PROFESSOR: So today was a little different than yesterday. So I thought it would be good for us to just sort of recap what happened. Let's go back to the sixth graders visit. Thank you, Jamie, for prepping them for it. I woke up this morning. I was like, I didn't prep them for it. If I were them, I would have been super overwhelmed. I'm a terrible person.

Was that helpful to you? What did you guys think about that whole experience?

AUDIENCE: I immediately knew that whatever ideas I had yesterday was completely off. And wrong. 180 degrees in the wrong direction.

PROFESSOR: I mean, do take what they say with a grain of salt. Sixth graders don't always know how to articulate what they want. In a pitch, robots always sound cooler than food decomposing. But there is a way to make that awesome, if that's really what you're interested in. So as with everything in this class, the feedback is ultimately for you to decide what to do with it.

Was there anything surprising that came out of the first hour?

I know it's hard to put yourself back into that perspective. That's what I meant yesterday with the whole thoughtfulness quality. One of the values of the class is being able to take yourself out of the perspective that you have here.

We were shooting science out loud during the first season with two grad students who are in AeroAstro. They were making a video about how engines work. And we were discussing one of the scenes that they had planned was to describe a turbine engine. And I'll go into this more during Thursday's lecture. But one of the students was trying to describe that it's the turbine blades that push the air forward. And we he was thinking to do an animation with it. And we thought, this is really complicated. I couldn't understand what he was trying to say.

And finally, the other student who was there was like, oh, well there's one Boeing 777 in the

hangar in that building over there. Like, is it worth filming with it? And just sort of that mentality of like, you have access to an actual turbine engine. And it didn't cross your mind to film it. And they were awesome to work with. And you know, that the whole day of shooting was actually really fun.

But the ability to take yourself out of the things that your experience all the time, or take for granted. Creating that window for people who don't necessarily have access to the world that you live in is surprisingly difficult to do. And hopefully the first hour of classes sort of helped you orient into that new perspective.

But I know that's a challenge for me a lot of times is, I don't think people are going to think this is super interesting. And it's not the content that's not interesting to people. It's just the delivery. How you package it up.

PROFESSOR: I think that getting the right angle for-- like, some of you had really broad topics. Right? And the thing that's really hard is that there are so many things within that topic that could be really interesting. And like the food decomposing thing. Actually think there are a billion really cool topics in there that could be really fun. Like cheese is technically mold. And why is some mold good, and some mold bad. Right?

And there's some really cool things like that can do about that. And getting back to microbiome things, or bacteria, or there's some really cool stuff in there. And just like every one of your topics that you guys brought up. There's some really cool little pieces of truths inside of there. And the hard part is figuring out how to give-- I mean, this is what writers do, is having the right angle to your story. Right?

And so, many-- I think all of what I heard, I heard many your ideas. I'm like we're in the right zip code, but we haven't quite narrowed down the right building yet. Right? Or the right street. And for the hard part is figuring out within the topic of shipbuilding, or within the idea of hacking, or building a game, what is that little cool angle that you're are going to take to make it really exciting and interesting? And snare enough and focused enough and that kind of thing that makes it really interesting.

Because I do think actually that lava sounds cooler to like a sixth grader because they're like, lava! That's cook. Right? But the food one. I'm not ready to give up on that yet. Like, I think there's a lot of cool stuff in there. And the hard part is figuring out, really narrowing down your

story. And then figuring out which one has more meat to it.

PROFESSOR: I mean, I think it's a very beautiful story, actually. The whole idea of material objects on this earth transforming in a way that's tangible to us. And maybe that's just like super romantic sounding. But I do think that there is-- I loved what Chris said yesterday about making not just the unfamiliar familiar, but making the familiar unfamiliar. And I think that's a lot of what of what VSauce does. And I think that's a lot of what Veritasium does is it's taking the things that you see, and taking the world that you're used to seeing, and showing you a new lens at looking at it.

And I know that sounds very abstract. And I'm sure that we've thrown out a lot of things to think about that you're not maybe quite sure how to implement on a practical level. And I promise that that's what we're going to hit next. And once you guys write a script tonight, or just try writing it, it'll help you a lot to sort of understand how to implement these things practically speaking.

So worry. I am aware that that might be a frustration that you have.

PROFESSOR: I wonder if we have a little time today to give them more time to flesh out their ideas a little more.

PROFESSOR: Oh, yeah. Absolutely. So I was originally planning on showing you guys a couple hosting case studies. But if you would find it more helpful to just maybe brainstorm script ideas--

PROFESSOR: I feel like that's where they are right now. If you think I'm wrong. But I feel like today made you think a little more. And now before you go home and have to really implement some idea, maybe it's worth really making sure each of you know what you want to do before. I don't know. What do you guys think? I'm feeling some anxiety right now that like it would help to flesh out your ideas out a little more. Yes.

PROFESSOR: OK. We will totally do that. I did want to show you something. Because for me personally, it's hard for me to hear abstract level ideas. And I just need to see an example to help understand that. So. And again, I'm not saying that the way I necessarily do things or the way George or any of the teaching staff do things is necessarily the best way. Because again, best is not really been defined.

