JON GRUDEN: Dr. Joel Moses, who is going to give us a talk that will clarify and get us to think deeply about the nature of engineering as a learning discipline. I think he'll talk less about engineering as a professional society, which is what a lot of people talk about when they talk engineering or as a profession.

And I think he's going to talk less about it as a practice of work. In other words, sociology of work. We're not going to talk a whole lot about what engineers do when they go on the job. We're going to talk about what we call a learning discipline [INAUDIBLE]. Incidentally, that's the focus about this. So we got a lot to follow up on. There's different points.

And as I said, I'm teaching this course, Engineering Ethics, as an engagement of two learning disciplines, engineering and ethics. So I got a little bit on the ethics, and I'm putting lot more on the engineering, and we'll cover other [? things. ?] So with that, I think you're ready.

JOEL MOSES: Right.

JON GRUDEN: OK.

JOEL MOSES: OK. So the emphasis here is going to be a philosophy of engineering as opposed to ethics. Ethics can be drawn from that. So how would you classify engineering again? Metaphysics.

JON GRUDEN: Metaphysics--

JOEL MOSES: Epistemology.

JON GRUDEN: Epistemology.

JOEL MOSES: OK. This is really more about metaphysics and epistemology than it is about ethics. So I won't have too many references because this is-- I didn't spend my life trying to remember everybody who said what. But this is my belief. I think there's a lot of truth to what I have to say.

OK, so here we're going to ask a question, how do different countries think about engineering? Attitudes. Germany and Japan have relatively positive attitudes on engineering. Britain, much less positive. And in Britain, an engineer is someone who runs-- who operates engines.

In France, contrast, the word "ingenieur" is very similar to the word for "ingenious," ingenieur or something. I can't pronounce it necessarily very well. Much more positive attitude toward engineering than in Britain. Where do we get most of our ideas from? Britain.

But nevertheless, there is a clear difference in the US. No, no. I'd like the lights on, if you don't mind. There's a clear difference in US with Britain we're not quite as positive than it is in Japan, but not as negative as in Britain. Somewhere in the middle.

So what's our claim-- our thesis? National cultural values, especially the dominant philosophies in a particular country has a great deal to do with these difference in attitudes toward engineering. That's one belief that I have. Also another belief-- a general belief is, there's no right answer. Everything depends on context, there's a context change. Cultures change slowly but they do change.

And so for example, if you compare American attitudes toward manufacturing in the '60s and then in the '80s and then in this decade, there are a lot of differences because the competitive issues. So it's not a static situation at all. So continuing to a discussion of these cultural attitudes. Yeah, compare engineering to medicine, law, and business-- MBA type education.

The kids that come to MIT have been viewed as not entirely, but largely lower middle class or maybe middle class people who are aspiring to move up in the economic chain. Now let's say they have moved up in the economic chain. Do they want their kids to go into engineering? Do mommies and daddies want their-- what do they want? They want them to become-- and maybe MBAs, right?

Now that's not true in every country. In Japan, the engineers are more highly valued than lawyers, I would dare say. In India too. In the US, parents want their children become doctors, lawyers and MBA. If you want more women and minorities to enter engineering, you can concentrate on getting women minorities into engineering. But will also pay to improve the general attitude toward engineering. It's not bad, but it's not as good as it is in other countries.

Now you can go too far. In Germany, if you are a professor, doctor, you go into a company in the United States, they'll say, what does he know? He's an academic, et cetera. In Germany, they'll say, yes, sir. Absolutely. Yes, sir. We do what you say. You can go too far.

But in another aspect where problems show up is in Britain or in England. The lords-- if you are aristocracy, well, if you have a big company, you need an aristocrat to become the CEO. What do they know about that business? Not lots. But they are aristocrats. By golly, they deserve to be CEOs. That's not necessarily the best thing. So you have problems in Britain in technology.

Now let me switch gears a little bit. And this is getting closer to my real interest. Who are the two greatest philosophers in antiquity? It's Plato and Aristotle. Well, I could have said Moses and Aristotle, but that requires another lecture. A quote. Plato is Moses writing in attic Greek. I didn't make that one up, but that's a side discussion.

So the two greatest philosophers in antiquity are Plato and Aristotle. We're talking about 380 BCE. Aristotle was Plato's student. Makes life interesting. Have a very different attitude on math, science, problem solving, design, organization. And these differences between Plato and Aristotle show up in the next 2,400 years again and again and again.

It's as if somehow or other these are the two poles of ways of thinking deeply about a lot of important issues. Aristotle was interested in science. If you look at what is he known for in biology? Does anybody-- the classification of things and the species, et cetera, families. Oh, he was a born classifier.

Now how did he get-- he got money to send people out throughout the Greek islands and to get him all the various kinds of flowers, plants, different kinds of animals and what have you so he could classify it all. Where did he get the money to send all these people out? He had a student-- famous student, Aristotle did. Who was his student?

AUDIENCE: Alexander the Great.

JOEL MOSES: You got it. Alexander the Great. You know how much money he got out of Alexander the Great? 30 talents of gold Yeah, I know, multimillion dollars, 30 talents of gold that he spent to do this research. And what did he do? He came up with structures for classifying.

What do we call this-- what do I call these structures? These are called tree structures. So in his biology work, he creates this classification structure. We still use it. But it turns out that everything he did-- his mode of thought-- everything turned out to have this kind of a diagram. So let's look at the world according to Aristotle.

Tip of the world is God. But there is no God. This is called the unmoved mover. Ring a bell? Everything in the world is somewhere in the tree. You take a snapshot, you know where everything is. Advance one second, things move, but they're still in a tree structure. Maybe it's slightly different one, but it's a tree structure.

