PROFESSOR: OK today, teaching with blackboards and slides. And also several questions from the last time. And, related to that, a handout, which I've put online, which is on how to make a lesson plan. So I'll do all that through the questions.

So now just a quick bit about lesson planning, because a couple of you pointed out that you'd have liked to know more about lesson planning. And reminded me that when I taught the chemistry TA workshops, I actually gave everyone a handout on how to plan a lesson. So I've put that handout online, and I'll just show you what it looks like here.

So this is basically the sheet I use for planning any kind of lecture recitation. At the top, you need some kind of course, and date. And then the objective. So that's quite important. You'll see the exact sheet. And there's a PDF file, you can just use it yourself. There's a course objective for that particular session. And that relates to your overall goals for the course. So, for example, in this problem, my objective might be something like, to show that easy cases-- in fact, this was my objective-- I wanted to show that easy cases-- extreme cases-- are useful not just for checking formulas, but also for generating formulas.

OK, so I write that on the top. So I remind myself, why am I here? What am I doing? Then there's a three-column table. Basically you just plan items in your lecture. The first column is minutes-- how long you expect each thing to take. And then the middle column, most of the space is, what's your goal in this local part of the lecture? And what are you going to do for that? So here's my overall objective. And my local goal may be, just this example-- getting that one third.

And then here in the third column is props. So there's actually a piece here, too. So

props are anything that I need to bring. So I just stick that in the margin. OK, bring the cones, or the pyramids, whatever they may be. And so then, when you're filling this piece in, about what to bring, you just scan down this last column, and just write everything here. OK, cones. Homework three, solution set two-- whatever it may be. So now, at a glance, before you go to your session, you review these two things. Make sure you have everything, your know why you're here.

But then here, you're going to follow your script. Which is a loose script. It's not exactly a word-for-word script. It's, maybe, a few equations. Suppose there's a question. What is this constant? OK, so that's my overall, what I'm going to do for, say, ten minutes.

And then I break it into sub-questions. OK. What is H and B? How many pyramids do I need? What's my goal shape? So these are questions that I ask students. And for each one, I write down the minutes. Maybe in parentheses, put the total up here.

So now, when I've done my two or three pages-- and by the way I find, just at the level of detail I use, if I ever go beyond three pages, I never get to that material. So it's just sort of for a security blanket by the time I'm beyond three pages. It depends how detailed you write these things, but I've generally found that's where I am. And then, you estimate the time. And what you'll find is, the first time you do stuff, you'll massively underestimate the time. You'll be off by a factor of two. So, in other words, if you think it takes five minutes, it'll really take ten minutes. And that's true even after you take account of this rule. Sort of.

OK, so then you put down all your minutes on this page, and the next page. You add them up, and you make sure that you're not over 50, or whatever the amount is. And then what you'll find is what you thought was 50 really is going to take you 130. So the next time, when you evaluate minutes, you'll have a better idea. And you'll find yourself actually tuning your time sense pretty well. So now I've got my time sense that I don't really need to put the minutes down, because I can just do it by number of pages. Three pages, too much. And so you'll find your own writing level, and detail level, how many pages to use.

Now the other point is, where do these questions come from? OK, well this is a way you can turn any regular lecture into an interactive one. So suppose you have a long derivation that you're going to do. Or, for example, suppose the first way I planned this, was I wanted to show people that this was 1/3 over here, this is three here. And the way I was going to do it, was I was going to draw six pyramids, show them in a cube, and show that 6V, and do all this showing. Well, first draft, write it all out like that, with times and everything, without questions. Then, any time you come to something interesting-- so here.

So before you have [? tel. ?] So now you look at your sheet, and you say, hmm, where did something interesting happen? Hopefully, there is at least one point. Because if there isn't, maybe you shouldn't be giving the lecture at all.

So now, let's just say, by construction, you found some interesting things. OK, so that's interesting. Oh, it's interesting that it makes a cube-- it's not obvious. So just think, where does something require thought, and that you're short-circuiting the thought by telling. So then, what I do is I have a green pen, and I turn it into a question. So I'll circle it in green, and write, "ask" next to it. OK, or you can just rewrite your sheet.

Telling something, then asking, and then continuing. OK so that's how you can turn any regular lecture into an interactive one. And that's your sheet that you walk into class with. And what you'll find, is that the first time you do it that way, there will be a bunch more spots you realize were actually subtle. Because, for example, at the end of class session, when you collect your feedback sheets, people will have questions about different parts. You'll realize, oh, there was actually something interesting that happened that wasn't obvious in one of these telling points. And you'll be able to turn that into a question, as well.

The master sheet with all that formatted for you is online, on the course website. And you're welcome to use that in your own teaching, and distribute it to everyone you know Any questions about that? Yes.

AUDIENCE: When you run over time, then you have to shift some of the things to the next

lecture. So how do you do that?

PROFESSOR: What happens when you run over time. The first time you teach the course, you basically find out there's just twice as much material in the course as there should be. And you'll always be running over time if you try to cover every single thing. So, the first time you run out of time-- there's two approaches to it. One is just to slow the entire pace down, and cover half of the amount of material. So that's quite a reasonable approach.

The other is to sort of keep rhythm, but not cover every single thing. So my piano teacher, a while ago, she said, when you're sight-reading new piano music, the most important thing is, keep rhythm. So don't just stop, and then think for like ten seconds about one measure, and then continue in this herk and jerk. Just keep playing at speed, but skip some of the notes, and do whatever you have to do to keep rhythm. So you can try that approach too. And then, what you do is you say, OK look I'm not going to cover every single thing in lecture. A lot of stuff is in the book. And that's good to do anyway. So a mix of the two approaches is one way to deal with running over time.

AUDIENCE: [INAUDIBLE] So each lecture you have some objective. And then, if you run over time, then in the first lecture, you only finish half of it. And then, the second one seems to start from the middle of [INAUDIBLE].

PROFESSOR: Right. OK. So that's one reason it's worth writing the objective first. Because then you know what the main goal is. So one way to do it, which I do like, is to make sure that-- right away-- the objective is reached. So you do it as sort of a layer cake. So the first example-- maybe the first two examples-- just from those, if everybody just doesn't do anything else but the first two examples, which you expect will only take 15 minutes-- but it takes 40 minutes, it's okay. Because the first two examples reach your objective. Now they don't reach the objective 100%, but they give you 80% of the objective. So you want to plan your lecture structure like a layer cake, or like JPEG.

People know how JPEG compression works? So JPEG, the way you do it, is the

low-frequency, quote, "most important" terms, come first. And then the higher-frequency, say, less important terms, come later. So sometimes you see things rendered in your browser step-by-step, and they just sort of take focus. And it gets better and better as you wait longer and longer. So you want to plan your lecture a bit that way. So that it's robust to time shortage. So that if, for example, there's a fire alarm halfway through your lecture, still the main point got across. Now it didn't get across in all the detail, and the beautiful glory of that you wanted, but the main point still got across.

So then, if you run out of time, it's OK. You say, look, there's two more examples of this which we didn't do, but they further illustrate the main point. See the notes. And then you can keep to your plan. Assuming that your plan is a reasonable one. If your plan is that, I'm going to do f equals ma today, and I'm going to do rigid body rotation tomorrow, that's probably not a reasonable plan. And the fact that you ran out of time on day one is probably a good sign that you should actually spend a little more time on f equals ma. Does that answer your question? Other questions? Yes.

AUDIENCE: I have a question about [INAUDIBLE]? A lot of people have told me over the years that it's good to write really big. And I know you're constrained by that the people have to be able to see. But, given that you're writing large enough for them to see, what's the advantage of writing any bigger than that? As opposed to having the [INAUDIBLE]?

PROFESSOR: OK, so that's a good question. Actually, why don't we save that. We'll talk about that today. So the question was, how big should you write? Just enough so people can see, or bigger? So that you can keep the full story there.

OK, so, any other questions on the lecture planning? And blackboard, and slides, we'll come to starting right now.