But this was a video we did during second season. And it was the first biology video that any of us had worked on, which I was really excited about. But it did present these challenges of like

how do you create a visually interesting video that's worth making as a video. Because again, I mean, I think asking yourself, like why do I need to make an animation about synthetic biology when I could just create a cartoon about it? As Chris was saying, visual elements, just pictorial representations of things are very, very engaging.

We really were asking ourselves, like what's going to be the visual purpose of her explaining what basically became a little bit about systems biology, actually. And one of the things that we really fixated on, which is an idea of hers, was a metaphor. And so this is about a four minute long episode. Would you guys mind if showed it? And then we can workshops scripts. But let me turn off this.

Is the light already off? You guys can see it OK, right? OK.

So I'll show this to you guys and maybe we can un-pack what you've think is successful or not successful about our attempt.

[VIDEO PLAYBACK]

-Paclitaxel is a compound that can treat cancer-- Paclitaxel is a compound that can treat cancer. salicylic acid reduces headaches and fevers. Carotenoids can turn your skin orange. And miraculin changes your sense of taste. What do all of these awesome compounds have in common? They all come from plants!

[MUSIC PLAYING]

More than 100,000 natural compounds occur in plants and we barely explore them. These small molecules are called metabolites. Just like how all the DNA in an organism forms the genome, all of the metabolites form the metabolome. Even though it's metabolite can be made from only six elements, there are so many possibilities that it would take scientists thousands of years to make each one try and figure out its usefulness.

Luckily, plants have already done this for us. Plants have the disadvantage of being rooted to the ground. So over time they've trial and errored making lots of compounds to see which ones help them survive and thrive best. And because they've been interacting with other species like us for 100s of thousands of years, some of their chemicals turn out to be really useful, both inside and outside our bodies.

But to use plants to their full potential, we have to know what chemicals they make and how to make them. Instead of studying every chemical one by one, what if we could study all of them at once? We could start by mapping the huge network that connects metabolites. In any living organism, molecules are always on the move. Being converted and shuttled, decomposed and built back up again and re-used. It's just like a subway system! Except in biology, the people are the chemicals and the train is the enzyme that converts and moves them.

If you look at a city from above, how could you map the whole subway system? Similarly, if we look at a plant, how could you figure out the entire metabolome network? To figure out a path and a system, what we actually need to do is break it. If we mutate or disrupt a pathway and see how the metabolite quantities change, we could figure out the connections between them.

Let's say the train from Central to MIT breaks. We wouldn't see students arriving at MIT, and would instead see them building up at Central. But not only that. Anyone else traveling along the red line would also be affected. So it's the redistribution of people which reveals the red line subway path, and tells us where the train broke.

We can use the systems thinking to uncover the plant metabolite network. For example, we know about a compound sinapoyl malate which protects the plant from UV damage by interacting with UV light, making the plant grow green. But without it, the plant would glow red. So if we see a red plant, it's like seeing no people at the sinapoyl malate station. But we wouldn't yet know where the train broke, or what other stations are along the route.

To do that, we can mutate a lot of seeds, plant them, and choose the reds ones.

[MUSIC PLAYING]

Now we can analyze these samples by using the mass spectrometer.

It measures how much of each metabolite is present in the sample. Then we can use a program to see which compounds were effected and map that part of the network. It's like reviewing the red line.

Once we figure out how the entire metabolome works, we can use it to engineer plants to create new bio materials, medicines, and clean energy. We might even discover that plants

have the secret to living forever. We just need to unlock their chemical mysteries.

[MUSIC PLAYING]

[END PLAYBACK]

PROFESSOR: So Anastasia's topic was-- it was really hard to visualize. It mean, if you can imagine, our first meeting she was talking about basically mapping chemical pathways in plants. And it's a hard concept to describe verbally. And I think that there are some things that we did well with that video. I still feel like sometimes it's easy to get lost in the metaphor that it doesn't really do as precise of a job as it could.

One of the things I did want to hit though because someone had asked, how do you know if your idea is too-- was it you who asked, how do you know your idea is too big, or not?

You're not going to appeal to everyone. And you're not going to be the perfect video for every viewer. And that's OK. I think understanding your niche is one of the biggest lessons that I learned in producing *Science Out Loud*. At the beginning, our intention and our goal was to be something like SciShow or VSauce. Something that kids just sort of watch on their own. And we quickly realized that that won't necessarily be the case for us and that's OK. And that we serve a very powerful function being coupled in classrooms, or after school programs, or parents watching them with their kids.

And that'll dictate what concessions you might make. I mean, in this video, we kind of just said whoever is going to watch it is going to understand a little bit about chemistry and biology. And that is what allowed us to sort of gloss over some of the details about chemical pathways. I think that video worked for us, that there was a reason that we made that video partially because Anastasia I think is really good on screen. And that if you didn't have her, and if you had just a narrated video or an animation, it would be a very different visual experience.