Little problem with this Aristotelian physics. He cannot express the notion which is Newton's law, an object in motion remains in motion unless there's a force applied. The concept of motion doesn't exist because all what you have are snapshots. So a thing is always somewhere. It ain't moving.

Now you take another snapshot, it's somewhere else. There was something happen, we don't talk about that. But nevertheless, the point I'm trying to make is, in back of Aristotle's mind is this notion. And it explains everything. Aristotelian logic. You got it.

My guess is, Aristotelian ethics will have this character. I haven't studied that. My guess is, Aristotelian, I think, has that character because that's how I Aristotle thought. Everything breaks down, decomposes. Those things get decomposed. Things get into finer and finer detail. Empiricism rules. Details matter.

Top-down tree structures. He's a reductionist par excellence, loves science. Plato, very different. He's not a scientist, he's a mathematician. Plato describes himself as a geometer. Actually proved the theorem in geometry. He is an idealist. Ideal forms.

Remember how many different kinds of perfect bodies there are? Things that are ideal. Abstract thinker. Details? Nah. Abstract thinking. What kind of structure does he have in back of his mind? These kinds of pyramids are called layered systems.

So what's Plato's most famous book? *The Republic.* Here is society in *The Republic.* At the tip of the society is a-- you remember? Philosopher king. That's right. That this level of people who work together-- they're not individualistic. This is highly individualistically oriented.

I'm not saying Aristotle was as individualistic as people became later. But that lends itself to individualism. These people are together. This is communism before Marx. These are called the guardians. And they are the top layer of this society-- the perfect society. And also called the gold layer.

And therefore, this is silver and this is bronze. And people here wind up in this level because they couldn't pass certain educational levels. And they wind up in here because intermediate educational level-- the smartest people, the ones who pass all the tests, they wind up in here. And the absolute smartest person at any given time is the philosopher king.

And the key is here, these guys are absolutely worked together. It's only a theorist like Plato could make an unbelievable mistake about society, which is what he did. In order to be sure that these guardians who determine who passes a test won't give their own children an unfair advantage, he wanted to be sure they didn't know who their own children were. Therefore, all the women in here are at large. No one gets married to a particular person because then they'd know who was the father.

Only a theorist could make this mistake. There's nothing perfect about this. It's just an entirely different way of thinking-- abstraction, reductionism. Plato was a member of the Greek aristocracy. Of course, his party fell out of favor, and he got pretty pissed off. Maybe you can cut that out.

He got quite unhappy at the killing of Socrates at the fact that his party lost, et cetera, with the Athenians. And he tried to create an ideal society insistently, but that didn't work. But in any case, it's an entirely different way of thinking is my claim. There isn't anything right.

And engineering-- let's go back to engineering-- needs both science and mathematics. And my claim is mathematics is a different-- is ideal, science is empirical. You need both the abstract capability from science and the reductionist worldview of mathematics.

And if you have a society that is highly empirical, like the British emphasizing science, you may not get good engineering. If you have a society it's too heavily abstract-- that's unlikely-- then you probably also won't work. I can't think of an example like that quite. But a society that has both working for it, like the Germans or the Japanese, then engineering will flourish. That's my argument.

Here is a structure. I claim that when Americans talk about hierarchies, they usually think this way, almost entirely. But this is also a hierarchy. People here are in some sense higher than people there. Likewise, people here are higher than that, et cetera. This philosopher king is the highest of all.

Give me an organization that is modeled like that.

AUDIENCE: A university.

JOEL MOSES: A university. Exactly. And this is the--

AUDIENCE: [INAUDIBLE].

JOEL MOSES: Provost.

AUDIENCE: Provost.

JOEL MOSES: Yeah. This is the provost. These are the deans, department heads, faculty. Or maybe these are the full professors, associate professors, and assistant professor. It's a pure three-layered hierarchy. And in olden times, all the full professors would get together and make decisions as a body.

What happened in a critical year for University in 1807, is that there was this character-- forget his name right now-- in the hospital in Berlin and he had this notion that he had to split the surgeons from the-- who are the guys who checked to see if the stuff was done right? The pathologist. They were constantly fighting each other.

Pathologist saying, you made a mistake. The surgeon said, no, no, no. I did perfect. Don't tell me I made a mistake. So he created departments. And departments break up the university and break up this structure.

So this was in Berlin in 1807. And by 1880, again in the medical school, this was at Johns Hopkins. And in 1885, it made it to Harvard. And ever since, we've had it in the United States.

But where did the University get their idea how to organize things? You said last time, the original universities like Bologna and Paris-- especially Paris and Oxford were associated with what?

AUDIENCE: Well the way I said it was that they were associated with the Holy Roman Empire.

JOEL MOSES: Holy Roman Empire. You're getting close. So where does this come from? The church. The Pope. The Cardinals. The bishops. The priests. Now let me tell you, Moses was the original Platonist. This shows up in the Bible. How did it show up in the Bible?

AUDIENCE: As the fathers.

JOEL MOSES: Close. High priests, the kohanim, the priests, the Levis, the Israelites. You want to talk about neural networks? It ain't quite like that, but you're getting close. So we see examples. In the West, Plato and his mode of thought was dominant until about 1,300. And what happened?

What happened was starting-- let me guess, around 1150, people rediscovered Aristotle. His writings were lost. And the rediscovery started with the Arabs. They had access to Aristotle's writings from the Middle East. And it went through people like Maimonides.

And then finally, it went through St. Thomas Aquinas around 1250, let me guess. And by 1250, St. Thomas then redefined Catholicism to be more in line with Aristotelian logical, rational, somewhat more individualistic-- not so much science based. I don't think it's St. Thomas really cared much for the science.

But that whole development beginning 1250 led, eventually, to the Renaissance to a science mode emphasis, et cetera, et cetera, et cetera. And that's why the name of the rows that we were talking about last time are such an interesting book. Because it was written for about this time when the transition from Platonic thought or Neoplatonic thought of the church to Aristotelian thought could be influenced one way or the other.

