ELIZABETH CHOE: Well thanks everyone for coming. I know that this is kind of a funky time of day. So I really appreciate everyone coming out to support the students of 2219. This is the very first time we ever offered this class. This is the very first time I've ever taught, so I-- it was an awesome experience for me. And hopefully it was a great experience for all the students. I am going to pull you guys up on stage at some point to talk about what it was like. Just as a heads up.

So this class was initially called, Becoming the Next Bill Nye. But as many of the students might tell you, it's not exactly about becoming the next Bill Nye. What it is about is trying to figure out how to occupy the space that's in between education and entertainment-- a space that's not very well defined, a space that doesn't have very good best practices or best practices at all. But the things that are important in this space are to create materials that leave a door open to the world of science, technology, engineering and math to everyone, to create materials that foster a lifelong love of learning, and to create materials that promote stem literacy within the public. And these are all super broad sweeping ideas, but that is sort of what I think at least defines the space that's in between education and entertainment.

These were the four class values that we had. And sorry guys, I know you've heard this already. But this is for people who have never been to the class. Because we couldn't really grade things like is this scene well lit, because honestly we were asking them to do so much within the span of two or three weeks, these were the values that were important to us. Do the materials that the students make exhibit a sense of spark? Is their enthusiasm for the topic matter very evident? And this doesn't mean that they're talking with their hands, waving all the time. It doesn't mean that they're acting like Hank Green with like super hyper personality. It just means that their genuine love of the material is evident.

Is it clear-- "kill your darlings" is the phrase I used over and over again-- but are you able to really determine and distill what your message is very clearly? Are you thoughtful? Is every decision that you go into making-- what your scene looks like, what your line is, what your location is-- is that clear? And then are you pushing yourself outside of your comfort zones? I think there was only one student in this class who'd ever had experience with cameras or film. And I think most of the students were a little nervous about being on camera, which is totally understandable. It's very, very intimidating to be in front of the camera. And I think that over the course of the two, three weeks, all these projects exhibit these values which I'm very happy about.

So what exactly happened in the last month? Well, we basically took production, which is all of the stuff, which I think is actually structured the wrong way. This is really what production is. And they had to learn all of it, in basically two weeks, because they spent the last week making their videos. And this isn't just how to turn on a camera. It's how to write an effective script, how to engage people with your texts and your body language, and the way you're presenting things. And then on top of that, they had to learn how to use all the equipment. And then they had to learn how to edit sort of on their own, and learn how to plan things, and learn how all of these things interact with each other.

So what you're about to see are things that they basically put together in like two or three days, which is kind of nuts, and with very, very limited resources. We had these crappy little canon camcorders. So it's pretty impressive when you think about the constraints that they had.

One of the things that we talked about was storyboarding. So I storyboarded the class for you guys. Day one, if you don't remember, we talked about intro to the class. Chris Babel gave a guest lecture on sort of introduction to using the camera. Then on day two, I made the terrible decision of not telling people that we were going to have 20 sixth graders come to the classroom. But luckily Jamie took care of that before I got there. And they basically had to pitch ideas for videos to 20 sixth graders from Winthrop. And then Natalie Kuldell came and talked a bit about her experiences launching BioBuilder, which is this educational nonprofit.

And then George came in and did a hosting workshop, if you guys remember this. This is only like two weeks ago, which is crazy. And then Josh and John from Planet Nutshell gave a workshop on storyboarding. And then we had our table read. And then you guys shot for the first time. And then you had another table read. Wow, did I mess up my pictures? Sorry.

And then we talked about post production. You guys literally learned the philosophy of editing in two hours. And then you went off to film your episodes. And then we had one screening. And then what-- two more days passed. One day passed. And then we're here at today. So it was a very condensed, very expedited version of all that stuff in the web that I showed earlier.