I don't know if you guys agree with that or not. But that's sort of how I felt.

The other thing is, she naturally as a person is really like that. She's really jazzed about biology. It's OK if your personality is not like that. But the way she wrote her script-- I mean, she was probably one of the best during the day of shoot just remembering her lines. Because the way she wrote her script was the way that she just sort of talks about that stuff in real life.

And that was a big tip that I wanted to give you guys before you started scripting, was right things the way that you would say it.

And George will talk about this a lot tomorrow, as well. It's a very, very obvious statement that is very, very difficult to implement. I don't know if you guys were pay attention to that in some of the BioBuilder videos. their purpose is to be very instructional like Natalie was saying. It's like a very encyclopedic type of product. And it works well in schools, but most people don't talk in their everyday conversation like those characters did.

And that's OK for their product. But if your intent is to engage someone like Hank Green does, then you have to think about the way that you're writing your script. And again that may sound like a very abstract tip. So what I would say is, if you're struggling with that in your script, literally read your words aloud. And then put your script away so that you can't see it. And just explain your sentence sort of ad libbed to someone next to you.

So this happens a lot to me. I actually went through all the exercises that you guys are going to do this month myself to sort of see if what I was saying made sense. And George and I created an episode about snot. And the writing process for me was a lot harder for me than I thought it would be, even though I've coached so many people through it. And it was because I fell into this habit of being super newscastery.

And that's my personal habit that-- I'll say things like, you think this would do this. But turns out, it doesn't. Right? And I would say, this sounds awful. And George would take my script away and he would say, Elizabeth, what is so cool about snot? And I'd say, well it's awesome because you think that it's just like this crap that flows out of your body. But it turns out that has like all these really amazing things about it. And he would say, well you should just say that.

So as you script, or as you try to think of ideas, turn to your partner. And just tell them as you would tell anyone what it is you're trying to convey, what it is you're excited about. Do you need to do-- want to add anything to that?

PROFESSOR: Well, I think right now we've got about 35 minutes before the end of class. And I suspect we have some wrap up that we need to do to talk about what to do tonight and what to do to get ready for tomorrow. So that really puts us more at 20, 25 minutes. Right? I feel like maybe what we need to do is old school actually have each of one of you think with paper and pen and brainstorm a little. And then come back together as a group a little bit, so that you have

some time to really conceptualized.

Like if I were to do this on my own, I'm just saying like, I would actually do an old school spiderweb to get my ideas out. Which is-- put this guy down here. I would actually probably put my topic in the middle and start brainstorming everything that I can about it to just keep me thinking about what, like-- and then to maybe realize if shipbuilding is in the middle here and we talked about ships, like what specifically within ships am I thinking about? Did we want to talk about sea sickness?

All right, then if I wanted to talk sea sickness, what would I put in my video? Right? And to really visualize for yourself, all the topics, concept, things you would want to film. And then start getting a sense for yourself of whether or not this is a doable concept. And you may realize that actually this is the branch I want to keep exploring, as opposed to this whole big thing.

And if this were my brain, that's how this would work. But if there's a different way that your brain works, we want you-- I would think that you should use this time a little bit solo. And then we'll have a chance to maybe bounce some ideas off. So I feel like people, at least what I heard from people was that this morning was really helpful. But it made you realize you really need to narrow your topic and really think it through a little bit.

So maybe what we do is we spend about 10 minutes quietly working on our own to really flesh out our concepts. And then we get back together as a group. Do you need paper. I have paper. Does anyone need-- you need some paper and pen? I'll go grab them in my office. I'll go get some.

PROFESSOR: Real quick. I mean, there are so many strategies. And some people have different preferences of beginning to script. I wasn't going to share this until tonight. But maybe it would help to do it right now.

So when I was sitting down to script the snot episode-- and again, I'm not saying that this is the best way to do it. Nor am I saying it's the right way to do it. But I was fixated on the idea that your body makes a gallon of snot a day. That was really the seed that began the idea of the episode. So George, who you'll meet tomorrow, said, well just list every amazing thing about snot that you want to talk about. So I didn't even start with an idea of a story or anything. All I did was list every sort of fact about mucus that I was interested in.

And this is sort of the same concept of having a web. I just put in a list. But it doesn't really matter. And as I was going through-- and some of this was stuff that I had learned in a class I took as an undergrad. So I was looking through my old notes, basically. There was a lot of stuff in here. And I ended up taking out maybe 2/3 of it for the final script. But this is what got me started.

Mucus as a problem. Mucus as a solution to things. Just like random, cool facts about mucus. The research that's happening. And just the process of going through all of these things helped me discover a story. And just the process did. So if you would find it helpful to do sort of a brain dump idea in the next 10 minutes, feel free to do that. Again, we're not saying that you have to do any of these methods. But this is what's helped me personally in the practice of doing this. So feel free to do something like this.

