I'd have a prosthesis with wheels. We made one and my gait speed was roughly double my walking speed, because we had skateboard-like [INAUDIBLE]. The wheels could hide in the shoe, and you could have them come out and lock up when you're going up and down the stair. But matching human mobility is really tough.

INTERVIEWER: Are you still doing courses --

FLOWERS: I haven't been involved in that stuff in quite awhile.

INTERVIEWER: -- You've talked a little about wanting to bring more education on ethics and leadership into the mix. How would you do that?

FLOWERS: Well the leadership question is hard, and I don't feel that I am an expert on that. But in the senior design course in our department now, I think the students do learn a lot about leadership by just being in a position where they have to do it else they will not succeed in the project. You have a big team, you have to learn to work together, and there are some basic ideas that you put across. But Ed Crawley is pushing now to get MIT to embrace the Gordon Leadership Program. I hope it works.

I've been interviewing a former student's daughter as she goes to the Air Force Academy asking her about her leadership training. It seems very clear to me that the military recognizes the need for leadership and actually cultivates it. And the major part of it is you put people in a position that says you're leader; make it happen. I think we can do more of that stuff. I think technically trained people need to see themselves as leaders to assert more leadership. The fact that our governance -- Congress is so short on technically aware people it's really scary, but it's really important.

INTERVIEWER: Have you talked with other faculty members at MIT about this and how much do you feel like they share your vision?

FLOWERS: Well, when I was in charge of our senior design course and when I would have a section of it, we would do some ethics things, in particular. It's quite interesting to look at the results of the exercise. For example, our seniors -- when asked to develop the canons of ethical behavior with regard to intellectual property within your group, and then develop canons of behavior that have to do with the way you treat one of your colleagues that's too drunk, develop canons of behavior that should outline how you should behave with regard to digital copies of music -- series of those things that we've done, the group does not produce a set of ethical canons that are consistent. They're smart. They're good people. If they think about it a while, they will make it work. But at first blush, there's no philosophical consistency. Their intellectual property is sacred when they're talking about engineering stuff, but when they're talking about music, not so much.

So I believe that making sure that they understand that in the first two or three years of your career, there's almost a 100 percent chance that you will encounter an ethically complex situation. So what do you do about that?

Caroline Whitbeck helped us create some instructional materials that help them understand how they might go about dealing with that.

INTERVIEWER: You mentioned that you wanted to die proud of having been an engineer. How much pride do you have now in being an engineer, and do you think it's been shrinking or growing?

FLOWERS: I have a lot of pride. The decision to retire was remarkably easy for me because it's a whole bunch of things that I want to do. But I feel really good about what my career at MIT has represented, and I feel very good about how it has proceeded. MIT has allowed me to do my thing, and I've done my thing, and the students and colleagues have been really kind in their response. So I feel pride. I feel a lot of humility because a whole bunch of people have done a lot better job of a lot of things than I could.

But I'm thoroughly enjoying a lot of the other things that I'm doing now based on what I learned through my interaction with the MIT community, and I'm enjoying this interview. I think Margaret and I have just finished most of *The Hidden Brain* -- delightful book -- that is a very good argument that we don't really know what's conscious and what's subconscious. But I think I have been comfortably honestly answering all those questions, and that feels good. I don't think that I have a need to or an urge to misrepresent what has happened in my career at MIT.

INTERVIEWER: Thank you for talking to us. Congratulations. Good luck.

FLOWERS: Thank you.

INTERVIEWER: Enjoyed it.