And so speaking of storyboards, we are at our first project. This was Yuliya's first storyboard. And yes, I combed through the Tumblr, and I'm pulling up all the embarrassing first drafts of everything that people posted. Yuliya's first storyboard-- and I'm bummed because the text is super small and you can't see it-- but it's her first version of her script. And it's basically her first attempt at planning what her video was going to be. And the intro was what do a snowflake and cellphone have in common. And her plan was to go out by the Charles, maybe while it was snowing. And then she's going to have all these things about fractals, and how fractals are everywhere. Fractals are crazy. They're in broccoli. Oh my gosh, so many fractals! And then she starts talking about fractals. Yuliya, do you mind coming on up here? Pin this to yourself. What was the process like-- hang on, I'm going to give this to you too-- what was the process like going from this storyboard to the video that we're about to see?

YULIYA: Well I mostly changed the script since this storyboard. But this kind of helped me think through what are some possible locations I'm going to film at, what animations I can use. So this was very important for me to kind of imagine what was happening, but not just in my script, but also how it would look on film. And then I noticed that there were some issues with the storyboard, and then changed the script afterwards.

ELIZABETH CHOE: And how-- your script probably changed the most. Well, there were some drastic changes that happened. But from your very first idea from day one, your thought what to do something about math, but how math wasn't real. It was like this very philosophical idea. And it was awesome. But we had no idea how she would tell it in five minutes. So how did it evolve over the course or what were some of the challenges that you had revising it?

YULIYA: So I started with talking about Godel's incompleteness theorem, which asks the question of is math real? And then I pitched that idea to sixth graders. And I came back, and I was really shocked that I ever thought that I could explain that to sixth graders. So then I have to think, well what else can I tell about math? And I like theoretical math, so all of the concepts that I line in math are abstract, and don't really have a concrete application. So I start freaking out.

And then eventually I came up with this idea of fractals which were doodles, and they were present everywhere nature. So it could be made relatable. It could be made concrete, even though it was this very abstract math concept. So that was the third script that I wrote. That was about fractals and chaos theory.

Then I wrote another one, which didn't talk about chaos theory, because that was also complex. So the issue for me was coming up with a topic that I could enjoy talking about, but also sixth graders would enjoy hearing about. And in the process I also realized that I need more help than I thought, and more practice than I thought. So it was a very humbling experience, especially the table reads.

ELIZABETH CHOE: And how do you feel about your final video? Again, what they're working with are these small cameras. Most of them had never touched a camera really before. None of them had used editing software except for maybe one or two. So how do you feel about the final product that we're about to see?

YULIYA: Well, I'm not very happy with the quality of the video. And I think part of it is I had to transfer between computers, and work with software. There are definitely some scenes I would re-film if I had more time to get better lighting and better sound. And it's only three and a half minutes long. So I could definitely add more math to it. But I think that yesterday when I uploaded it, I was pretty happy with what I got in the time that I had.

ELIZABETH CHOE: Awesome. OK, well we'll watch your video.

[VIDEO PLAYBACK]

-What do snowflakes and cell phones have in common? The answer is never ending patterns called fractals. To explain, let me start by drawing a snowflake. First, I draw an equilateral triangle, divide each side into three parts. I draw another equilateral triangle on top of each one. Then take out the middle and repeat the process, this time with one, two, three, four, times three, which is 12 sides. Eventually, the shape will start looking something like this. In mathematics, this is called a cox snowflake. If I repeated my process again and again, I would see this same pattern anywhere I looked.

This is a cox snowflake, this time drawn on your computer. Such neverending patterns that are under any scale, on any level of zoom, look roughly the same, are called fractals. Computer scientists can program these patterns by repeating an often simple mathematical process over and over.

And in 1990s, a regular astronomer, by the name of Nathan Cohen, used fractals to revolutionize wireless communications. At the time, Cohen was having troubles with his landlord. The man wouldn't let him put an antenna on his roof. So Cohen designed a more compact, fractal radio antenna instead. The landlord didn't notice it. And it worked better than the ones before.

Working further, Cohen designed a new antenna, this time using a fractal called the menger sponge. The menger sponge is not the name of the sponge you'd be scrubbing your back with. But you can still think of it like that. Imagine with water and soap getting through the sponge's holes, except the water is Wi-Fi and soap is safe Bluetooth. The fractal's infinite sponginess allows it to receive many different frequencies simultaneously.