Teaching with slides and blackboards. What are the advantages, and disadvantages of each. I'll tell you my bottom line, which is that my zero-th order term, so this is my objective-- if the lecture ends after the next two minutes, at least you'll have the zero-th order term. The zero-th order term is that, if you can't help

yourself, use slides, but otherwise, use blackboard. For 90% of things, blackboard is much better for teaching than slides.

There are some cases where slides are useful, and you can make an argument for it. There's some cases where maybe the slide is as good as a blackboard, few cases where it's better than a blackboard. But the default is, blackboards are better than slides. Now let me show you an example of why that's true.

Suppose you're teaching the-- an example I've done with you before, slightly, is the Navier-Stokes equation.

Let me write it down, to start with. Actually, I'll put it on a separate blackboard.

So there's our topic. So we always know what our topic is, because it's up there, and it's just going to live there for a bit. And in fact, in some classrooms-- you can't do it so easily here, but my favorite classroom is 4-265 because it has pretty much this much blackboards in the front, and it has blackboards all around the side, and on the back. So I don't use the back ones so much, but the side ones are really, really useful. Because you can, for example, put the topic, like I've done here, on the side blackboard, and just let it stay there the entire time. You can put an outline of the lecture.

OK, so let's say we have a lecture on Navier-Stokes equation. We want to look at them, try to understand them.

So here are the equation. Well "are," "is," the plural is a bit ambiguous. This is actually three equations, one because it's a vector, vector, vector.

Already there, you see something that's harder to do with slides. You'd have to work harder to do that in slides. You can just go back, and annotate as you go. And here, you can see the entire topic while you're looking at this. So, for example, the student has now got overwhelmed by all the little symbols here-- the del squared, the partial derivative, the v dot grad-- that part always scared me when I was a physics student. I knew what del dot v is, but what's v dot del? So you get scared by all that. And then people forget, they panic. Because their short-term term memory got filled

with every single, little, chunk here. Their chunks are, remember, very small. And they forgot, what are they doing? Navier-Stokes equation fluid mechanics. OK.

And now, you can even improve that first blackboard by talking about, what does this apply to? Drag, turbulence, river flow, airplanes. So here, you can have a reminder of why it's important. So now that just stays up there the whole time. And people can re-center themselves every time they get confused of what they're doing, just by that.

And then, you can continue. You can say, OK, let me try to explain the meaning of these terms. So let's do the terms one at a time. What's this? So this term here is Dvdt. We've seen things like that-- that's sort of like an acceleration. You can annotate the equation right there. That's also hard to do on a slide. I mean, you can do it, you can work at it, but it's very natural on a chalkboard.

Now, there's some things that are common to chalkboards and slides, which is the use of color. So now this, unfortunately, is blue, which is not the ideal color. Unfortunately, I don't have my-- orange is generally better, but anyway I have blue. Can you see the blue? So marginally? Maybe this orange, even though it's not as big, will be better than the blue. OK, well this shows you an example of color, and the importance of choosing the right color. There used to be a green one here, but they're isn't green anymore. Blue is not ideal, I won't use the blue. Let's try this. Is that better? OK. So let me use this orange one, and I'll try to write large, even though it's not as bold.

OK, so the use of color. That's important in both slides and blackboard. What's the use of color here? Is it just because it's nice to have a pretty picture? No. The reason for using the color is that you get layering. So again, remember the students' dilemma. Pretty much all students' dilemma come from the following problem, which is that their chunk size is one symbol. You've been teaching the Navier-Stokes equation for 20 years, your chunk size is the entire equation. Right? So that's one chunk to you, you just write it down, like I just did. But for the student, every single, little thing is one symbol.

So now, if you then write all of this stuff in the same color, as your rest of your equation, it just becomes more stuff. They don't know how to separate it into two different objects. But, if you write your labels in a different color, it pops out in a different layer. They know that lives in a different space, so you're already helping them chunk.

So what is this? This is also a change in v. So it's sort of like an acceleration. Well, it's part of the acceleration, actually. So this is another acceleration. It's a change in v, but it's a change in v because you've moved to a new place. So this is a change in v because you waited-- you move to a new time. This is a change in v because a little piece of fluid moved to new place, where the fluid velocity is different. So these two things together are two different contributions to the change in v. So we'll actually call this whole thing D of vdt, which is actually its actual name. So this is an acceleration. These are the two pieces of it-- this is the acceleration.

What's on the other side? Well, this guy, pressure-- p is pressure-- grading of pressure. So that's the differences in pressure. So that's going to do some kind of thing, like a force. And row is density. So you're taking a force-- I'll put it in quotes, because it's not quite a force, it's sort of force per area. But now you divide by density, and you get f over m. So f over m. So we have, here this guy-- acceleration is equal to f over m. Do you recognize that equation before? Yes, Newton's Second Law.

So this whole thing, so far here, is just this is a equals f over m. So this is the pressure forces, and this must be the-- and this is the viscous forces divided by the mass. So these are the two contributors to the forces-- pressure forces, viscous forces-- and those produce the acceleration. So the Navier-Stokes equation comes out just as Newton's Second Law all over again.

So now, this kind of drawing is quite difficult to do in the slide. Yes.

AUDIENCE: So I actually would argue with you. You could prepare a set of slides with annotations, and then you could do everything. You could put all the information [INAUDIBLE] in a slide, or in multiple slides. [INAUDIBLE] animation.

PROFESSOR: Yeah. So you could put them on multiple slides, and then flip to it, one by one That's true. So you can do it, which is why I said you can do it, but it's hard. Because it is a bit of a pain, and you can do it.

OK but then the problem is, you want to now leave that on. So now you want to have not only this, but you also want to have this, and leave it on for the entire lecture. Because this is the meaning of the terms. And now you're going to leave it there, and talk about each term, one by one. Yes

AUDIENCE: But you could also give them a handout, with all the slides there, so they would have everything in front of them. And if they ever want to go back, they can look back on the previous slide. [INAUDIBLE] but I think so far this is not a strong argument against the slides. Maybe the question's about interactivity. If somebody asks you a question, what about the third term? If you don't have a slide for that, then--

PROFESSOR: Right. And this is the point I'm coming to. So there's that. And I agree with you, you can do this with slides, you can give people a handout. Though the problem with the handout-- suppose you put all of this on the handout for them, so that now, when you erase this screen, and that screen, you go to another thing they still have something to refer back to you. The problem is that you want it all in one visual field. And you don't have that when it's on a handout. So you have a problem of split attention.

So now the student's attention is switching between the screen, and the handout-- screen and handout. And when they look at the screen, they're trying to remember what they're confused about. And now they look at the handout.

This is the analogy. When I was in Prague, I would look at a street sign, and I would read the word, and look at all the letters. [INAUDIBLE] or something like that. And I would look away. Two seconds later, I could not remember more than one letter that I saw on the street sign-- on the street name. The reason is, because each of the letters was random to me. So, yes, someone who's Czech, just says, oh yeah, that's Main Street, of course. No big deal. What's there to remember? It's Main

Street, it's in the Main Square. Whereas me, as the foreigner, has no clue. And it's all new data to me.

So it's the same way for the students. This is all new to them. So when they're looking at something else, you're talking about-- you're going to discuss, what's the dimensions of this term? They look at this thing, and now you have a big analysis of the dimensions of this, you want to check that all the dimensions are right, and your goal is eventually to work out the dimensions of this-- viscosity, let's say. They might be frightened of the partial. So they look at this, and they say, oh, yeah, where does the Dvdt come from? And then they look back at their handout, and they've already forgotten pretty much what this was. Because they are the foreigner. They are the tourist in this land.

AUDIENCE: Yes. I was just going say that I would have said something very similar. The annotation part of it is to [INAUDIBLE] slides at all, because if I was making slides for this lecture, I would've done exactly what you did. But it would all be nicely spaced, and there would be no handwriting issues. So if anything, slides would be better for that. But I think that the argument for slides is [INAUDIBLE] having them linger on, but also pacing. Like, the fact that it doesn't flip up so quickly, because the [INAUDIBLE] that I've taken where they use slides and use [INAUDIBLE], it goes by so quickly that you have no chance to internalize. The fact that you have to write it out by hand forces you to slow down, in a way that is really helpful for the listener. And so that's something that's really important [INAUDIBLE] difference.