And that's why the murders occurred when people read Aristotle's logic, which book had a tremendous influence on the way people were thinking in the Renaissance and beyond.

AUDIENCE: [INAUDIBLE]. This is going to be an assignment [INAUDIBLE].

JOEL MOSES: OK, there he is. Sean Connery is the guy who figures out who killed and why.

AUDIENCE: And he was roughly-- brings a conflation of several characters who are roughly William [INAUDIBLE], wouldn't you say?

JOEL MOSES: I don't if he was William [INAUDIBLE], but the author obviously made it up. But he had a point. And I think that's the point. That here is a tremendous sea change in Western thinking from a Neoplatonic-- I'm not saying Plato is right. It's different. And it has advantage in some cases, disadvantage in other cases.

A tremendous sea change going on in mode of thought. So this guy was trying to hold back and say, no, no, no, no. Let's keep the order. In a sense, this slide coming up, Catholic Church historically influenced by Neoplatonic. Organizational hierarchies largely layered. Pope, college of Cardinal, synods of bishops. Aristotle's closer to Protestant.

And Protestantism is closer to science, et cetera. It's more network oriented as supposed to centralize hierarchies. Lends itself to more network distributed things. And that's the final comment. Be careful, dear student. Not all hierarchies are alike. Americans think all hierarchies are like this.

But here is an example, this is hierarchical in a different way. And it has advantages and disadvantages. I would claim-- I don't if I do it in the slides-- that Japanese organizations are more like this than they are like that. Internally, locally, they are tree structured. But there is a way of looking at the structure of the firm which has this character as well. Because Japan does have that set of approaches.

So philosophy and religion intimately connected, intimately connected to ways of thinking. Engineering is going to flourish-- I said this before-- in nations that have both a holistic, as well as reductionistic model. So Plato is the ultimate holistic thinker, but also rational. So in contrast to mysticism, which tends to be holistic and not necessarily rational, Plato is rational. But he also tends to think holistically.

So these guys all work together. It's the whole. We are trying to improve this society.

AUDIENCE: I have a question.

JOEL MOSES: Sure.

AUDIENCE: The Platonic model over there.

JOEL MOSES: Yeah.

AUDIENCE: When we talk about the university. Let's talk about the university, but this time is talking about it in terms of curriculum. And let's talk about how we organize the curriculum. Now let's talk about two kinds of curriculum. General education and special education.

It's just occurred to me that maybe we could think of general education in the Platonic model, because--

JOEL MOSES: That's the way it was.

AUDIENCE: --at each level, everybody knows a little bit of something about it.

JOEL MOSES: But that's exactly right. When you think of Middle Ages, the university taught either quadrillion or the four things, the rhetoric and geometry. And everybody was learning the same thing.

AUDIENCE: Yes.

JOEL MOSES: The specialization starts occurring with the medical schools. The medical system said, we need you to understand anatomy. It isn't one of the four things that everybody is taught. So the medical schools force the issue on specialization. And they force the issue on department structure.

There was no department structure in the Middle Ages. All the professors were-- full professors were alike. And they would teach their courses all right. But they'd get together for lunch or whatever. We work together. We're in it together.

Oh, now, they would make money by asking the students to pay tuition if they attend their classes. But it seems like the departmental structure really made it an absolute sea change in the nature of the research university. So how does Germany get to have this holistic and reductionistic thing?

Partly because Germany is Catholic in the South, Protestant in the North. And they have melded the two views. I'm not saying Catholicism is super Platonic, it's more Platonic than it is not. They've melded these views. And you could argue, well, people say, how did Nazism succeed when the Germans are so highly educated and this, that, and the other thing?

And the answer is Hitler beat them up and he tried to break the melding. He tried to get the Southern point of view become dominant over the northern view. Rather than melding, break the melding. And he took a while, but he succeeded. And so the Germans behaved in ways that were surprising to people who knew them.

The Japanese have three dominant religions and have the most flexible culture in terms of attitudes toward reductionism holism. They could switch on a dime.

AUDIENCE: On this point.

JOEL MOSES: Yeah.

AUDIENCE: You have to say something special about Germany when it comes to the university, the research they do in Germany.

JOEL MOSES: Yes.

AUDIENCE: Because everybody else was talking about handing down traditional knowledge. I mean, nobody was adding to Aristotle.

JOEL MOSES: No, that changed. Indeed. So what the first wave, say between St. Thomas and say 1550-1600, the first wave, they viewed the Greeks whom they rediscovered as God. I mean what they said went. So let me give you an example. I may have the numbers wrong but the idea is just right.

So when Aristotle said-- and Aristotle, remember, was somebody who'd gathered a lot of information. And he had these 30 talents of gold that allowed them to do these things. When Aristotle said that a fly had eight legs, no one bothered to check. Well, the flies have six legs.

Oh, maybe he said six and they have eight. But whatever it was, they got it wrong. No one checked because Aristotle said so. In medicine for hundreds of thousands years, Galen's book on medicine-- Galen said, I tell you what to do. You take the blood out, you give them these root extracts. None of which works.

But Galen said, I know what I'm doing. And he wrote at that time period through the Middle Ages, that's what they did. No one bothered to check. Science begins slowly but surely around, let's say, 1600 suddenly. And they are doing experiments.

In the Middle Ages, they weren't doing experiments. They were buying Aristotle's line. The philosopher was telling you to do this, it is. It's only later that they actually changed. But the fact is that they Aristotle was a necessary bridge between the Neoplatonic thought of the Dark Ages and the first Millennium, say, after Christ. And it was a necessary bridge to allow the science to develop.