I had some ideas of demos I could do. Ted Ed. When they recruit people to write scripts, they have a requirement that you have a sharable fact in your video. So what's the fact in the video that's going to go viral? So I was brainstorming, what could be some shareable facts in the script? And then I was thinking about what's the point? Mucus is alive. that actually ended up not making the final video at all. But the exercise and the act of doing that helped me figure out what the point of the video was going to be.

PROFESSOR: So let's maybe spend like 5 to 10 minutes of just quiet time for you to really think about your topic. And then maybe we can like slowly check in with people, and then maybe come back together and see if people are struggling with anything. I assume that from you're head nods that sounds like a good plan? Yes. OK.

[NO SPEECH]

PROFESSOR: Do you know of omnivores? What is it? Not omnivores. What's it called? Opportunivores.

AUDIENCE: No.

PROFESSOR: No. They're people who like running food. It's like a--

AUDIENCE: They discover?

PROFESSOR: So I have this great story I'll have to give you if this is what you decide to do. A non-fiction

piece that was written by a journalist exploring people who actually live off of people's decomposing food scraps.

AUDIENCE: Oh, so like freegans?

PROFESSOR: I guess. Is that another work for it? Like I know-- I actually do know some people who their diets is basically composed of free food.

PROFESSOR: Right? And like what is fermenting? Fermenting if like beer and cheese. And like fermenting is a whole other concept in here, right? Which is actually a really cool concept. I know. I kind of was like there's a lot of things like beer and cheese. And I was like, what isn't there anything of that I'm interested in? I guess the conflict I have right now is that is seems people are more interested in volcanoes. And that's easier because I actually know a lot about this. This would be something I'd have to learn about a lot.

PROFESSOR: OK.

AUDIENCE: But that's kind of what I want to do more.

PROFESSOR: OK.

AUDIENCE: Is I want to learn a topic as opposed to just going in with what I know.

PROFESSOR: What makes you excited about this topic?

AUDIENCE: I don't know anything about it. And I think that's something that happens a lot. Whether it's because my dorm hall's terrible at maintaining our fridge. And there's always things in there.

PROFESSOR: That's rotting?

AUDIENCE: That's rotting. And I'm looking at it, and it's like wow. This is the-- how did this beautiful broccoli turn into this black muck? And different things like that. That's actually something that fascinates me a lot. Like the transformation.

PROFESSOR: And like why do things--

AUDIENCE: And like different things. Why things-- some things decompose in different ways like where if meats starts to rot, then even if you cook it, it's not going-- that's not good. You just can't eat it. But some things you can kind of like say, well, if you cook it well enough, it'll be fine. And also like the whole concept of how you prevent this. you know like these-- I was looking at it and

there's like all these different ways that you could prevent-- just like they have the three topics of like killing things. How to like bacteria and fungi that cause it. And it's like attacking like preventing like their functions. I think they're like their enzymes. And then there's more like controlling a growth.

PROFESSOR: So maybe-- I mean I love this story that you picked. PS remind me sometime to tell you about the story I wrote for *Backpacker* magazine where I took a whole backpacks worth of food and saw what rotted over the course of a week to see what the best foods are to take hiking. So I did a piece on this in my earlier days and it was really fun. But I actually found that there were maggots that showed up in the completely sealed bologna. And it grossed me out entirely. Because you like, they must have been there from the start. That's terrifying.

AUDIENCE: Yeah, that's-- Yeah. The things that like start and they-- with meat and like things that the animal has--

PROFESSOR: Right.

AUDIENCE: Go through the entire process and they survive.

PROFESSOR: Right. But the story that I love that you just told me about was you going into your dorm and seeing that broccoli and being like, why did this happen? And what does it smell so bad? And you can make your whole five minute piece about that.

AUDIENCE: Yeah.

PROFESSOR: Do you know what I mean? Like just that little anecdote of you looking in your fridge and seeing this nasty broccoli and being like, why does this happen? That's your story. You know?

AUDIENCE: And I thought--

PROFESSOR: And then all this comes from that.

AUDIENCE: It's just like a very big topic. Because I made my video and I looked and I don't really go that far into anything. And it's five minutes already. You know? And I've--

PROFESSOR: But if you were to really narrowly look at what's going on what that broccoli, that's actually a really great five minute piece.

AUDIENCE: Because like, I mean, I looked on YouTube. They have this time-lapse of things decaying. But

there's nothing ever explains why, or how, or what does it.

PROFESSOR: Right.

AUDIENCE: Like, basically the only thing that there is on the internet in like video form is watching things. But there's no explanation.

PROFESSOR: Of like why does it become so darn smelly? Right?

AUDIENCE: You know, I can go and read academic papers. But academic papers are academic papers.

PROFESSOR: Yeah. But also the question-- I mean, if you think about this, if your center becomes instead of food decomposition, but broccoli. The broccoli. Right? Looking at that broccoli. So many questions come out of that. Like when is it not OK to eat it? It looks nasty. But is it still safe to eat it? I'm like what's happening in there? And how long can I expect my broccoli to last?