Before Cohen's invention, antennas had to be cut for one frequency. And that was the only frequency they could offer. Alcon sponge, your cellphone would have to look something like a hedgehog to receive multiple signals, including the one your friends use when they call. Cohen later proved that only fractal shapes could work in such a wide range of frequencies. Today millions of wireless devices, such as laptops and barcode scanners, use Cohen's fractal antenna.

Cohen's genius invention, however, was not the first application of fractals in the world. Nature has been doing it the whole time, and not just with snowflakes. Natural selection gave us the most efficient systems of organisms, all in the fractal form. The spiral fractal, for example, is present in sea shells, broccoli and hurricanes. The fractal tree is relatively easy to program, and can be used to study river systems, blood vessels and lightning holes. So many natural systems, previously thought off limits to mathematicians, can now be understood in terms of fractals.

Mathematics allows us to learn each of those practices, and then apply them to solve real-world problems. Much like Cohen's antenna, revolutionized telecommunications, on the fractal research, is changing medicine, weather prediction and art, here at MIT and everywhere in the world. Look around you. What beautiful patterns do you see?

[MUSIC PLAYING]

[APPLAUSE]

[END PLAYBACK]

ELIZABETH I forgot to mention-- so obviously, if a student's on screen hosting, they are not filming their

CHOE: own project. So what we did was paired people up into groups, and they filmed each other. So that piece was filmed by Kenneth and PJ, and they all worked together to help each other out and direct each other, and it was awesome.

Next up, we have PJ. Now PJ, for you-- you can come on up. I took your second pitch from the Tumblr posts--

PJ: All right.

ELIZABETH CHOE: --where you had come up with the idea of talking about ships. His first-- yes? Oh, thank you, sorry. You had come up with the idea of talking about the science behind poached eggs?

PJ: Yeah.

ELIZABETH CHOE: And--

PJ: Yeah, you shouldn't show that one.

ELIZABETH CHOE: How did--

PJ: I don't even know how to poach an egg, so--

ELIZABETH CHOE: How did that turn from the science of poached eggs to what ended up being a video about how ships basically don't sink?

PJ: Well, honestly I was trying to look for something easy. And poaching eggs isn't actually that easy. So I wanted to learn how to do it. And I thought it'd be some where I'd be able to present on something, and also learn something myself but-- also I could just do it in my kitchen at home. So it seemed very accessible. But yeah, I decided to ditch that because it's a lot harder than people-- or I think people know it's hard to poach an egg so--

ELIZABETH CHOE: OK, so let's watch your pitch and then we can talk about it, and how it changed to your final video. Oh, woops. Can everyone see that OK? Can I leave the back light on?

PJ: Let us assume for a second that this cardboard box I hold in front of you is a ship. Let's say it's a box barge. It kind of looks like a barge. Now what I've done for you is drawn the water line. And what that is is that is the level at which the barge would float on top of the water, assuming that it's going to float.

Now if I take these scissors, and create damage to the bow section of this barge, what do you think would happen? You'd probably be right in saying that water is going to go through this hole that I created, fill up in the barge, and that the barge is going to sink. Now let's take that same scenario and do it again. So you want to damage this bow portion right here. Now what do you think would happen?

You'd probably say that well, you just did that so it's going to sink. Water's going to climb in that hole, and it's going to sink the ship. But you'd be wrong. What I did is I took these cardboard pieces right here, and subdivided the vessel. And what that means is that when water comes in through this hole, it's just going to fill up this compartment. Now what that's going to do, it's going to cause a trim condition in the barge, but it's not going sink. And people on board are not going to be injured as a result of the vessel sinking.

Now I show you this example as a segway into what naval architects do. One of the most important features of designing a ship is making sure it's not going to sink, as easy as it sounds. And the way that we do that it through subdivision.

ELIZABETH CHOE: So I showed that because basically the difference between this and the video that you're about to see in terms of content isn't super, super different. The science, the basic science behind it isn't incredibly different. So what happened between you making this to you making your final video?