So Germany and Japan have a positive attitude toward engineering. And in the 1980s, when we were losing in the car manufacturing to the Germans and the Japanese, especially Japanese, we were really trying to figure out why is it that they were doing so well. And again, I would say it's a little bit of this issue coming up. That is here, we were highly individualistic, weren't working as teams as well.

We learned the Japanese worked in teams. And so we picked up on some of these things in the early '90s. Teamwork, dah, dah, dah, dah, dah, dah. Did we really understand how the Japanese work? No. But we made a fair progress. I mean, all cars nowadays, based on teamwork and a number of other things we've picked up from the Japanese, really are better than they were otherwise.

Now it turns out the Japanese didn't stop improving and we didn't realize that. So what's happening in the automobile industry in the United States is that they have taken their understanding of the Toyota process, as it's called. The lean manufacturing is another term for it. That they've taken their understanding and they've made it into a religion.

You do this, you do that. Reduce waste. You do just in time. You do this, you do that. The Japanese-- the Toyota people have figured out, hey, you know, that doesn't work as well as we should. For example, it used to be that the Toyota people had this line where you basically put the car together. And the idea was that things move without stopping.

Now if anybody screwed up, your job as somebody on the line it's to pull the cord, stop the line, fix the thing at its source-- not at the end when it's hard to fix. Fix it at its source, and then continue. Well, these lines were very long and they had maybe 50 different people on the line. And these poor Japanese who noticed an error, they were afraid.

Oh, my God. We stopped this 50 person line. Maybe I shouldn't. Oh, I'm scared. I'm not going to do it. So they figured this out. They said, hey, we can't have a 50-person line moving without having everything just in time. No stacking up of anything, blah, blah, blah. And if we really want to fix the error at its source, we're going to have to break it up into lines of maybe 10.

Now psychologically, you're more likely to pull the cord when you should, et cetera. Did the Americans understand this? No. Because they had the rules. They're following the rules of 1988. And by 1998, they were falling behinder and behinder. We learned from the Japanese, but not enough.

Now of all the major manufacturing countries in the world, England had the most problem. So not only is it largely a Protestant country, so it means-- there's nothing wrong with that, obviously. But it means that you are more likely to be here, everything is more individualistic, reductionistic, science based. Not so much engineering because you have both of these things going on.

In addition to which, they still have this remnant of the hierarchy from the Middle Ages because of aristocracy. So they don't have the mode of thought, but they have this thing-- really problematic. And so what happened in the automobile industry in England? It got bought out.

I mean Ford owns-- they own Jaguar. The Germans own Land Rover or something. Mercedes owns one of the companies. So basically, there's nothing left. I mean, they just lost out completely on the automobile part.

So they have just as many smart people, tinkerers people come up with ideas. But when it comes down to a sizable business, then you run into this issue of, we better get a lord in there. And it doesn't necessarily work very well. So obviously, they do very well in certain issues like insurance and variety of other kinds of things. But when it comes down to things that require depth of engineering and large scale, they have really done poorly.

So the US gets much of its philosophy, at least, from Britain. So to some degree, engineering is not as highly valued as doctor, lawyer, MBA. But we do better than the British because we don't have a class structure mentality. And many of our technological firms are run by their founders, at least, initially and others who may have an MBA. But they appreciate the technology to a large degree, and so we do better.

Now we do even better? I think the answer is yes. But it's not going to be easy to make the transition. So I've taken you to here, 1300. People realized that there was a conflict between those two. Because Aristotle was rediscovered and the university professors said, now, wait a minute. These different modes of thought.

So there became a controversy. It was called the nominalism versus realism controversy. You ever hear that term? About somewhere in the 1300s, I would guess. Now which one of these guys, Plato or Aristotle, is likely to be the realist?

A-ha. Trick question. It's Plato. So let me explain what the issue here is. Lambda calculus. The meaning of a name in lambda calculus is nothing. X is an X. It could just as well be a Y. That's the Aristotelian position in the 14th century, nominalism. Names don't mean anything.

Realism says, the name might tell you something about the person or but the future of this person. Boy, names mean a lot. They convey the reality of the situation. They get at the essence of the person, maybe. Plato.

A chair isn't just a chair. Think of Shakespeare, a rose is a rose by any other name, nominalist position. A chair is a representative of the ideal chair in heaven. The fact that it's a chair means that there's a direct correspondence to the ideal. This thing is a copy. It's not as good, but it's a chair. It has some chairness to it.

So once I learned that the correspondent named chair to the chairness of a thing that's a chair, there's reality attached to the name. I wouldn't say that Aristotle and Plato would argue quite this way in 400 BC. But in 1400 BC, the professors are getting this way as their descendants, if you will-- intellectual descendants.

This was a big issue and it shows up in the Bible when Moses says to God, now, if you're going to send me down to Pharaoh, what should I tell him and the Jewish-- the other Hebrews, what's your name? And boy, you remember the answer? What a weird answer. I am that I am.

Is that a name? No. There's somebody who doesn't want to tell you the name because the name would reveal too much of the essence. And this is in essence it's indescribable, has no limit. Therefore, attaching a name to it is too restrictive.

This is a person who believes that name really represents reality of a kind. Therefore, don't get-- God, no name. Be careful with the name. Be very careful. It really is circumscribing to much, this notion.

AUDIENCE: That brings to mind, since we can talk about films in this class, I don't know if you're familiar with this film called *Pi.* Yeah? But it's a young mathematician, a genius, who is trying to figure out some patterns in the number pi as you take it out.

JOEL MOSES: Yeah.

AUDIENCE: [INAUDIBLE] being able to predict the future within it. He's being accosted by all of these people from the stock market and everything. And he winds up with this rabbi who wants him to tell-- wants him to say that there's a pattern in pi after so many numbers, and then it repeats. And it is the name of God.

Now I never understood that part of the film.