PROFESSOR: Right. And that's a fundamentally important point about pacing. And this partly addresses your question about how big should you write. So one of the reasons for writing big, is that you're writing slower. And writing slower, generally forces your pace to match the pace that is absorbable by the students. So I'll come back to that point in just one second.

So let me just finish the point about the visual field. The good thing about the blackboard is, you could call it cognitive offloading. In one glance, everything that the students need, can be there. So they don't really have to remember much. And

the short-term memory isn't overfull. They're registers. They're a low-register machine. Or rather, they have the same number of registers as us, but they don't store as much information in their registers. So their registers don't get overfull, because everything's right there. Whereas there is a much bigger danger of register overfilling with slides.

Then, as you point out, there's the issue of interactivity. So this is partly a performance question. Slides, not only are they much more pre-prepared-- I mean, you can prepare your blackboards, as well, but you actually do have to re-perform it each time. Whereas a slide, as you say, you just click to Return, or Next, and there you are, at the next slide.

So there's much less performance in it. And it seems much more pre-scripted. Now, what does that signal to the students? The pre-scripting. It says to the students, look, this is all one, tight thing. It's sort of like a play on a stage, that you're only supposed to applaud at particular times. A modern-day play. Back in Elizabethan times, in Shakespeare's time, people cheered, and screamed, and cat-called, and it was a much more lively thing on the stage. But now, everyone sits really quiet, God help you if you cough, you try to wait, and you think about your coughing, and then you don't think about the play, and you try to prevent your coughing. So all that transfers a bit. That same mentality comes when you're using slides. People think, oh my God, this is a pre-scripted thing-- how dare I intervene, and break into that.

So if your goal is to encourage students to question, it's harder to do that with slides. You still can do it. You can, for example, put questions on the slides-- and you definitely should do that you're going to use slides-- but the random, spontaneous character of your session-- the good side of that, is going to be minimized by the slides.

So this one was just to continue saying, OK, now we're going to leave these two on, and we're going to do the dimensions of each term. I have one, two, three, four, let's say-- four terms I want to talk about. I'll do the dimensions of two terms on this board, dimensions of two terms on that board, now I'll have all the dimensions

there. And now I can start, for example, doing dimensional analysis on this side of the room. And we'll eventually get to the Reynolds number, which is vr over nu. Once we know this guy's dimensions. And v, we know his dimensions, r the size of your sphere or something. So this is dimensionless.

Now you've got the Reynolds number, you've also got, say, drag coefficient, which is f over 1/2 [INAUDIBLE] v squared times some area. So this is also dimensionless. So now, you have two dimensionless things.

And then finally, the finale is--

So now, let's say by the end of the lecture, you get to the point where you've plotted the drag coefficient, a dimensionless thing, versus the Reynolds number, on a log-log scale.

And then you can talk about this, you can go back and you say, OK, well what is this? This is really interesting. It looks like it was constant. And then what happened? Well, you can go back and talk about that. And as you talk about it, the entire graph is visible to everyone, as well as the source of all the pieces of the graph, which is all the-- why is everything dimensionless? Well, you have it on these two boards. And what are the terms that you used? Well, those are all on there. So all of that is visible in one glance.

So that's an example of something that is hard to do in the slides. Now, it's not easy to get it right on the blackboard, either. You do have to plan. You have to plan by saying, what am I going to put on each board? And how am I going to structure the boards? But you can do that on your lesson plan, for example, on the back of the lesson plan. Say, OK, how many boards do I have? And what am I going to use?

And then, if you want to take advantage of the fact that everything is visible all the time, you generally don't want to use the up-and-down nature of the board. You just want to use two boards on each of the regions. If you push this up, and start writing on this guy, you're now OK, still. But then, when you push this up, and you write on here, you've covered this guy up. And yes, you've lost some of that advantage.

Again, you can plan it out, and do a trade off. But that is harder to do with slides.

Now, your question about how big you should write so that everyone can see, versus telling the whole story. I think it is important to try to tell the whole story. It doesn't have to be the entire lecture sits on the set of blackboards, but a coherent chunk of the lecture should sit on the blackboards.

You have two things you could control. One you can control is the writing size, and the other is what you write down. So this is a similarity between slides and blackboards, which is you don't want to write everything down. Because if you write everything down, then you say, well for example, did I write every single thing I said here? No, because I want the main ideas to come across. Every little detail that I say, that should be either in the notes, or in some book. But the main point should be on the blackboard at a level of detail that people can absorb.

It's the same thing with slides. You don't want to put everything on the slides. So, you can still write big, if you just cut down how much you write. And generally, that is more suited to what students need. Because, again, they are living in the dirt of what is this, and what is this. And you want to try to bring them up higher. So you don't want to spend a whole bunch of time on all these little guys. You want to try to bring them up higher, and put some high-level chunks onto the little bits that they have. So use a big chalk, write, large, just don't write everything. And try to fit a coherent piece onto all the blackboards. It doesn't have to be a whole lecture.

Although Feynman, at Caltech, when he gave the Feynman Lectures-- well, what later became the Feynman Lectures-- he did actually plan it so that he would start at one corner, and he would end all the way here. And I find that's too hard to do if you're also going to make the lecture at all interactive. For example, if you're going to have questions where you're going to have the students give answers, and you're going to write down the answers. Well, you're not necessarily going to keep all the answers for the rest of the class. So the goal of corner-to-corner, I think, is a bit too strict. But the general idea is sound.

Any questions about that before we take a break, and then go onto slides, and slide

design? Yes.

AUDIENCE: I just wanted to comment that also, a lot of students, if there are slides, and they're available online, they will just print them out, and not come to lectures.

PROFESSOR: That's true. A lot of students will just print the lecture slides, and then just think they can thumb through them, and understand the lecture. So that's partly-- you could call it the optimism of youth. That they don't realize how much they're actually not seeing, because they didn't actually come. They think if they just follow each slide, they've understood everything. But there's no way to put everything in a slide. If you packed a slide with everything you said that was worth remembering, or that was actually part of the structure of the argument, then it would become not a slide, but a book chapter.

And so, yeah. I think there is a reasonable argument that if there's a book chapter-- maybe they don't want to come to lecture if all you're doing is reading the book chapter. But slide, and lecture, are so different. It's sort of like, if you just take a few photographs of the blackboard, could you replace the lecture? No, but you're right, students do think that. So actually I don't like giving them handouts of the slides, if I do happen to use slides. Because it's really not a substitute for a lecture. It's an aid to the lecture, just like the blackboard is an aide to the lecture.

But what's important about the lecture is, what are you having them do in the lecture? And that's the reason they should come into lecture. Because in lecture, they're actually struggling with some stuff, and you've structured it so that they struggle, and learn. And somehow you have to convince them that that's the value. And it's hard, because of what you say.

Other comments or questions? One second, in the back.

AUDIENCE: [INAUDIBLE] But at the same time, I've probably taken at least half a dozen classes where every single word that the lecturer spoke, was present on the slide. And then it felt kind of worthless going, because you show up, you pick up the slide handouts, and you can read the slides during the lecture. You pay no attention to the lecture,

because he's not saying anything that isn't there.

PROFESSOR: Right. So that's sort of the worst of both worlds. So now, what they've done, is they've taken the constraints of the slide format-- because there's only so many words you can put on the slide, and make it even at all readable-- and often they don't make it readable, and I'll show you an example when we come back. And so then they've torqued the lecture to be basically reading out the slide. So now they messed up the lecture, and the slide still isn't really a good substitute. It's a huge problem.

I think the answer to that, is that if you're going to use slides, they're really an aide, but the students really need to learn how to read a book, or your notes. Or something that's actually a coherent presentation of the material. Yes.