PJ: Well I kind of knew the resources that I had at MIT to do a pretty decent job trying to show it. So that was tough trying to organize that, like getting the labs I had to go to because I don't actually work in these labs. So it's-- it was tough to schedule that. But I knew it would be possible. So I just tried to do it, and had lot of fun int he process so--

ELIZABETH CHOE: I don't think that this is actually a bad video at all. I think that you'll go on YouTube, and you'll find a ton of videos just like this one where it's someone that just set up their camera back at home, and they're talking a little bit about a physics concept. Which one do you like better-- this one or the one that you made for the project?

PJ: I liked the first one better. No, the second one's definitely a little bit more in depth, and kind of goes into the science a little bit more so--

ELIZABETH What was the hardest part about getting to this final video?

CHOE:

PJ: I'd say-- I think it was probably organizing all of it because just the different shots that had to take and everything-- it was pretty tough. But it was good having Kenneth and Yuliya. They definitely helped to-- I think my storyboard was kind of all over the place. But they were like, no, you should do it from this angle and you should try it from this angle. So I got a lot good stuff that I could edit.

ELIZABETH CHOE: Yeah, and you actually said that it was easier for you to be on camera when you were around other people than when you were by yourself.

PJ: Yeah.

ELIZABETH CHOE: Well, let's have a look at your final project.

PJ: You want me to sit down?

[VIDEO PLAYBACK]

[INAUDIBLE]

-When we take complex things, and break them into smaller pieces, we find out that we know a lot more about things than we think.

[MUSIC PLAYING]

Now let's this box Orca One, and create damage below the waterline which I've indicated right here.

[MUSIC PLAYING]

Now let's take Orca One on the water and see what happens.

[MUSIC PLAYING]

The Orca One sank due to the weight of the added water. What if the Orca One contained cargo or oil or even people? Now let's take Orca Two, and do the same thing.

[MUSIC PLAYING]

[BELL RINGING]

So we can see that Orca Two did not sink, although it is sitting at an angle towards the bow. So why didn't Orca Two sink? As easy as it sounds, this simple demonstration is essential to the design of huge, complex ships-- ships that are responsible for carrying about 90% of all our stuff. If [INAUDIBLE], how do we [INAUDIBLE] ships carrying our stuff to make into ports safely and not sink?

[MUSIC PLAYING]

He we have Orca One and Orca Two from before. Although Orca One and Orca Two don't engage in international trade, they behave just as 1,000 foot container ship would. Now let's take a look into Orca One. We can see that there's nothing in it. It's just a box. But if you look at Orca Two, we can see that it's subdivided into these watertight compartments by these tranverse watertight bulkheads. Now what that means is that if we were to damage a ship right here, water would only flow into this compartment. It would not go into this one, this one or this one. That would cause the ship to be angled or trimmed in the water, but it would not cause the ship to sink completely. We refer to Orca Two as being subdivided.

And we can see subdivision in many of these ships' plans. It is unclear when subdivision first started being used in ships, but accounts of fifth century Chinese trade ships indicated that water would be able to enter the vessel without sinking. So let's find out why this happens. Let's imagine a barge divided into ten equal compartments. One of them springs a leak from damage. Since the ship is subdivided, only the first compartment floats and the ship remains afloat protecting both its people and cargo.

Although the added water causes the ship to trim, is still has enough buoyancy to return to port for repairs. Ships still sink, though. It's both expensive and impractical to try to design an unsinkable ship, especially when these ships will never see that amount of damage. That's why, as naval architects, we use computer programs to help us out with subdivision. Computers make it easy to see certain damage cases in practically no time.

With different software, we can damage certain compartments and see how the ship responds to it. This gives the naval architect a good idea of what parts to improve on the ship, if any. So even though ships seem like these intricate, complex things, they're really just based on principles that we all already know.

[APPLAUSE]

[END PLAYBACK]

ELIZABETH CHOE: All right, so [INAUDIBLE], I don't know if you saw me mess up, but you're up next. I accidentally fast forwarded through all the slides. So I'm also going to show-- that's this just the sound that's there. You can't see? Shouldn't have done that. Here we go. So Andrea, you can come on up. So I'm going to show the second pitch that you did. I guess my question for you is, you knew pretty early on where you were going to write about. I think your topic stayed pretty much the same, but the way that you were saying it changed a lot over the course of the class. So, I guess, what was the most important thing that you learned in the past few weeks?