JOEL MOSES: So that brings up a different issue. I wasn't going to bring it up, but now that you mentioned this, I'll tell you. So this is Moses way of thinking. Abstract, don't bother me with details. The rabbis actually learned from the Greeks. You see, Alexander the Great attacks the Middle East around 322 BC.

So they come after that. They're affected by the Greeks. They won't admit it necessarily, but they effected by the Greeks. They become ultra empirical, ultra rational, logical. Not so much individualistic, but they take on a lot of Aristotelian kind of way of looking at things. And become even more so in the case of my Maimonides.

When Aristotle's whose writings were rediscovered by the Arabs, he spoke Arabic and he learned from them. And he modified Judaism to become even more logical, rational, rule based. He has axioms. He's got 13 axioms. It's amazing. But where do the Jews rediscover Aristotle?

Because they have. And it comes back to what you were saying. In mysticism, Kabbalah. What's Kabbalah spend a lot of its time on? The name of God. God is without end. There's only one God. And boy, if you only knew the name of God, this would be so powerful a weapon because you can get all the power of the universe in your hand.

And you've got to be very careful. You can't do that. You've got to shy away from that. It's one of the key issues. So to the extent that mysticism, which exists in every religion on Earth, is the closest analog we now have in religion, I would say, to Platonic thought. Not quite there, but it carries some of the same ideas.

AUDIENCE: Do you think we're trying to get that idea today in the word icon?

JOEL MOSES: I don't know.

AUDIENCE: Because it's supposed to be that looks like what it references.

JOEL MOSES: Yeah, but you see, think of the mosaic commandment. Do not make a graven image. So if you want to have God be abstract-- and the mystics do. If you want God be abstract you can't have a real icon. That goes against abstraction.

And now you've got it down there. This is what God looks-- no, no, no, no, no. Can't have that. Can't have that. See Moses really was an abstract thinker. There's one God, no graven image. Be careful with the name. Do not take the Lord's name in vain. I say, that's simpler than what people had in mind. Don't ever use the Lord's name because then you are attached to much specificity to this abstract notion.

So to continue the path. This is 14th century. In the 18th century, are Hume and Kant. So let's say this is about 1700 and this is about 1775. A lot of things happen around 1776, it turns out.

What is Hume saying, among other things? He's British, Kant's German. And from now on, the British and the Germans are going to be fighting each other. And they're fighting over this set of issues.

Hume says, a baby is born "tabula rasa"-- I think he got the term from Aristotle-- which means the baby doesn't know anything, complete clean slate, and everything is learned. Everything is learned. The biologist would argue. Their claim would be, hey, these genes really have an impact. No, no, no. For him, a baby, clean slate.

And that's the British view, which emphasizes logic, rationality of that kind. Kant comes in, and what's the name of his famous book? *Critique of Pure Reason.* Because Hume is the ultimate pure reason view. You have axioms. You have deduction mechanisms. And everything follows from that.

No, no, no, no, no, Kant says. Pure reason doesn't explain the world very well, or not enough. And he believes in built in things. I forget exactly what he calls them. What is Kantian categories? You have built in categories.

So if you look at cognitive science nowadays and you ask the question, how does a child manage to see things? We know that they have built in mechanisms for seeing certain things. There's a famous paper written by one of our colleagues which says, what the fly's eye tells the fly's brain-- is that what it is? Yeah, I think that's what it is. What the fly's eye tell the fly's brain.

And what they did was they would put electrodes into the fly's brain and they would see when things would light up. And they would send images across the field of view of the fly. And it turns out that if you had something which looked like this and it went through the field of view of the eye and it moved, then certain kinds of things would light up.

You see, those neurons in the fly's eye I we're looking for things like that moving. Because that could be a-- that could be something that it could eat. Now is this a fly's eye? What the-- oh, I'm sorry. It's a frog. What the frog's I tells the frog's brain. And what's the frog want to do? Eat flies.

So you see something moving like that, that's a fly. So this thing was trained, built in category to look for that kind of stuff. And I don't know what we are trained to do, but the assumption that we have built in categories has a lot of truth here. This is a more of a Platonic view-- not purely Platonic, but more of a Platonic view than an Aristotelian view, which would say it's really just logic. It all follows from a few axioms.

And so when you see Lord Russell-- you may have heard Lord Russell, a famous logician mathematician in the 20th century and the Cambridge professor-- say, I can't understand these Germans. I mean, Kant, who can understand him? Of course, other philosophers will say, Kant's the greatest philosopher in the last 200 or 300 years.

But the British, especially, the Cambridge school, just they don't get it. They don't understand it. So this different mode of thought, which is my opinion, goes way back to Aristotle and Plato. Different ways of thinking about the world. Even though Aristotle was Plato's student, they didn't see eye to eye.

So what does this have to do with engineering? Well, let me go back. So I think Taft introduced this as being a different way of looking at engineering. People who write about engineering philosophy tend to emphasize what makes engineering unique, different from science, different from mathematics, different from social science. Design, for example, makes engineering unique.

Well, I want to argue. I think engineering isn't that unique. Because in a sense, everybody designs in a university. So let's talk about what they design. And philosophers care about design issues. But in a sense, this approach is systems engineering. Take a problem, break it up into pods, keep doing it. Blah, blah, blah. All the great American systems engineers think this way.

This approach is maybe more of the way mathematicians like to solve problems. Take a problem, abstract it. Make it even more abstract. Get it down to something so simple that you can actually solve the abstract problem. And now specialized to a particular solution. Here, get it down to the simplest thing, which you can solve and back it up. This one, no, move it up and then down.

No, no. These guys say, no, no. Down then up. Different way of looking at things. And nobody is absolutely right all the time. So let's talk about design, organization, et cetera. So I claim design is of interest to every field in the universe. Writers, composers, artists, obviously, architects. Biologists nowadays. Maybe physicist not so much though. I don't know.