There's this cool people you might end up wanting to talk to you. That I went to an innovation conference last year the-- I'll have to look up the name. These people made this device to be able to tell you when you're food is rotting in your fridge. And it's an innovation that's happening on campus that you could actually go talk to those people. That they've actually really, really thought deeply about food waste. And created a device that attach to your fridge to tell you like bananas are going bad in three days. You know?

And they are people on campus. So I have to think about their name, but there's this really cool lab that's actually really exploring this topic that you could talk to.

AUDIENCE: And then I actually just had a random idea that was completely unrelated to everything I had before. Which is the concept of a world without decomposition, and what that would look like.

PROFESSOR: Why do things die? Or sort of--

AUDIENCE: A world in which things did not decompose.

PROFESSOR: What would that looked like?

AUDIENCE: Yeah.

PROFESSOR: Which better gets to the question, why do things die?

AUDIENCE: Yeah.

PROFESSOR: Right?

AUDIENCE: Well, I mean things would die but then they would just sit there.

PROFESSOR: Right? Why do things decompose?

AUDIENCE: And if they had to be broken down by other means than just bacteria and fungi.

PROFESSOR: The decomposition cycle. Right?

AUDIENCE: Without a need for carbon and nitrogen cycles.

PROFESSOR: That's much conceptually harder than a concrete broccoli. But you can allude to this in the exploration of that broccoli. Do you know what I mean?

AUDIENCE: Yeah.

PROFESSOR: By looking at one thing really, really deeply, you actually allow yourself the ability to abstract from it. That-- think for a few minutes about that broccoli. A little more. Cool

How are you doing?

AUDIENCE: After talking to [INAUDIBLE], I realized probably my initial idea is I want to go into talking about how we go from [INAUDIBLE].

PROFESSOR: Time?

AUDIENCE: Yeah. I will think of that. And then another topic, closely related topic [INAUDIBLE]. The one I submitted was the pre-conceptual time traveling.

PROFESSOR: Is time travel even possible? Is that the question?

AUDIENCE: No. Not really. More along the lines of problems with time traveling. Like for example, there's the grandfather paradox. And then the idea and theory of the multiverse universe. And multiverse theory [INAUDIBLE].

PROFESSOR: But I mean, even like the idea of like is time travel possible is a really cool concept.

AUDIENCE: But it's really broad. Right?

AUDIENCE: That's why I decided not to delve into time travel, if it's possible. Rather looking at what happened-- why concepts for then. I think maybe it's--

PROFESSOR: I think you're still too broad.

AUDIENCE: Yeah.

PROFESSOR: What-- to tell me more about what you actually do in your studies.

AUDIENCE: That's what you think--

PROFESSOR: But what about-- like, there's got to be something in there that's really exciting to you that you could explore.

AUDIENCE: I mean, yeah. But I really doubt kids would even really want to see how a computer does information. Because mostly I do AI. So, it's lot-- It's to do a lot with like filtering of information and deciding what we do with our information.

PROFESSOR: But I mean, this came up with a different group. Which is when type-- filtering information's actually really interesting. Like when I Google something, how does my computer know what to send me? That's actually a really interesting question. Right? If I'm using Google Shopper, how does it know--

AUDIENCE: Identify what you--

PROFESSOR: You know? And explaining that like a system. That's actually interesting.

AUDIENCE: Bringing that layman terms can be challenging.

PROFESSOR: But important. Right?

AUDIENCE: That would be quite hard.

PROFESSOR: I mean, is it possible to pick something that you do that's conceptually hard but to really flesh it out to challenge yourself to think about how to describe that or show that. Like the train concept. A little bit hard. But I kind of got it. Right? Is there something that you could-- something in your work that you're passionate about and you know a lot about that you think is actually really useful for the public to know, as well.

AUDIENCE: That's really hard to think about. I honestly don't think anything's that relevant to the public.

PROFESSOR: What do you want to do with your degree?

AUDIENCE: Probably robotics, itself.

PROFESSOR: OK. Robots are really cool topics. So what about-- what about robots?

AUDIENCE: They contain information. Probably how they input-- how they take input and how they decide what to do.

PROFESSOR: Great this is an awesome topic. Can you think of one very specific question that you could answer, ask a robot, and how it would be able to figure out the answer it? Yes or no? Have you ever design a simple robot or a simple machine?

AUDIENCE: Really rudimentary.

PROFESSOR: Or like is there any way of very simply showing how a machine makes a decision?

I'm trying-- you know what I mean? What I'm trying to push you to do is think about it robotics were exciting to you, is there one teeny--

AUDIENCE: The concept behind them are quite abstract. That's the thing. They're really like mathematically behaving. That's why I'm thinking of it. I'm not sure how really it can be brought across. Or whether is should be brought across in that space. So I was actually exploring something maybe a bit more. Maybe more on like a pain. I was a medic back in the military. So dealt with a lot. Like every day we see people coming in and looking for pain killers. So maybe a bit more like for people to understand better.