AUDIENCE: So when you write something on the board to respond to a comment, and it [INAUDIBLE] some of your space that you could otherwise use to plan for the usual stuff. So when do you erase that comment?

PROFESSOR: That's a good question. So how temporary should stuff be? One way to do it is to think about the number of minutes each thing deserves. So that-- I like things like that to be on the board the whole time, if possible. And now it may be that, halfway through, I might reclaim that board if I don't have a choice. But I'd like that to be there for a while, at least, because that's really the main reason we're doing all this stuff. And what are we doing. So ideally, I'd put that on the side blackboard, and just leave it there forever.

Something like this, I would like it to stay there the whole time, so we remember. So this, I would mark as, "don't erase," if at all possible. So when I'm writing stuff down, I would know, how perishable is the material? That's the word I'm looking for. So suppose I ask people a question, like the wood blocks. OK, what's the frequency going to be? And we get a bunch of reasons. I think the reasons are quite perishable. After we write them down, and we talk about them, and then we reconcile everything, I'm perfectly happy to erase all the reasons, and just have the reconciled picture on the board.

But while I'm reconciling, I want them all visible. So then, what I would do, is I would try to have all those reasons go, say, here. I might cover that up temporarily. What I would do, is I would write the reasons here, and then do the reconciliation here. And then-- so let's call this Reconciliation-- so this is actually the picture that I would use for the wood blocks, which is this. And I would draw a bunch of arrows, and stuff, dot, dot, dots, and spring [? bogs ?]

OK. And now, I need to reclaim this board with perishable material on it. So now I reclaim the board. So this had reasons before. Lots of reasons. OK, and then, reclaim this. And I still have that reconciliation up there, and I have this board back.

AUDIENCE: So you think it is a good idea to separate the perishable things on one board, and then the more permanent things on the other board?

PROFESSOR: Yes. I think it is a good idea. That's a good point. I hadn't thought of it that way, but that is a good idea. Because that way you can reclaim the entire board back, and then replace it with more permanent things. Or, if something perishable is going to go back on it, put it here. And then, when it's done, to erase it, until a permanent thing goes on there. And then you move onto the next board.

So it does require some board planning. But what you find, basically, is the first time you teach the course, you wish you'd planned it more in the first lecture. But then you start to be more automatic about it. Yes.

AUDIENCE: I have a comment on the performance aspect of the board. So when you were writing these equations, and then as you went back in the vector symbols, and also when you're circling things, because if you're doing it right, the students are engaged. Their focus is [INAUDIBLE] chalk.

PROFESSOR: That's a good point.

AUDIENCE: It's as much of an interactive activity as they can with you writing on the board. Whereas with a slide, certainly [INAUDIBLE] a physical pointer, you might circle something, but then there's nothing there. A laser pointer's even worse, because

you're not actually touching anything. Even if you have an animation drawing, you're still separate from it. So I think that's a big advantage of the board. If their attention is at your chalk tip, then that's some degree of engagement with that action.

PROFESSOR: Yeah that's a really good point. So the point is that when I'm, for example, circling this, it directs people's attention, and then there's a permanent trace left. So you can, kind of, do it on a slide. If you knew you were going to do that ahead of time, you can make an animation that goes, circle. So you can do that, but it's hard. So one of the cures for that is this tablet, a kind of PC. So you can actually write on the tablet as you go.

AUDIENCE: Yeah. But even so, the thing is that you're still over there [INAUDIBLE].

PROFESSOR: I know.

AUDIENCE: [INAUDIBLE].

PROFESSOR: I think that's true. That, actually, we are together, doing this, on the object.

AUDIENCE: Yeah that's exactly what I was not saying very well earlier, was you can do all this, what you're saying, on a slide, just as well. When I do [INAUDIBLE] presentations, I do actually animate the circle. I find that that's the most intuitive way for me to do something. But it's not the same as actually drawing it yourself. It's not the same level of activity. And obviously you kind of have to use slides for [INAUDIBLE], but in a classroom you don't have to.

PROFESSOR: Right. OK, so that's what we'll talk about when we come back-- the difference being technical presentation, and teaching. And then we'll actually look at an example of slides, and we'll critique them, and I'll show you how to redraw them. OK so break for 10 minutes. We'll start at 10:18 sharp, by that clock. So you can set your clocks accordingly. And I will erase all this, and put up a slide that we're going to critique. And then we'll talk about technical presentations versus teaching. Because there's a lot of misconceptions that come from technical presentations. And therefore, people think we should use slides for teaching.

OK, so see in 10 minutes, or if people have questions during the break.

OK, so our next task is to figure out, if you are going to use slides, what should you do. And related to that point is, when are slides appropriate. People have the idea the slides are always appropriate for teaching, because they see them used all the time for seminars. So if you go, and give a talk at a conference, you go to a conference, most-- almost all the talks-- or at the department seminars, basically people now come with some form of slides. When I was an undergraduate, it was sort of transitional-- people came with overhead projector foils. And it was sort of shifting, from seminars used to be blackboard seminars, and then they shifted to overhead projectors, at least in physics. And now it's pretty much slides all the way through.

But there's a fundamental difference between seminar presentation, and teaching. And seminar presentation-- basically you're talking to people who are sort of experts. They may not be experts in that particular area you've understood. Probably not, otherwise they would have invited one of them to talk, instead of you. So now, you're the expert locally, on that local area. But in the broader area, you're talking to basically people who are already interested in, and are professionals in the field. And maybe some apprentices in the field, who are going to soon be professionals, like graduate students.

So your goal is not to slowly, necessarily, uncover one or two ideas, especially if it's a 10-minute conference presentation. Your goal is something like, here are the core, main ideas-- one or two points-- and here's something to show you that really interesting stuff is going on. And you should pay more attention to me is part of the goal of the seminar.

Now that's very different in teaching. In teaching, your goal really is to kindle some new thoughts in the student. And who are very different from a seminar audience. They are not professionals. Maybe they would like to eventually be, but part of your job is to kindle that interest so they would like to become professionals. So you have a very, very different audience, and generally much different time constraint. In a

seminar, maybe it's 10 minutes, maybe 15 minutes. Rarely, once you start getting well known, maybe you get invited to give a 50-minute seminar. But, teaching, you generally will have 50 minutes.

So your time is different, your audience is different. So just because slides are used so much for seminars, does not mean they should be used so much for teaching. You should really use them when you don't really have a choice, and when it seems like it's the optimal thing to do.

So for example, art history class. Now, an art history class, it would be fantastic to go to Sienna, and look at all the tapestries, and take the whole class with you. Now that's just too expensive. So, instead, you show slides. That's exactly why they're called slides-- they originally were 35 millimeter slides. 35 millimeter? Yeah, 35 millimeter slides.

So for something like that, yes, slides are ideal. And drawing the tapestries of Sienna on the blackboard is not even close to showing the actual pictures. So, in that case, 100% go with slides. Other cases generally go towards blackboards, but there are cases where, for example, there are no blackboards in the room, and you have to teach with slides. There's no whiteboard, either. Whiteboards are not as good as blackboards, but they're a reasonable substitute. But there's neither, and it's just slides. Or, yes--

AUDIENCE: Why aren't whiteboards as good as blackboards?

PROFESSOR: I find the markers always dry out, whereas chalk always works. So blackboard markers never quite work as well. And the other problem, just me personally, is that I'm sensitive to the chemicals in them. So I eventually just get a bit dizzy using them. So I don't like him for that reason. And there's quite a few people. I'm sort of the canary, so I'm more sensitive, maybe, than many people, because I have lots of allergies. But I think lots of people are bit sensitive to them. But, generally, I find the markers just don't work as well. And, also, there's very rare room has lots of whiteboards. Whereas many, many, classrooms have this many blackboards. When they replace them with whiteboards, usually it'll be one whiteboard. So then you're

back to many of the disadvantages of slides, which is that you can't get a big field of view.