I mean, they could say, look, we're not trying to figure out the nature of design because we really only care about one design. How did God do it in the first place? So design variation, which is the interesting thing to me, how do you maintain flexibility in a design so you can make changes easily? It's things that's not an issue.

Biologists care about design variation because development and evolution, things of that sort. But physicists, less so. So bottom line, you have to look hard to find a field which isn't interested in design, and therefore, has some relationship to engineering.

So the claim is that legacy views-- and lots there are different legacies. We, as humans, have a legacy. We're limited by our ability to solve problems. The phrase 7 plus or minus 2 ring a bell? You've heard it, right? But you haven't and you haven't?

So there was a psychologist here at MIT 50 years ago, his name was George Miller. And he wrote a paper called The Magic Number, 7 Plus or Minus 2. And The Magic Number, 7 Plus or Minus 2 is based on experiments that he did with people. Now ring a bell? And what do you think-- how many different things you can remember?

It could be numbers. It could be words. How many different things you could remember at a time. And people can go between five and nine, depending on the individual, et cetera, et cetera, et cetera. So here is a legacy-- a restriction that we inherit as humans, assuming he's right, of course. And he seems to be.

But there are other legacies-- other things that restrict our ability to do things. One is the country we were born in. Maybe our religion, certainly our education. If we're trained as electrical engineers or civil engineers or mathematicians, that'll have a way of affecting it. I'm certainly affected by having been trained in mathematics because, remember, this guy isn't things like a mathematician. That's a logician. That's a funny kind of mathematician.

So let's look at mathematics, which I a little bit about the history. Especially in the 19th century, British mathematicians didn't do well in the 19th century because there was so in love with Newton. So what they did was they went into the study of differentiable equations, special cases, the differentiable equations. Even more special cases of solution differentiable equations, this that and the other thing.

And they got stuck in there and they really didn't make much progress. And again, it shows the empirical aspects-- it's special cases, empiricism are very closely connected. On the other hand, the Germans, who I claim have this more abstract view of things, they made enormous progress certainly by the mid-19th century in algebra.

Algebraic geometry, algebraic topology, abstract algebra, blah, blah, blah. All of which emphasize abstraction, which is a consistent with their content philosophy. Which again, is consistent with Platonic way of looking at things, et cetera, et cetera. And these guys want out in terms of most of mathematics. Not all.

Certainly, logic-- the kind of stuff that we study in computer science, logic and combinatorics is more like this. But the stuff we don't study in computer science that is real mathematics, topology, geometry-- well, we do a little bit of algebraic geometry. Algebra. Even analysis tends to be much more abstract, much more based on these kinds of notions.

So I would say, by the mid 20th century certainly, most mathematicians followed the German approach. It doesn't mean the German approach is right for everything. I keep saying, there is no right answer. But let me tell you, you can take this too far. The French took it too far.

So one of the problems you can run into if you're going to be abstract is to say, well, I'm going to make lots and lots and lots and lots and lots and lots and lots and lots of abstractions. And I had the whole power with 20 different-- actually in software, we see this a lot now. If people building in one software layer above a layer, they go nuts.

The idea is to have relatively few layers that really add something, rather than lots and layers that add very little. And if you're a logician, then you buy into the notion that abstraction is a good thing. but if you carry it to the extreme, then you will have so many layers you just get lost completely. You don't really say anything.

That's what happened in mid 20th century. In France, there was a movement called the Bourbaki school. The Bourbaki was one of Napoleon's generals. They made up the name. A bunch of mathematicians wrote under the name Bourbaki

And they read did-- they re-approved a lot of mathematics that was already known from a fundamental point of view of set theory and logic. And this had an effect, for example, on education k-12 in the '60s and '70s when we did new math. That was those guys in the American context.

So Bourbaki was going to revolutionize the teaching and research and mathematics by redoing it all from a very fundamental point of view. Lots and lots and lots and lots and lots and lots of abstractions. And eventually, people said, this is nuts. This is absolutely insane. Get rid of those guys. And they stopped doing it. Don't go crazy over abstractions. Some are good, too many is too many.

So back to an issue I discussed already, manufacturing. I'll read it with you. US Manufacturers in the 1980s were very concerned over the ability of the Japanese to manufacture cars more cheaply with higher quality than the Americans. The German produced cars with greater performance than the Americans. Not necessarily higher quality or cheaper, but better performance. And so caught between those two.

Then we started looking at the Toyota process. And I got to tell you a story. There was a joint Toyota-GM plant in California called NUMMI. I don't know why it was called NUMMI, had some meaning. And basically, an existing GM plant took over all the union labor that they had in the plant. And they retaught them, with Japanese managers, how to do things.

And the quality went way up. The production rate went way up. And GM sent all their vice presidents to go in there and investigate. What did these guys do with our plant? They're working with us. They did something. It all works.

And I talked to one guy who had seen the plant six times. And he said, I don't see anything different. They do the same thing we do. What is going on? I mean, why-- I can't figure this out. So finally, he admitted-- he said, OK, OK. Let the guys who run the plant-- the Japanese guy-- give me a three-hour lecture as to what they think is different.

So he finally, after six visits to the plant, when he didn't get it, OK, got a three-hour lecture. And then his eyes lit up. It was such a different way of thinking. He just couldn't see it. Simply could not see it. But once explained, it made sense.

So it was a different way of looking at things. And we learn from them. And I claim that the reason that they were successful is they looked at the production process in a more abstract way. And that fits in with the national cultural of value, my claim. In Germany, where quality wasn't so much the issue. It was mastery of details. The German mastery of details is a big deal of that culture.

Meister is what they call them, meister, uber meister. And that gave him the ability to do things better and better. Some people actually claimed the Germans lost World War II because they were too wedded to this notion of mastery. So they have all these great guys on their production plants making tanks.