PROFESSOR: Like do I take and Advil or an aspirin? Like do I take a--

AUDIENCE: They're roughly the same thing. Yeah. Something like that. What is the difference in two kinds of medication? And why do we take one more than the other? But we just assume more useful than the other. I don't think so. It's more like-- it's like doctor, MD. You know? OK. A bit more explanatory around there. So I was thinking of something like that.

PROFESSOR: But I'd hate to use to not talk about robots when that's what you're studying, and that's what you're passionate about, just because it's hard.

AUDIENCE: I don't think it's because its hard. I mean, if it were to be an instructional video for someone at

my level, maybe it's not un-doable.

PROFESSOR: But is there anything within robots that you think is a cool idea. Simple. A simple, simple, simple something. So not everything about how a robot works. But even how to get-- just something very simple. I don't know your world old enough to be able to help you think about what is that thing. But I challenge you to think for a few minutes really deeply about what within the robots is a simple enough concept? Do you have an idea?

AUDIENCE: I actually-- just listening in and I know something I think is really cool.

PROFESSOR: What?

AUDIENCE: I very basic on-- but this might still be too complex. But probability based maps.

AUDIENCE: Probability-based maps as in based on the probability of what-- something happening that you predict what that is?

AUDIENCE: Like when the robot has to construct a map of an area it doesn't know.

AUDIENCE: Oh, mapping. Yuck. Not my favorite project. Done before. Yeah.

PROFESSOR: But if you can think-- maybe you brainstorm for a second about robots to see if you can get narrow enough that it's a concept.

PROFESSOR: I mean, I think that there's a seedling here. Right? But like what is the relate-ability and the drama that's hooking people in? Right? Because I personally think that it's fascinating that we live in the 21st century with all these super computers. Yet this seemingly basic problem of you have constraints x, y, z. You can only work four hours in the day. You need to make chairs and you need to make tables. What's the optimal number of chairs and tables to make? Like, that seems like a question that we would be able to solve.

And the fact that we theoretically actually can't is interesting. Except there's not enough at stake in that example. Right? Like people will say, oh, we lose a couple cents on making chairs. Like, that's no big deal. But if you say something like, because integer programs can't be solved right now, this is what's preventing us from knowing-- like this is the reason, or one of the reasons why companies can only achieve like certain profit margins, for instance. What would happen if we can solve integer programs?

Like what would happen to humanity, I guess? You know?

AUDIENCE: Hm.

PROFESSOR: Do you know? I mean, I don't know.

AUDIENCE: It's just means that-- when they say you can't solve a problem, just saying that you can't solve is easier than the-- you actually can solve it. By the way to solve it is to just go through every single point on the graph

PROFESSOR: So it's very inefficient.

AUDIENCE: It's just complete--

PROFESSOR: So like it limits us to the types of problems we can solve.

AUDIENCE: Yes.

AUDIENCE: You can solve it for like very small variables. Like in this case, it's two variables. So you can solve it.

PROFESSOR: Yeah. But you can't solve until you proof the problems.

AUDIENCE: The more variables than-- actually I was mentioning this before. I think it's called it n problem.

AUDIENCE: What? You know how you were saying as long as the number of variables increased, the number of times you must try exponentially that you can't really solve the problem.

AUDIENCE: There's a concept called NPI. Or NP. So it's about categorizing a problem. How difficult a problem is. And if it's harder than this problem--

PROFESSOR: I think that's very--

AUDIENCE: Like problem in the world can be made into a type of problem called a-- I'm forgetting like--

PROFESSOR: You should write this. I think like maybe this might be specific enough.

AUDIENCE: Yeah. This sounds really-- because--

[INTERPOSING VOICES]

PROFESSOR: You don't have to baby anything down for the audience. You know what I mean? Like you

don't have to talk to them like they're ten.

AUDIENCE: Because that helps encourage the conversations afterward, too. Because like when I watch a video about something that I'm unfamiliar with, if I want to learn more I'll go out and search the words that I don't know. Like as you with the sixth graders, maybe they kept asking questions. If they're curious about something they'll keep wanting to know about things.

And so-- and they're are a lot more intel-- you think sixth grade was way too long ago. But they were very like they're actually intelligent. They're actually curious. So you don't want to take out things that you're saying just because you think it's too intelligent for them, or it's too far above their level. Because if you transition well into it, if you script it properly, and do the proper build up-- here's your introduction. Now these are the details I'm going to talk about. Then they'll remember some of those details, and look up the things that they still want to know.

AUDIENCE: Is it OK if we just use the vocabulary, but instead of the-- because to say what a problem can become two separate [INAUDIBLE]. Like a lot of--

PROFESSOR: Yeah. So for tonight's assignment, we're going to have you guys just write a rough draft of a script. And at this point, I think it's OK if you want to err on the side of having too much jargon. That's OK. Because George and I are going to workshop all the scripts with you tomorrow. And we'll--

It's always a fine balance. Because you don't want to sit and define everything. Right? Like, it's OK to challenge your audience. You don't want to alienate them by talking in a language that they don't understand. Right? So it's a balance between that. I think for tonight, we want you just like get something on paper. And so don't get too stressed about that. Really focus on what the overarching story's going to be.