But now let's say you are going to use slides. How do we make good slides? Well, one way to figure out what constitutes good slides, is to look at what constitutes bad slides. So this, here, is a horrid slide. So what we're going to do is, I'm going to show you how to re-write the slide. But first, let's figure out what are some of the problems with this slide. So, take a couple minutes with your neighbors. You can all see the slide. What are the things that just don't work about it? And there's many. It's a very competitive field. And I'll write some stuff down on here.

By the way, one thing is that the JIT, that I just actually shortened. It actually was, "Just in Time Learning". I've just shortened it to improve the typesetting, assuming that the audience knows what it means. So the original slide didn't have that problem. So I see you found lots of trouble. Give me one thing that's wrong. Adrian.

AUDIENCE: There's no message.

PROFESSOR: What do you mean by message?

AUDIENCE: What is the person trying to tell you here. You have to infer what the person is trying to tell you by analysing it yourself.

PROFESSOR: OK, no message. So, the reader, the viewer, the student-- this was actually used in a class, never mind where, but it's not here. Yeah, what is the teacher trying to communicate? So Jean-Luc Doumont, if you saw him during IAP-- he has a great way of talking about what's a message, versus what's information. So the message-- so information, that's what that slide has. It has lots of information. That's the "what." Message is the "so what."

His native language is not English. I wish I could come up with things like that in other languages. I think it's fantastic, because there's lots of "what." Well, 12% said Just in Time Learning-- JIT Learning-- was a bad idea. But your question is, so what? And there's no answer to that question. So there's no message. Yes.

AUDIENCE: So a counterpoint to that would be, this is documentation, this isn't propaganda. Right? You don't want to say, this is what you should all think about this data, instead of, look at the data yourself, and make your own conclusion. Presenting the data in an accessible manner is a different issue. But I don't know if I agree with this, "so what" idea.

PROFESSOR: And some of that is that, yeah, definitely in a seminar, you lean much more towards the "so what." And you would put in the "so what," really first. And in teaching, maybe you start with the "what," and then you lead to the "so what." So, for example, the wood blocks. Here's the "what--" what do you think is going to happen? And I haven't said, "so what," really. And then we talk about a whole bunch of ways of analyzing it, and then we finally lead up to the "so what.". But at some point, you do want a "so what."

So, yeah, without seeing the entire lecture, it's hard to know if they ever gave a "so what." But I can tell you that the succeeding slides just went on to other topics. So it wasn't that they were using that to develop the point-- what do you think about Just in Time Learning, or how should we analyze Just in Time Learning. They just moved on. Yes.

AUDIENCE: Going back to your art history example as a good use of slides, that doesn't have anything in it that gives you "so what." It gives the presentation of information, and then the discussion of it is what gives that. So I don't necessarily think there's something inherently wrong with giving information on a slide, and having not answered the discussion in the slide.

PROFESSOR: It's not inherently wrong, and that's a good point. So the art history one, it's sort of a different use of the slide. So there, it's really like you're bringing in a prop. So the cones, these pyramids themselves, didn't have a "so what." They only got a "so what" as we used them. So it's the same way with the art history slide. It would get its "so what" in how you discussed the slide.

But here, the slide is really the alternative to the lecture-- to the blackboard. If you've gone to slide talks, or slide teaching, which aren't art history. I think art

history is really a separate example. It's, I'm telling you stuff, I'm telling you stuff, I'm just telling you in a way that you don't really know what I'm telling. Like, I may be telling it to you verbally, but the slide doesn't match what I'm telling you. Sorry, you're next. Go ahead first.

AUDIENCE: You may have already said this, but is this slide supposed to be for the students, or is this for a faculty meeting?

PROFESSOR: No, this was for a course about-- what was the course about? It was a computer science course somewhere. Maybe it was a discussion of a-- no, it was a computer science course, or a teaching course. I forget exactly what course it was, but it was from a particular course. So it's a slide used in teaching. Yes.

AUDIENCE: That partially answers what I was going to say. This material doesn't belong in the lecture in any course, unless it's a course on teaching. The surveys are filled out, so they benefitted the lecturer so that they know what to do when planning and running the course. The students don't need to know what the results are.

PROFESSOR: I think it wasn't for the course itself, it was for the students in a teaching course, is what I think it was for. And either way, whether it's for a seminar, or for a teaching course, it has the same problem, which is you don't even know what to think about it. You just have a lot of data. And there's no integration. OK, so that's the no message-- the "what," versus "so what."

What else is wrong? Yeah, Wendy?

AUDIENCE: The data is just terribly organized. [INAUDIBLE] One thing is that there's bullets under bullets. By the time I get to [INAUDIBLE], I'd rather skip, I've forgotten [INAUDIBLE], I don't remember what we were talking about.

PROFESSOR: Right, so the organization is ghastly.

AUDIENCE: And another good comment, which is that the numbers of the percentages are not organized in any way. They're not going from highest to lowest, or lowest to highest. So you've seen, maybe 52, you're like, I assume this is going in descending order,

and then things get flipped around.

PROFESSOR: Right. So the percentages are kind of random. It's sort of like the "what." To organize it towards the "so what," you would put some theme in it. But there isn't any, or none that's obvious. And the typesetting, yes, is related to the organization. The typesetting is a bit off. Yeah.

AUDIENCE: So related to that, [INAUDIBLE] the numbers and the questions are given completely equal footing, because the numbers are organized, [INAUDIBLE]. And so the numbers just follow better to worse. I'm sorry, the answers to the questions are organized from better to worse. [INAUDIBLE]

PROFESSOR: OK, so then it comes out. OK.

AUDIENCE: And then it comes out, but that's not [INAUDIBLE].

PROFESSOR: So the Likert scale isn't obvious. The Likert scale is the better-to-worse scale of how much you agree with this statement. Right. So you're saying, also, the answers have equal prominence to the questions.

AUDIENCE: Equal prominence to the percentages. You have no clue what's organizing the information.

PROFESSOR: Right OK. So the emphasis is random. Yes.

AUDIENCE: So [INAUDIBLE] so she suggested [INAUDIBLE] or [INAUDIBLE].

PROFESSOR: OK, so it's not visual. A pie chart, or a histogram, or something would help you see much more. So that's one of our principles, right, that your perceptual system is so much smarter than your symbolic processing system. So you're actually slowing everyone down, and making them much dumber, by forcing them to try to extract--basically build a mental picture which you could build for them. Yes.

AUDIENCE: I'd say there's too much.

PROFESSOR: Too much. So what do you think is too much?

AUDIENCE: All at once, you're getting lots of text, and it's all these different things. Too much [? given ?].

PROFESSOR: Yeah, it's too many chunks. It just overloads you. You don't relate it to the lack of messages. If there are messages in there, there are too many messages. You don't know what's important, and what to pay attention to. Other problems? Yes.

AUDIENCE: Format switches midstream.

PROFESSOR: Where?

AUDIENCE: At the bottom, the last question.

PROFESSOR: Oh yeah. You're right. OK So the format.

AUDIENCE: [INAUDIBLE].

PROFESSOR: Right. It's sort of related to too much. Right, I tried to put too much on my slide, and I really tried, really hard. So the format changes at the end, right, so they could fit everything onto one slide. Yes.

AUDIENCE: Extraneous use of bullets, colons, [INAUDIBLE]. Not helping.

PROFESSOR: So a random use of colons and bullets. And it's not clear how those actually help. Other problems. Yeah.

AUDIENCE: Is that all bold?

PROFESSOR: Yeah. I think it is all bold. So everything's equally emphasized. So all bold. So again, it's presenting all the information, right? It's just you don't know what's important-- what's the "so what." Yep.

AUDIENCE: The numbers are very far away from the text, so by the time you get over there, you don't know.

PROFESSOR: Right, it's sort of like a table of contents. And that's OK, for a table of contents. It's not ideal, but there are ways of doing table of contents that don't have that problem.

For a table of contents it's OK. You don't need to sort of get the entire table at a glance, right? You just want to know where chapter five begins, and you just scan across, and you go there. Whereas here, you can't match the things. You want to try to match it all together, and you can't, because the numbers are so far away from the text.