Well, each one of them makes a slightly different tank based on his way of doing things. He won't listen to anybody else. You make the tank this way. So the Germans went into battle against Russia with a whole slew of tanks, which are fine and dandy. Each of them worked very well, until for some reason, some part failed. And they had a problem getting any parts because all the parts were different.

Whereas, the Americans made the same tank over and over and over again. And by golly, there was no problem with interchangeable parts. Anyways, probably not the only reason they lost, but maybe one of the reasons. So we learned from the Japanese, who are still ahead, as I said before.

And one of the things we learned was wrong. So one of the things we thought we learned is how to organize firms, which we realized were hierarchical. But as they grew, we allowed the hierarchy to grow into many, many levels. And so we said, no, no, no. The way to understand the Japanese is they don't have middle managers. Let's get rid of the middle managers.

Well, what it really, to me, explains is we don't understand middle management. What's the role of a middle manager? Well, in the American way, a role of the middle managers to check up on people. Are you doing what you're supposed to be doing? Are you screwing up?

Oh, that's not the role of a middle manager. The role of a middle manager is, is there any way I can help you? Can I teach you what it is that you need to know? On the next project-- I mean, it's a different attitude toward the role of middle manager. You can have fewer levels of middle management if you recognize what the proper role is. But if you simply say, middle management is just at waste, just added fat, let's get rid of it. You're going to get run yourself into some difficulty. And I think many companies have.

So what saved us in the '90s is the line here. The two problems. Problem number one is that Japanese got hurt by the real estate bubble. In 1988 or '89, the government of New Zealand sold its embassy in downtown Tokyo. And the value of real estate was so high, they were able to zero out their national debt.

The value of the few acres in downtown Tokyo near the Emperor's palace was equal to the assessed value of California. I mean, it was out of sight. And did they have a bubble. And then the Japanese don't allow themselves to let the banks go out of business readily. And therefore, they just took years and years and years to get out of this. And they're just starting to come out of it.

And so that helped the Americans in the '90s. They didn't have the Japanese-- the same Japanese to compete with. And what hurt the Germans in the '90s was reunification with East Germany, where the West Germans had to send a lot of money over to make the East Germans appear a little closer in terms of their economic status to the West Germans. And so they got hurt that way.

On the other hand, now, as you could say, well, so we're doing fine against these guys. But they're coming back is my argument. But now everybody is worried about China and India. And it's not clear exactly how these different modes of thought and variations on them are going to deal with the challenge from a billion three or whatever the number is of people in China and the Indian challenge.

I'm not predicting the future. I'm just saying that this way of thinking about it tends to clarify, at least in my thinking, what has been going on, even as recently as a decade ago. But in terms of predicting the future, it's not as good. End.

JON GRUDEN: I hope you stay up there. We got some more questions.

JOEL MOSES: OK.

JON GRUDEN: Or comments. Let's have a little more discussion.

AUDIENCE: Could we hear a little bit more about the Toyota-GM you said that--

JOEL MOSES: NUMMI plant.

AUDIENCE: --the manager went out there and could see--

JOEL MOSES: The vice president went out there, yeah.

AUDIENCE: --three hours, and what were the differences?

JOEL MOSES: He may not realize the importance of things like just in time. I mean, things were being delivered, but they got deliveries in GM plants too. But the fact that their deliveries were relatively few and specialized to the cars just now being worked on, maybe something he may have missed.

Now mind you, this is the guy who came a year later here and gave a talk at Kresge. And he said, well, I got my MBA at MIT. And then he had a briefcase with him. He threw out the contents of a briefcase. It was a bunch of books. And he says, these are the books they taught me.

Now, in the automobile business, we have recalls for things that don't work. MIT should have a recall. And for free, they should re-educate us. He was a character. So after he learned these things, he saw the light.

The trouble is, I said earlier-- and maybe you missed it, Tony-- is that in some sense, it became a religion after a while. These are the seven steps to heaven. And we didn't realize the Japanese were constantly tinkering with the process and they were improving and improving. And even the Germans got better.

I mean, what happened was that of all the firms, the worst performing in terms of quality and cost-- well, not so much quality, but certainly cost-- were Daimler-Benz Mercedes. And the president Mercedes called up president of MIT in '88 or '89 and he said, you can't publish that result. You're going to be like a laughing stock. You can't tell me a Mercedes is the worst performing plant on Earth.

Well, we published the result anyway. And this guy got canned. And the new guy came in. He says, I'm going to make every vice president of the company read that book. So he got the religion. And they all did because once you show what the numbers are-- a little dose of reality-- it made a big difference in the automobile industry.

AUDIENCE: I read somewhere and-- maybe I'm thinking of something else. We're talking about lean manufacturing?

JOEL MOSES: Yes, it's exactly what we're talking about.

AUDIENCE: If you're on a certain level of the hierarchy, you don't move up? Is that true? Because if you're his friend and you do a certain job, you do it really well, maybe you get a different kind of reward. But you won't be promoted to--

JOEL MOSES: So the promotion process, to remind you, you don't have very many levels. So one of the things that happens is promotions, if they do occur, are slow. Americans love to be promoted fast. I want to be promoted fast. Two or three years on the job and I want out of here. Leave all the mess to my successor.

So the Japanese move slowly. Now in terms of promotion, what happens is first off, they retire early, 55, unless they happen to be senior management. Then they can retire at 60 or 65 maybe. But 55 is a normal retirement age for so-called salaried workers. And what happens is they move over to a subsidiary company. And a subsidiary company knows that they better hire some of these guys otherwise they're not going to remain as part of the supply chain as much.