AUDIENCE: This is day two of the class and scripts take like a long time to write and refine and--

PROFESSOR: So we're not expecting perfection or anything.

AUDIENCE: I'm just concerned about like something like this because there's no like visual elements like what you were saying.

PROFESSOR: So do you want me to show you the computer-- Or have you see the computer?

AUDIENCE: Yeah. I've seen-- You're talking about the one where he puts like these pin balls.

PROFESSOR: With the balls. Yeah.

I don't know any videos on top of my head. But what you might want to try doing is just looking on YouTube for maybe like VSauce of Veritasium videos that were about computer engineering and see what they used visually. Sometimes it's just their persona like on screen.

VSauce does that a lot because he talks a lot about psychological concepts that are sort of hard to visualize. And it's just him on screen talking. He's just visually engaging that way.

I do agree. This is going to be hard to-- it's going to be hard to visualize. But maybe this is a place where animations could help. And I always think animation should be used sparingly. People have a tendency to rely on animation because think it's like cheaper, or easier to make. And when Josh come in, maybe he and I and you can talk a little bit more about how you would implement that exactly. But having a person with just an animated overlay like you saw at the beginning of that video, that can be a really simple solution to a way to engage people visually.

But I think the idea is-- personally, I think the idea is very fascinating. The notion that we live in a world where we think we've achieved so much technological prowess. But a problem that seems so basic like that understanding how to solve four, five, six things is actually incredibly challenging. And this is why. This is the thing that we can conceptualize in our minds as human. But when you try to get a computer to do it, like it's actually impossible. It's impossible.

I went to this talk awhile back given by one of the guys who runs the Humanoid Robots Group at MIT. And he was saying how it's so hard to program a humanoid robot, a bi-pedal robot to walk like a human behaves. And it's because we walk every day. Right? And we don't think anything of it. But to model the movement of your knee bending and putting your foot down, it's actually possible to mathematically model with a precision of reality.

And I don't remember the exact math about it. But I remember hearing this notion that like there's no way in math for us to model something that we do in reality every day. Right? So even if we create like the world's biggest super computer, a robot is never going come close to what the human body can achieve in their sleep. You know?

And I thought that was such an interesting concept that humans are still like so complex, even

with all the advances we've made in robotics.

And that was a theme that we tried hit in one of our episodes, actually.

Does that help a little bit? I don't know. Maybe you just have more questions.

So at the end of the whole treatise, we each will come with a video and post it

PROFESSOR: Mhm.

AUDIENCE: OK.

PROFESSOR: Yep. It'll be great.

AUDIENCE: Can I just picture--

AUDIENCE: Sure.

AUDIENCE: So I mean, I have one of an algorithm. And like the simplest algorithm I can think of this is one search. So I was just thinking like wal-- You know, wal-- or whatever you call it. Where is Waldo?

PROFESSOR: Oh, *Where is Waldo?*

AUDIENCE: Yeah. So like just-- it would probably be like just some guy just hiding in the building. And then he'll be like, what's the best way to find Waldo?

PROFESSOR: Yeah.

AUDIENCE: Yeah. Then we'll just be running around. Row

PROFESSOR: Yeah.

AUDIENCE: Yeah, like-- so first wave, open every door in the university and you just keep going that way.

PROFESSOR: Right.

AUDIENCE: Then there's another way where you keep going up. Yeah but then I start to realize that the energy might break down somewhere half way. Because the algorithm on the [INAUDIBLE] was a binary search which is just like, you cut half. And then you see whether, is Waldo on the right side or the left side? And then you cut half again. And less, and less.

PROFESSOR: I think that's very interesting. What is the final application of search algorithms?

AUDIENCE: Google.

PROFESSOR: Like Google?

AUDIENCE: Yeah.

PROFESSOR: Yeah. I think as long as you relate it back to the big picture of like why that's such an awesome thing. Because what you don't want happening is people to think like, OK, cool. I get that. It's a binary search. He split things in half and half. So what? Like why should I care? Right?

AUDIENCE: Yeah.

PROFESSOR: You should care because it's like what drives the most used website in the world. And I think relating it back to that-- like that's what we tried to do with the switches video. Is like, OK I get that the billiard ball hit with the switch on or off. But we tied it back at the very end to say like this toy has 20 switches but most computer have like billions of switches. And that's what makes a semi-conductor. And that's what makes every modern electronic possible.

As long as you relate back to the big picture, to the thing that people relate to, the thing that people use every day. I think that can be powerful.

AUDIENCE: OK.

PROFESSOR: I mean, I also-- I like this path in GPS thing. Like how exactly does a GPS work? How do you find your way? You know? Knowing what-- knowing your location in GPS? I know but I was-- like mapping a path, that's a different problem.

PROFESSOR: OK

AUDIENCE: Yeah. GPS--

PROFESSOR: It's like how does Google Maps know?

AUDIENCE: Oh, I see what you mean.

PROFESSOR: We are about out of time. Maybe we should get everyone back together.