ANDREA: Oh gosh, the most important thing.

ELIZABETH CHOE: Or maybe the most practical thing. Here you go, sorry.

ANDREA: OK, two things-- persistence and iteration. And the persistence was by far the harder thing to really do, because I'd experience a block at something. My first one was that I was too much in, like, businesswoman presenting information mode, and it wasn't very authentic. And I didn't think-- I was like, I'm not trying to sell orthodontics to the sixth graders. That's kind of of ridiculous.

ELIZABETH CHOE: [INAUDIBLE]

ANDREA: I'm trying to teach them about science. So it was just a series of blocks that I really just had to work through, much like life.

ELIZABETH CHOE: What type of advice would you give anyone who's going to give a talk, who's going to make a video? Just anyone who's trying to communicate their technical ideas to lay audience. Because you come from a very interesting background. So, Andrea is a Sloan fellow, so she has a sense of presentation and communication minus the video. So, I guess drawing on all these experiences, what type of advice would you give to folks?

ANDREA: Well, I think the first time you ever try to present information, you think you're going to get through a lot more information than you actually will, and that was the first thing that I learned when I taught. I went with a lesson plan of like 20 things, and I only got through, like, maybe four. So I think that that's your first lesson is, keep it simple initially.

ELIZABETH CHOE: Awesome, do you-- well, let's watch your pitch first.

[VIDEO PLAYBACK]

-My name's Andrea [INAUDIBLE], and I'm a Sloan fellow, as I mentioned earlier. And my pitch idea is actually having to do with something that I actually know something a little bit about, that many middle schoolers also struggle with. And that is having braces. I just recently got my braces off, and I also worked for an orthodontics company before I came here to MIT. So it's something that's both near and dear to my heart, and also I think I've seen a lot of high schoolers and middle schoolers struggle with this whole process. I know I didn't know a whole lot about it.

So basically, that would be my pitch. To teach kids about what's happening with their teeth as they're having braces on. How the teeth move, how osteoblasts and osteoclasts work, and to deposit and dissolve some of their bone, which is actually one of the reasons why it hurts so much. And also why your mouth gets dry-- all those kinds of scientific aspects of something that these kids really deal with on a daily basis during a very awkward time of their life. So that's my main pitch.

[END PLAYBACK]

ELIZABETH CHOE: So before we see your video, what's one thing that you're really proud of, and one thing that you want to change if you had more time or more resources?

ANDREA: OK, that's a really hard question. I'd change the whole thing. But the one thing that I liked about it is that I tried to keep my sense of humor in the video, and the one thing that I wish I could change is learning more about lighting and editing, and just more of the technical details.

ELIZABETH CHOE: Awesome. Well, let's go ahead and watch it.

ANDREA: Do you want me to stay up here?

ELIZABETH CHOE: You can move down.

[VIDEO PLAYBACK]

-Eating is one of the great pleasures and necessities of life, and to enjoy everything from energy bars to apples, we rely on one part of our bodies to do an important job, our teeth. Teeth are the hardest substances in our bodies. They are harder than our bones, and they're even harder than iron or steel.

So, why doesn't our jaw just crumble under all of those forces? Between your tooth and your jawbone, there's a specialized piece of tissue called the periodontal ligament, or PDL for short. The PDL can easily absorb the normal forces that a tooth experiences when we chew, say, an apple, cushioning or protecting our jawbone from our teeth. Teeth sound like they're already perfectly designed, but sometimes we really need to force them in a certain direction, like with braces.

As the braces slowly force the teeth to move, the PDL is squeezed in one direction and stretched in the other. To make room, the mechanoreceptors in the PDL trigger cells called osteoclasts that actually come in and dissolve part of jaw to make extra room. The mechanoreceptors also trigger another kind of cell called and osteoblast, which comes in and builds up part of the jaw bone. This allows the PDL to get back into its regular, cushioning shape, thus, holding the tooth securely in position.