So slower promotions-- not nonexistent, but slower promotions. Some people don't get promoted, but they don't get demoted either. They get given a chair further away from the action. So in principle, everybody in a given level at the company is at a given level of the company. But when you listen to people, you listen only to a few of them.

The others can talk all they want, nobody's going to pay much attention to-- everybody realizes that within this particular level, all these guys who are 40 years old, two or three of them are really the ones to listen to. It's a complicated game. But again, very much related to this issue.

Whereas, the fast promotion, if you have 20 different levels, you want to go through, [SHUFFLING SOUND]. And again, also the salary ratio, we worry about how high the ratio is in the United States. Several to one between a CEO and the lowest paid worker. But maybe only a dozen to one in Japan.

I mean, it's a different attitude. And again, the attitude of, we're all in it together. We are the Toyota team. And we are going to beat out, not only GM and Ford, but Nissan and Honda. On the other hand, we're going to cooperate between Toyota and Nissan. We're going to cooperate on processes, not on products.

We're going to cooperate on business practices, on knowledge. But not things that are intimately tied to our products. So there is an attitude about what's to be cooperated on and what's to be competed on. And it is a very different way of doing business. And it works some of the time, not all the time. Nothing works all the time. You hear that?

AUDIENCE: Can I ask you about your claim that design isn't as unique as engineering.

JOEL MOSES: Of course not.

AUDIENCE: Which I agree with. But so then I wonder, how do you think about defining engineering? I guess you would say just engineering is closer than to what systems philosophers do. But [INAUDIBLE].

JOEL MOSES: No, systems philosophers worry about all kinds of systems or organizational systems. All kind of things. What engineers tend to do is they use their knowledge of math, science, and engineering science in order to develop products, processes, systems for society. There are certain kinds--

AUDIENCE: --specific purpose.

JOEL MOSES: Absolutely. Absolutely.

AUDIENCE: OK.

JOEL MOSES: Absolutely. But see, in a sense, so is design and music. But the musician doesn't necessarily rely on his understanding of physics. He doesn't rely on energy as a variable.

AUDIENCE: That's [? definitely ?] strange. Like, music isn't necessarily constrained--

JOEL MOSES: It's constrained in some ways, but not in other ways. Let me give you an example of constraint. So I was taking music appreciation 101. And a student got up in the course and he said, Professor, I don't understand. How did Mozart manage to write so many symphonies when he was so constrained by the sonata form, ABA?

The professor's answer was, because Mozart was so constrained by the sonata form, he was able to write lots of music. Constraints can be good. Constraints can be good. So computer scientists actually have a problem. They're not so constrained by physics and so they can try anything.

And boy, they bollocks it up. They get overly complex software without realizing it. And after a while, they can't make any further changes. I'll give you an example of overly complex software. So Jimmy Carter was president before you were born, but I remember him well. I'm sure Taft does too.

And he was not the smartest guy. He was an engineer, so not necessarily the smartest politician. Now one of the things he decided he was going to do because he believed in truth and all that is he was going to allow people to call him on the radio on Saturday afternoons and ask any question they want.

So a lady called up and she said, well, I get Social Security. And Social Security has updated, my check is increased relative to inflation. In those days, inflation was quite high. And it's done once a year. Because inflation is so high, it would really help me a lot if it were done twice a year.

He said, OK, I'll look into it. So months later, some enterprising journalists said, whatever happened to that lady's question? And Carter had to own up. He said, well, we asked the people at HHS where they can do this. And they said, well, if they try doing that they couldn't guarantee that the checks would come out because the system was so complicated, the ramification of that little change could create such a havoc that they dare not do it. That's overly complicated.

A minute to go, guys, according to that watch.

JON GRUDEN: Well, thanks again. And next week, we are off Tuesday. Is that right?

JOEL MOSES: Yes, because Tuesday's a Monday.

JON GRUDEN: Tuesday's a Monday? OK, well, then first thing I need to know is, what kind of publication rights are you going to give us with these slides since I've got them on my machine? Can we send them to the?

JOEL MOSES: Oh, absolutely.

JON GRUDEN: All right, then I'll take responsibility for that. I have a grading scheme. And I'll be frank with you, I really don't want to put it in concrete until you talk about it. Now I want to be able to reveal some of my subconscious to you before we do this.

You want to look at partly a Democratic process. And I emphasize partly. And you could say what you think is right, what you think is fair, unfair about it. The [INAUDIBLE], what I'm really looking for you to say is, well, look, Dr. Gruden, this latest scheme here is not as tough as we feel it should be.

We want a more rigorous class in here. We want to do x, y, z. I'm really looking for you to add something to this. You don't have to do that. But if you think something's unfair about it, I want to hear about it. And wherever I go from there, I want to be able to say, well, I heard from them. They won't do it, but I heard from them, if that's what it really comes down to it.

Your next assignment-- how you doing with this work?

AUDIENCE: Oh, gosh. My book, something happened with the mail, but they're resending it. I should get it in a couple of days.

JON GRUDEN: OK.

AUDIENCE: So actually, definitely about next Thursday, I would think.

JON GRUDEN: Oh, that far away?

AUDIENCE: Well, we can share.

AUDIENCE: I have your email, so I can [? work ?] on getting it in the next couple of days.

JON GRUDEN: Well, I have another copy. I'll loan you my copy. I have, actually, an older version in my office. I'll give you the updated version. What I want you to do is read two cases, since we have so much time. I want you to read the Ford Pinto case. And I want you to read the Challenger case.

Next week, we'll start converging on something much more high quality with the ethics. And then we're going to start putting the ethics and the engineering together. And my assignment for next week-- for the following week-- will be turn in the first analysis. And I'll give you the format, tell you how to write and see what's done.

Once you get my methods down, then we'll start talking about a little education. You'll start doing it your way. Also, you want to sign that you listened and watched this film. [INAUDIBLE]. OK, that's it.