AUDIENCE: I don't know what PI means.

PROFESSOR: Sorry, that was my fault, too. I just tried to shift it. Peer instruction. Yeah, you're right, so there's a lot of use of acronyms. Yeah, so the JIT, and the PI were my contributions to it. So maybe I made it a little bit worse. Yeah.

AUDIENCE: So how would you do this on the blackboard, instead, if you had a chance?

PROFESSOR: So this one, actually, if I were going to present this, I would either draw the thing I'm about to show you, or I would use a slide for it. Either way.

AUDIENCE: A slide with what?

PROFESSOR: I'll show you what the redrawn slide is. OK, so now let's redraw the slide. So I think the slide that I redrew-- I'll show it to you-- basically answers most of these objections, though maybe not all. I think most of them.

So what I'm going to show you is what Michael Alley calls the Assertion-Evidence design for slides. So Michael Alley, I'll write his name down. So Michael Alley, and his book is called *The Craft of Scientific Presentation,* I think.

And this is to get around many of these problems. So the idea is, first of all, so related to what Jean-luc says, talking about messages versus information, each slide should have one message-- one assertion. So that's the assertion part of the slide. And the body of the slide is the evidence. And it should ideally be visual evidence, because of all the reasons we talked about for visual evidence. So here is an example of that. There.

Is this the entire slide? No. This is just one, basically, third of it. But you can redraw

the rest of the slide, with two more slides, this way. So this is one slide, with one message-- most students like in-class concept tests. If that's the point you're trying to make. The problem is, it's hard to redraw slides with no messages. Because you don't actually know what the message was, so you have to sort of infer it. But hopefully the author could actually infer it, and redraw it themself. So here you have to play author, and I guessed the message-- most students like in-class concept tests.

The presentation is here, with a pie chart. And you notice all of the tags, the "I like them", the "please skip them," "I dislike them." They're all right next to their percentages. And then, what's color used for? There, color is used to emphasize the like. So the green, and the light green, are both categories of like. As asserted by the author. I mean, you could say, well, no "enjoy and learn from them" is the only category that matters, "like" isn't strong enough, or really you shouldn't lump them together. You can have those debates.

But what the author-- the teacher-- is trying to say, is that most students like them. And you can see it just at a glance, because most of the pie chart is colored in. So this solves most of the problems. First of all, you don't have the ghastly typesetting that you have here. The typesetting here is just horrendous, this is sort of typical PowerPoint typesetting. The alignment is nonexistent. There's random alignment lines everywhere. If you look, for example, at the way top, the yellow bar doesn't align with anything else. The left edge of it just doesn't align with the bullets. The open bullets are just random. It's just a big mess, as you pointed out.

So here, just get rid of all that. And you can do this with any program. You can make your figure however you want. You can put one assertion at the top. So now assertion, another synonym for that is "sentence headlines." So you want your title of your slide to be a sentence. If you're not writing a sentence, you're probably writing a topic. You're just mentioning something-- you're giving them "what." To give "so what," you really need a sentence. So fit a sentence of one or two lines there, and then, give visual evidence. Yes.

AUDIENCE: To sort of play devil's advocate, I mean, I agree [INAUDIBLE], but the advantage of having all the information on one slide is you can see the different things, and see the different conclusions.

PROFESSOR: If you could actually see them. The problem is, you can't actually see all the conclusions. I agree it's nice to see all the conclusions at once. So to do that, what I would do is, I would make-- I think there are really three messages here-- one for each of the questions. So I made a slide for the first one, which is about the concept test. You'd make another slide for the Just in Time learning, another one for, do lectures cover too much material. So now you have three.

And now, basically you want an overall message of, overall these instructional changes were well liked. Then you could have one summary slide, which just lists those three points. And with maybe three small pie charts, to remind people of each pie chart, to fit it all together. But to try to pull it out of that, the people won't actually get the three messages. So you have to guide them towards it. Hopefully you can use this for your seminars as well, not just for your teaching. This works for teaching, as well seminars.

Now, how would you actually put this into practice, in a teaching example? So that's what comes up next. I'll show you a mathematical example, which you could do on the blackboard, or I sort of optimized it so you could do it on slides too. And we can see how that goes.

OK, so here is just the comparison, side by side, of the two slides. Just at a glance. I don't actually mean for people to be able to read the words, just to see that one has enough information that you can get a point, but doesn't overload you, and the other is just a rat's nest.

OK, so then the mathematical example-- actually, a statistical mechanics example as well-- is the log of n factorial. So we're going to approximate the log of n factorial using pictures. Now why n factorial? Well, what is n factorial? 5 factorial is 5 times 4 times 3 times 2 times 1. Why do we care about it? It's the most important function in statistical mechanics when you're counting objects. And it shows up in probability

theory all the time. And statistical mechanics has a lot of particles, so the n is big. So we'd like to approximate how big n factorial is, because it's so big we take the logarithm.

OK, let's see if we can approximate the logarithm using pictures. So log of n factorial is the area of those rectangles. You can see rectangle for log 2, log 3, log 4, log 5, log 6, and log 7. And log of n factorial is just the sum of all of those. Say, 3 factorial is 3 times 2 times 1, so log of 3 factorial is log of 3, plus log of 2, plus log of 1. Log of 1 is 0, so all you have left is those rectangles to add up.

OK, so now let's add them up, approximately. So the area under the curve is your first approximation. So the curve is just log k. So let's see what that is. Well, OK, that's just the integral of log k from 1 to n, from the lower limit to the upper limit. So that we can just do symbolically, you get n log n minus n plus 1.

OK, now the error. Where does the error come from? Well, it comes from the protrusions beyond the log n curve. So there you have the protrusions. so we'd like to add up all those protrusions. Well, how are we going to do that? Each piece is almost a triangle. So let's just straighten out each little piece of log k curve, and make triangles. And now, it turns out they're much easier to add up if you double them, and make every triangle into a rectangle.

OK, so now I'm going to stop here, and see if you can figure out how to add up all of those pieces. What's the sum of all of those shaded regions? Take a minute and check with your neighbor.

OK, when you see it, raise your hand. Find someone around who sees it, if you haven't seen it, and check with them. Because it is fun to see. I don't want to spoil it unnecessarily.

Here's a little hint. So what you do, is you hold your hand at the right page, and you whack all of the rectangles, and they slide across, and go psssssh, and stack, and form the last one. So that means the sum of all the corrections, times 2, is the last rectangle. So log 7, or log n, is twice your error, roughly.

So now you just combine the integral, which is the piece under the curve, with the approximated protrusion, and you get that for log of n factorial. So let's see. So that is actually very close to Stirling's formula. Let's see how close it is.

Well where's the error? Well, the error comes from when we straightened out the pieces of the log k curve, and made triangles instead of the funny-shaped region. So the error is those shaded guys, which is not very big. And most of the error happens low down, so if you just corrected for that, pretty much it would all go So here is the total error. Here's an example. The picture method, so we get 7 factorial, gives you 8.594. The exact answer for the logs of 7 factorial, 8.525. So it's an error only 0.07. So all of this just adds up to 0.07. Which ends up being a 7% error in seven factorial.

So the moral of the story is that pictures can help you approximate log of n factorial, and here is your approximation. So one of the most important functions in statistical mechanics. 95% with pictures, and one tiny integral. OK, now. That's an example or something you could do if you wanted to teach it using slides. You could easily do that on the blackboard, and normally I teach it on the blackboard. But I made this as an exercise for myself to say, OK, well suppose I have to teach it with slides, what would I do?

And you notice here. So when I first drafted it, this slide was missing. And I went from here to there directly. And then I thought, oh, actually-- so this is about the interactivity question-- oh, actually I'm depriving people of a chance to think about something, and realize it. On the board, it's really easy to pause. You just put the picture up, and you wait. And you say, OK, what do you think? And then you start drawing stuff. So I thought, OK, well you can actually simulate that on slides, too. So I put the intervening slide in there, so that people had a chance to stop here, and think about the result before we continued on to the solution, where it adds up to the last guy.