So if braces use osteoblasts to physically reposition teeth for cosmetic reasons, what if wanted to use them to replace things in our bodies? Dental implants replace teeth that are damaged or missing to restore chewing function. Your jaw isn't the only place where these osteoblasts and osteoclasts are altering your bone structure. In fact, this bony remodeling process is happening throughout your entire body.

And these implants aren't just limited to teeth. Doctors can replace knees, hips, even spinal discs, and MIT engineers are using the properties of osteoblasts and osteoclasts that are already in our bodies to create a chemical coding for these implants. Just like in a mouth with braces, this coding helps create natural bone to help lock the implant into place. Right now, these implants are designed to have the exact same functionality as the parts that they're replacing.

But scientists are already developing implants to improve the performance of our bodies and brains. So at that point, will we be more machine than human?

[APPLAUSE]

[END PLAYBACK]

ELIZABETH CHOE: All right, so Nathan, why don't you come on up. Every day, the students had to write a daily reflection on our class blog, which is open to anyone. Any one of you guys can go see it, if you want. And this is in addition to doing all the assignments that they had to do. But they would just talk about what the day was like, what they learned, what was challenging-- just any thoughts.

And they could either post pictures, or write things, or make video blogs. And Nathan, by far, had the most entertaining blogs. And I'm just going to show you it, and then we talk about it.

NATHAN: All right, second day down.

ELIZABETH CHOE: Oh wait, Nathan, can you scoot over? Whoops.

[VIDEO PLAYBACK]

-All right, second day down. No, third-- third day-- so, third day-- all right, so, third day reflection. A lot happening. So much that's good, actually, so I guess I'll start with the first thing that pops into mind, which is shooting. I've just got done finally finishing my trailer pitch thing. And one thing I guess you always know, but you don't appreciate, is how many tries at shooting something it takes to get something you're satisfied with.

Because, oh my gosh, I don't still really like what I've come out with, but I spent a good hour and a half repeating the same thing over and over again, and I don't know. I am OK with what came of it, because I know it's still very, very rough, and that's the point of it. So--

[END PLAYBACK]

ELIZABETH CHOE: So that's part of his day three blog. So the reason why I said sort of becoming the next Bill Nye is that what I didn't want to end up happening was people thinking that this class was about molding them into some science celebrity that was becoming a next Bill Nye, or becoming the next Neil deGrasse Tyson, or becoming the Hank Green, because what I think is so awesome about what is here in the student body, and what everyone in this class brought, was their own individual personalities. And I would have hated it if Nathan was trying to be Bill Nye, because he's so much better as Nathan. And that's why his blogs are so great.

So Nathan, what was-- I know that you had said that it was hard to be on camera, and it was hard to do production, but your blogs are so effortless, and your video blogs-- they're very you. So what was so hard about doing something when you had a line to say? You can just clip it to yourself if you want.

NATHAN: I think we made it so hard was, if I'm just doing a blog sort of thing, I think of it in a way of, like, I'm just talking to someone. But when I'm trying to go with the script it becomes a lot more formal in my mind, and I just get nervous.

ELIZABETH CHOE: How do feel about how the video that we're about to watch turned out? How do you feel about your hosting? What was it like shooting that?

NATHAN: I think there's still a lot that I think could be better about it, but if I look back at the very first pitch video I did, and the second one, and even the rough cut, it's definitely improved. So, I'll take what I can.

ELIZABETH CHOE: What are you most proud of in your final project?

NATHAN: Probably that, I remember when we did the [INAUDIBLE], the first table reads as scripts, mine was, one, a lot different from what it is now, but also very, very long. And now, it took like about a little over five minutes to read through just on the table, which is, in theory, faster than it would be in a video. And the whole kill your darlings thing happened, and I ended up with about two and a half minute long video. So I think that's what I like most.

ELIZABETH CHOE: OK, well, let's see what you got.

[VIDEO PLAYBACK]

-Why does a fridge start to smell, and where does that icky black liquid come from? Wouldn't it just be easier if things didn't rot? If things lasted forever? Well maybe, but probably not. The average American household wasts about 25% of its food, and lot of restaurants are even worse.