PROFESSOR: Oh, yeah. Sorry. Thank you, Danny.

PROFESSOR: I don't have too much to say. Except for just the daily assignment. So another daily blog. Thank you all for posting your stuff on Tumblr yesterday. Keep in mind that you don't have to do a text post like I did. I just did that as an example. But if you guys want to do a video blog. If you want to just vlog on your laptop webcam, that's totally fine. But if you end up taking pictures of any of the lectures, or taking videos during the lecture, you're free to post those, too. And just post them with a hashtag day two and your Kerberos ID. All the stuff that is on Tumblr. I'd also do the day two thing. And then a quick 200 or 300 rough script based on some of the stuff we talked about now.

Don't worry about being too jargony in this. This is really about pulling the overarching story. We're going to work out the details of what's the best wording to use. We're going to work out some of the minutiae a bit tomorrow during our scripting workshop. For tonight, think about what's the point of the video, and what the overarching story of the video is. Those are really the things I want you to think about tonight.

If you get so stuck, and you just can't think of something to write, write down some facts like I was showing earlier. Just come to class with something that we can work with tomorrow. Because tomorrow's going to be a really informal day. [INAUDIBLE] and I are just going to workshop and then table read some of this stuff that we've written. And figure out how to implement the theoretical things that we were talking about in the last two days in a more practical sense.

So does anyone have any questions about those assignments? Yes.

AUDIENCE: Can you also bring back the canvas tomorrow?

PROFESSOR: No. Tomorrow will just workshopping. You will need them back at least on Friday. I'll send you guys an email the night before and the day we meet in the final class.

PROFESSOR: When I-- just as something to think about. When I walked around and led to some of you guys more deeply, I feel like a lot of you are sort of struggling with this same concept of broad versus detailed. And my two cents on it is that by asking a broad question but going very narrowly in with one example, you actually end up being able to bring people back up to that broader framework.

So if you pick something-- like we talked about food composition. And we started exploring

further. Maybe talking about why a piece of broccoli rots. And when is it too rotten for me to eat that I get sick? Is actually the perfect focus for him to ask all these other questions about food composition. And that by focusing really narrowly on that broccoli, we actually get to ask a lot more questions. Right?

Like with shipbuilding. Why does something really sink or float? But that question diving really narrowly into one scenario of one ship sinking. And why does it do this? It allows us to be able to ask some broader questions.

Why-- the braces. The opposite. Right? I want to talk about braces and what they do to your teeth. But all right, let's think about if that's a specific example, what's the question that we're trying to think through? And I feel all into a kind of in that place right now where you're trying to figure out what specific story do I tell in order to get these bigger, bigger concepts?

The narrower you are in that microcosm, the easier it is to extrapolate out. Because it lets you really dive deeply into that topic. So if you have a really, really broad topic still, see if you can get it really narrow. And then from that it allows you to get broad again. If that makes sense.

PROFESSOR: And that's why I personally like going with the whole just trying to list out as many facts as I can with this snot thing. Because it was just sort of, snot is awesome. OK. Like, you know, why is it awesome? What does that even mean? And so I'm listing out all these specific things that people study about it. And that helped me delve into the tangible examples that I gave. That allowed me, at the end, to go back out to the story of this material that protects you every day, and is amazing and awesome.

PROFESSOR: And I know we're just about-- we're actually over time, so I apologize. But I realize that some of you may not know how to implement Elizabeth's task of asking you to actually write your script. And that may be an overwhelming task. Is that feeling like that right now? Like sitting down and actually putting something on paper, you don't know where to start? Or do you feel like you know to at least dump something down?

Sort of like you know, Paul, colon, says this. Picture of something in here. Like just jot it down. Don't worry about format. Don't worry about any of that.

PROFESSOR: We're going to go over all the details tomorrow. We just need an idea.

PROFESSOR: Yeah. Just dump-- so when she says script, that word may be intimidating right now, because

a script can look certain ways in different genres. Like a film script looks very different from a theater script, versus this kind of transcript. Don't worry about anything other than getting some ideas on paper. And we'll deal with all of the other stuff later. If that makes sense.

PROFESSOR: And I'll stick around afterwards, if anyone wants to talk specifically. Yeah? And just upload all that stuff to Tumblr.

PROFESSOR: And we're both available. And we're all available via email. So if any of you are struggling tonight, and you need bounce an idea off of one of us, don't hesitate to do that. I do not check email usually until after 8:00 PM when my son goes to bed. But I will respond. So if you have a question or anything, don't hesitate to bounce ideas off. And I do really get back to you guys, as does-- do all of us.

So that's all for today. You guys can pack up and leave. But really just get ideas down more than anything. We will help you with everything else tomorrow.

PROFESSOR: Even if drawing is the way that helps you. Just get something down.

PROFESSOR: But do get words down. We need to have like some words. That would be great.

AUDIENCE: Is the script supposed to go on a tablet, or?

PROFESSOR: Yeah. Yeah.

PROFESSOR: Good work, guys.

PROFESSOR: All right.