So that's an example of basically somewhat interactive slide teaching of a mathematical idea. Yes.

AUDIENCE: So why didn't you animate a slide [INAUDIBLE] with boxes to take advantage?

PROFESSOR: That's a good question. Why didn't I? Actually, because, A, I didn't think of it, but it's a good idea. I should have probably done it. The problem is that I'm showing it as a PDF file, rather than through any program. So PDF animations-- I don't know if PDF has animations in it. It probably doesn't.

AUDIENCE: [INAUDIBLE].

PROFESSOR: Yes, that's true, it's sort of against the purpose of PDF, which is a stable format. Yes.

AUDIENCE: I actually thought this entire presentation was really clear, and would be just as good as if you did it on a blackboard. Because it was interactive, slow, had pacing, the suspense of having us ask the questions. So I think one of the major reasons why I would be opposed [? to teaching ?] in this way, is just because it takes you more time to create the slide. From my own experience, it takes a long time to make really good slides, just fiddling around with [INAUDIBLE]. So I think if you could spend all the energy we're spending on slides instead on [INAUDIBLE]--

PROFESSOR: That's a good point.

AUDIENCE: --or whatever, I think that might be [INAUDIBLE].

PROFESSOR: I think that is a really good point. And I hadn't thought of it until you mentioned it, but you're right. It took me a long time to make the slides right. To do slides well, you have to really think about the visual presentation, make everything visual, you're making a lot of diagrams. There's all kinds of little tweaks. Like, I made sure that all the diagrams are exactly the same size, so that when you flip from slide to slide, you don't get a shift.

So all those things, you don't have to worry about on the chalkboard. And yes, I would advise people, just as you do, to spend that time thinking about your teaching, and where you're going to put the interactivity in. And do it on the blackboard. So this is something where, with a lot of effort, the slide reaches to the

level of the blackboard. But with colored chalk, and lots of blackboard, the blackboard is just as good, and quicker. And the blackboard has the advantage that this could be two blackboards in your class. Say it's a class about visual representations, and you have two blackboards for this thing. The middle two blackboards for yet another example, the end two blackboards for yet another example. And you have all of them at once. Yes.

AUDIENCE: Last time I taught a class where I used all slides, and when I put the amount of time that, things like you put into this, to make them all so they perfectly line up, and the animations were really helpful and everything, just creating the slides probably took half the overall time that I put into the class. But I think the one advantage was I was able to use printouts of those handouts as class notes. Which I handed out after the class. They didn't have them during class. So that's the only advantage, is you can reuse all of these [INAUDIBLE].

PROFESSOR: And that's exactly true. So all these nice figures, we did it for this class, and for a seminar on making slides. And then I used them verbatim in my *Street-Fighting Mathematics* textbook. So basically, to make good slides requires making something pretty much publication quality. And then, you do have something publication quality, but maybe the first time you teach it, that's not where you want to be spending your time.

There was one other point that was raised in an email beforehand, which is, in Jean-luc's paper, he mentioned that he uses less popular alternatives to the Microsoft software for making slides. So, yeah, I highly do not recommend using Microsoft software, because it's not free software. And it's, I think, unethical to use non-free software. Free software meaning freely licensed, so you change the source code, view the source code, make your own versions, do whatever you want. And it's none of that.

Second, it's all proprietary formats. So you're encouraging other people to use proprietary formats. No one has fully debugged, and decoded, all the formats that Microsoft uses. So you should use open formats at least. Now, you could use Open

Office, but the problem is Open Office, the whole model of the way it does slides is kind of yuck, because it's just copied from the Microsoft way.

So actually I prefer-- maybe it's because of my computer science math background-- what I prefer is to program all the slides. So let's see. [? Log.tech. ?] Where are the-- yeah. OK. So I actually write in [? Tech, ?] or version of [? Tech. ?] And here is your title of the slide. And I can change the formatting later.

AUDIENCE: Maybe that's what took you so long.

PROFESSOR: Maybe. Maybe. But the thing is, you can't make publication-quality stuff otherwise. So if you're going to actually do a good slide, basically you want to do that. Otherwise, I don't think people should bother. And mathematical typesetting is just ghastly unless you use [? Tech ?].

AUDIENCE: [INAUDIBLE].

PROFESSOR: Oh. And I don't think you can make it look as nice. And I'm speaking here about Open Office, and it's probably a clone of rubbish that it replaces. The mathematical typesetting is just not as good. And so for technical presentations, it's just not as good. So now, making the figures, I have the same philosophy. So the figures I actually program as well. Where is that fig [INAUDIBLE].

So here are the figures. So this is a function that draws logarithm graphs. And then I tell it which parts of the graph to put in. So that's how I do the-- you draw all the lines, you drew all the pieces. And then here I call it with different arguments, and I get different figures.

So I'll put all the source code up for you guys, so you can see an alternative way of doing it. And some links, so you can try it yourself. And some templates. But it's not for everyone. Though it is a public format. It produces PDF, which is a public format. So I actually highly recommend it for those who have at all some programming affinity.

AUDIENCE: [INAUDIBLE] programs that ends up as PDF format.

PROFESSOR: That has the advantage of PDF, which is good. So I do recommend presenting things as PDF because you can view it on anything. It's just, you have the problem of, do you have good mathematical typesetting. And that's hard to find, except [? in Tech, ?] basically. That's the only thing that does it right.

OK, so if you could just take one minute, fill out the sheets. I'll answer the questions next time. I'll have office hours as usual. We'll meet outside that door. And then we'll go to the cafe area, and have a chat at the tables, as long as people have questions.

OK, so, the moral the story is use the blackboard if you can. Use the big visual field. But if you're going to use slides, Assertion-Evidence. Sentence headline. Visual evidence. One message per slide.

Answers from lecture nine, to questions generated in lecture eight. Audio quality for this video is poor due to technical difficulties.

PROFESSOR: [INAUDIBLE] is I'd like to go through the questions from before. There's one question from the time before, which is, could I get the reference for the works that said, there's a difference between telling people that they have intrinsic abilities-- saying, oh, you did that because you are really smart, versus, oh you did that because you tried really hard. And how those two ways of talking to people-- and children especially-- produced different interests, and confidence in trying new problems.

I mentioned that that work was done a lot by a Professor at Stanford, in the Psychology Department. Could I get a reference for it? The next update of the website will have the reference, with the reference is Carol Dweck, D-W-E-C-K. And she's written a ton of books, and papers. But the one that [INAUDIBLE] popular, [INAUDIBLE] is called *Mindset.* Which is a really, really fascinating read. So that will be on the website.

OK. First question was, you mentioned many times, problems that are PDF-- pass, D, or F, where P is made a decent effort, D is made an indecent effort, and F is

didn't make an effort. That's great, but then how do you balance that with the fact that exams become high-stakes, hit-or-miss performances that completely determine grades.

I don't use the exams that way. I give exams, they're balanced with the problem sets. The problem sets are PDF, and if you do P on all the problem sets, that contributes a large part of your grade, towards getting an A. So there's no necessity to make the exams all or nothing. Problem sets still account for quite a bit. [INAUDIBLE] It's just you're not forcing the students to get every last T, and dot every last I, which often means going through [INAUDIBLE] to try to do all that. Instead, you're saying, look, I want you to try to learn something big, important. If you take responsibility, then, you get a reward for that, by saying, OK, that'll help your grade, too.

About slide talks. Were there any questions about slides talks versus teaching, versus blackboards.

So one of the papers says that the best usage of slides is as a completed form that's understandable without the talk that comes with it. Is that for a research talk?

Yes, for a research seminar, that's what you want. You want two channels. You want the auditory channel, and the slide channel, or the visual channel-- whatever's on the blackboard, however you do it. You want them to stand independently. So if people are deaf, and they just see the slides, they get something out of the talk. And if they're blind, and they just hear your speech, they get something out of the talk.