So if we didn't have decomposition, what would happen to all of the food we throw away? Food and microbes usually get settled by bacteria, protists, and fungi that allow nutrients in the food to return to the soil and, eventually, other living things. These decomposers also break down other dead stuff, like trees. In fact, they're pretty much the only thing that can eat wood.

So even if in a world without rot, where you don't have to worry about your house getting eaten by termites, who align protists in their stomachs, pretty soon forests and landfills would be flooded with a lot of dead stuff. How do we avoid this problem? Well, basically in your fridge, on the forest floor, in the dumpster, almost anywhere there are fungi, bacteria, and protists that live entirely by eating dead stuff.

These dead things can be more or less divided into three categories. Carbohydrates-- sugar and starches-- lipids-- think fats-- and proteins like meats. All of these are chemically different, so they each get broken down by different enzymes in different ways before being absorbed by decomposers. For example, proteases break down proteins into amino acids, the cells building blocks. Lipids rely on lipases, and carbohydrates on things like amylase and cellulases.

So how does a perfectly nice broccoli floret start giving off this foul black liquid? Fruits and vegetables are almost entirely made of water, so on the most basic level you can see the cells are like extremely complex water balloons. The exterior of the cell wall is made of cellulose, a complex carbohydrate that gets broken down by enzymes that the smaller cell can get energy from.

The bacteria or fungi uses cellulase to eat the exterior of the cell. It's like if I were to pop the balloon. That's the muck you see in your fridge. What about that stink? For fruits and vegetables, a lot of times the smell happens after the icky black liquid forms. Other bacterial that weren't involved in the initial colonization move in, and start to stink everything up.

Meat gets smelly when lipases break down fat in the meat into glycerol and fatty acids, two energy sources, and fatty acids are kind of gross. And so while your food rotting may smell absolutely terrible, because of it the environment's able to recycle crucial nutrients it needs. And, well, that's why we have all this.

[APPLAUSE]

[END PLAYBACK]

ELIZABETH CHOE: All right, so David, you can come on up. As I was saying, the students all have to post daily blogs, and after the first day I was really curious to read what everyone thought about the class, how they were feeling, and David's was one of the first ones I read. I don't know if you can see it, but it says, "Today was the first day in the class of MIT 219. I felt pretty much overwhelmed with the amount of course work required from the get go, but also pleasantly surprised by the amount of enthusiasm from students and teachers alike in the course. This will be a day of many firsts, then. First time making a blog, first time using Tumblr, first time making a video describing something myself. Previously, we had done in a group setting and it wasn't such a good experience."

So I read that and I was like, oh no, I totally miss-gauged everyone's starting level. I gave too much to do. This is going to be an interesting month. How do you feel now that you not only have mastered Tumblr, but you're uploading videos, you're making videos on your own-- was it as bad of an experience as the first one?

DAVID: Actually, I felt it was much better. Really, a lot much better, and I'm very grateful for all the help that we've been getting from all the teaching staff. And at first I was really-- because the first three times that we made video I was quite demoralized, because the video came out quite badly. And then when I watched it I was, like, cringing at the videos.

So because of-- but I feel it is because when we did the video shoot most of the time I was doing it by myself, so I couldn't have another person to shoot it against, to let a person tell me what is good, what it bad about a video. However, in this class, every day we have opinions given to us as to what we can improve, what we can take out, what is better, what to cut. And so I think through this process we improve our videos much more than we could have alone.

ELIZABETH CHOE: And I forgot to mention, so the last three videos that I'm going to show are from SUTD students. So we got to host a few students who are from the Singapore University of Technology and Design, and it was super interesting having all of your guys' perspectives. I was thinking before the class started, like, how's this going to work? Culturally, are people going to have the same sort of digital media literacy?

And I feel like you guys were like, oh yeah, we've seen Slideshow, we've seen Veritasium. We already know about these YouTube channels. So I was like, OK, this is going to be totally fine. But David, you guys are going back to Singapore tomorrow morning. Do you think that you will take any of the things that we did in class? Either maybe making more videos, on in your talks, or what types of things were most useful to you?