That's, I would say, less true for teaching. The slides tend not to be so, message, message, message. You may develop a point, build up a bit of suspense, and then give a final message. So there's more interaction that happens from the lecture, generally, when you're teaching, than in a research seminar. So those are somewhat different. But generally, you do want your slides, or your blackboard work, to somehow stand independently. Although I've just violated that principle right there. This is meaningless unless you've heard what I said. But as I said, it's not an absolute rule. It's just that there's tendencies that are different between

[INAUDIBLE] talks, and teaching.

What do you do if you're assigned to a classroom with a bad blackboard situation. In other words, not like this. This is fantastic. It would be even more ideal if there was a slide [INAUDIBLE]. But what do you do if you go to a classroom with, for example, just one whiteboard, or just one or two blackboards?

Then you have to work harder. Then you have to plan even more carefully, how are you going to use the blackboard. And be more telegraphic. Put coarser details on the boards, not every single detail. Use the notes more. So you optimize the constraints that you have.

Should you only use the front half of the room. Suppose you're in a room which has blackboards all around. Should you only use the front half of the room?

Yeah, I generally try to use only the front half of the room, because people can look at that, and glance out of the side of their eye at the side, and then, the front as well. The back forces people to turn around, so they're much less likely to use it. So it's sort of like putting something on the ceiling. [INAUDIBLE] never see it. So generally, yeah, I use the front of the room, and [INAUDIBLE] the side.

Should all slides have a "so what" element, or is that only for research talks?

Definitely for a research talk, all the slides should have a "so what," so people know what the point is. And ideally, for teaching, you should have two. Now, last time, I didn't mention one of the fundamental benefits of putting a "so what," an assertion, in every slide. So that was the idea.

So the slide title is the "so what.". And then here is the evidence, maybe a picture, or a graph. Some kind of, ideally visual, evidence.

So what's the advantage of doing that? It's not just for the audience-- it's for you, as well. What you do, after you make your series of slides, with your sentences, your "so what." You extract just the sentences, which is easy to do if you're using a program [? like Tech. ?] You just [INAUDIBLE], just the titles. However you do it.

You make a list of sentences. And then you see whether the sentences flow.

With a sentence, you can tell, very well, because whether your presentation, your teaching, your seminar is well organized, if it herks and jerks, if sentence one and sentence two seem to have nothing to do with each other, there's no transition between them, well, maybe you need a sentence one and a half, a slide that goes in between. Or maybe sentence two belongs down here, next to something that relates better. So you can see not just at the level of the individual slides, but at the level of the entire presentation, whether there's a thread that goes through. And if you remember, one of the principles of good teaching is having a good story. So this helps you make a good story.

When you're teaching a class that has expectations for teaching lots of material, how do you reconcile your desire to teach the important things really well, and keep a reasonable pace?

Some things aren't really reconcilable. Classes that, for example, say, OK, we're going to go through the 1,600-page textbook, there's really not much you can do to help that. And students are just hosed. But try to avoid that, mitigate it. Sometimes it seems like, just out of habit, everyone does that 1,600-page textbook. But you could find out, what are the actual requirements? What do people need for [INAUDIBLE]? If may be a lot less. It may be that a bunch of stuff was just put in there historically, and could be taken out. So you might have some freedom to reduce that. The other thing is you put more stuff in the notes, and you give the higher-level ideas in the lecture.

Can I put my slides on the course web page? Yes, I'll do that, with the reference, on the next update.

What about having slides that scroll rather than flip? This was a suggestion to avoid the problem I mentioned of signal overload, where you fill up the short-term memory with a slide, and then you've forgotten what's on the old slide. And so, [INAUDIBLE] too small to remember the whole slide. So what about having slides that scroll, instead of flip.

And this may be a critique of the PDF format, which organizes things in [? pages. ?] I think it's actually not a critique of the PDF format, it's just a critique of the PDF viewers. So if you have a PDF viewer that can scroll, which many can, you could actually use that. The problem is that screens are not big enough. That's really the fundamental issue. So if this slide is taking up the entire screen space, when you scroll it, stuff goes off these screens, and gets replaced by new stuff. So that problem is really hard to work around. What you really need is multiple screens, and multiple projectors.

Many questions asked, what do you do if you're in a room with a bad blackboard situation, where you just have one or two blackboards. Well, almost every room has a bad slide situation, because you only have one slide projector. So you only use a small part of the room. So that's the really fundamental problem. And if you could get around that, it wouldn't really matter so much whether the slides scrolled or flipped. You'd put one over there, one over there, maybe one over there. Of course now [INAUDIBLE]. My guess is that the t prepare is probably proportional to n cubed, or something like that. Depending on the number of slide projectors you have to deal with. Because you have to do all the coupling of [INAUDIBLE] n squared [INAUDIBLE]. You'd have to do all the coupling between all the slides, and it will probably take you twelve hours for every lecture that you give, of one hour. Which is kind of [INAUDIBLE].

Do I think the video camera for OCW impacts the style of my lectures, blackboards, pacing, et cetera?

If anything, it probably improves it. Because I'm a little more conscious that I write clearly, and maybe it improves my dress code a bit, because I make sure to wear a tie. But other than that, it doesn't really affect, too much, what I do. And I usually forget that it's even there.

It's much easier to write equations [? in Tech, ?] and then copy and paste them into a presentation, than doing the entire presentation [? in Tech. ?]

Actually, I disagree. This is a case of start-up costs, versus running costs. So there's many examples of that, here at issue. It's actually a general principle worth knowing, because you can analyze lots of stuff.

Another example of this principle is, suppose you see a book that you really like, that's available in print, from publisher n, and there's also a PDF file online. Well, you could just print it out and replace your printer. Or, you could buy the thing from the publisher. Now, unless the publisher's a total thief -- unfortunately, many of them are, but many of them aren't-- it's usually much better to buy it at the bookstore, because it's much cheaper, than to print it on your laser printer, get all the paper trimmed to the right size, and have it all bound. So the running cost for you to do one book-- you have no start-up cost, you just do it. There's no fixed amount you have to pay, no matter how many books you do. But there's a running cost, and your running cost is pretty high.

Whereas the publisher, they have a big start-up cost. What they do, is they make all these plates, they take them to a PDF file, [INAUDIBLE], they make all these metal plates, and they ink the metal plates, stamp it onto the paper. So they do all that. That's a big start-up cost. But their running cost is much lower. They're much more efficient printing, per book. But it requires all that start-up cost. So there's a contrast between book publishers and you.

So it's the same thing, actually, with doing [? Tech, ?] versus doing, say, regular word processing. With [? Tech, ?] there's a lot of start-up cost. No doubt about that. It's not what most people are used to, you end up programming your documents. And so, if you're only making one document, if you only write one letter in your life, no question it's faster to write the letter. Your have lower running costs. You don't have to worry about the start-up costs if you write it using a word processing program-- Open Office, for example. You just type, and you make it look like you want, and just spit it out.

But, if you have to write 50 letters that all have a roughly similar format, it's much better to get the template. You pay the start-up cost once, learn [? Tech, ?] learn

some kind of program template. And then, you just enter the blanks into the template. The text, dear who, the address, and all that. [INAUDIBLE] formatting, that's all dealt with once. So you pay start-up costs, in return for lower running costs.

And that's basically true of lectures, too. Once you have all your templates ready, it's much faster to do everything [? in Tech, ?] or in some kind of programming, text-processing system, rather than in a word processor.

The problem is that, because of the start-up costs, [INAUDIBLE] lecture the day before, or two days before. Because of the start-up costs, you always say, well, I could learn [? Tech, ?], and do this properly, and it would save me a lot of time later, but I don't have the time right now. And then you end up paying the higher running cost to do it some other way. But each time, before each lecture, it happens again, over and over and over again And you would have been better off [INAUDIBLE] actually paying the start-up cost.

So, to that end, I will put my templates up, so other people can use them. So you don't have to pay so much start-up cost, and you can just take them, and use them for your own [INAUDIBLE].

So I think that was the main questions for this time. Any questions that have been created since then?