DAVID: I don't think that I'll be making more videos because I think it's really quite hard. And to do it, really you need a lot of people to do it with you. But one thing I will take back is how to give effective feedback. Because I actually feel that in this class, many times the feedback was very effective, and it came across very pleasantly. So I'm very thankful for that.

ELIZABETH CHOE: All right, well let's see your final project.

[VIDEO PLAYBACK]

[MUSIC PLAYING]

-If I went out front right now, dressed like this, you'd probably call me nuts, right? Because it's so cold outside that I'd probably die of hypothermia. However, in 2009, Wim Hof managed to run a full marathon in -20 degrees Celsius wearing nothing but shorts. While most people would probably die, Wim Hof has managed to survive. So, what makes Wim Hof able to survive while others can't?

The research team [INAUDIBLE] icy bath for almost two hours. Well, most people who had their core body temp to below 35 degrees causing hypothermia to kick in, Wim Hof's body temperature dropped to nearly 37.4 degrees Celsius, staying slightly warm. And the funny thing is that the researchers couldn't find exactly what had happened. Maybe it's a genetic adaptation. In a separate study, studies have found that individuals with [INAUDIBLE] ancestry have mitochondria that can produce more heat and lactic energy.

Mitochondria is like a mini furnace that burns the sugars from food we eat into chemical and heat energy. Individuals like get better able to survive the cold. However, scientists haven't fully studied Wim Hof's genome, so we don't really know. Wim Hof practices g-tummo as a form of meditation and [INAUDIBLE] which allows him to double his metabolism.

Regardless of condition before, Wim Hof can produce enough heat through his mitochondria with specific breathing and muscle contractions. They can produce enough heat to keep his body warm. Well, you might believe that this is not scientific. However, studies at NUS have shown that diversity increase the core temp of the individual using g-tummo, and the inner prior medication experience. Now, why could this be so?

Increases in alpha and beta waves are notices, and many have theorized that this has enabled the body to effectively heat the center as far as the and the knees. We do not fully understand Wim Hof's methods, and while some have tried following his footsteps, it would be unwise to do the same. And Wim Hof, you don't hear him saying he can control all parts of his body. Now, if this were true, and scientifically backed, who knows what doors could open? While science has already audited and I myself don't practice Wim Hof's methods, maybe I better be off only one jacket.

[END PLAYBACK]

ELIZABETH CHOE: Oh wait, sorry, did I cut it off too early? Actually, I'll show your pitch first, then we can talk about it.

[VIDEO PLAYBACK]

-Everyone has pretty much seen a science fiction movie in this day in age, and I'm pretty sure everyone has seen at least one that involves time travelling. Maybe it's *Star Trek*, *Interstellar,* or more recently, *Predestination.* And it's such a widely [INAUDIBLE] topic in science fiction, the whole genre of time travelling. But many times, Hollywood films always have these little, little loopholes in their storyline and their plot lines, and they often use theories and science to explain themselves, which are just like got from machine solutions-- totally not efficient.

However, scientists have actually put forward three main theories when it comes to time travelling. First theory-- the fixed timeline theory. Say, for example, you're trying to prevent World War II, and you travel back in time after inventing a time machine. And after killing the baby that was supposed to be Hitler, you put-- I don't know, some other baby from an orphanage, and put it in the same cot. However, when you travel back in the future, you realize that the baby that you had replaced it with was the one that turn out to be Hitler, and there is no changing of the past, effectively, or the future, or the present. It's all in a fixed timeline.

And this particular motions are actually often seen in movies such as *Harry Potter.* It was seen in *Interstellar* as well. It was also seen in *Predestination*. It's a good film. You have to catch it.

The second theory is the multiverse theory, which states that every time you go back in time and you alter the history-- for example, you step on a butterfly and that butterfly could actually maybe be the prevention of, I don't know, a hurricane that sweeps through Orlando right now-- you spawn a new set of events which happens in a separate universe. Which, in other words means that you have actually got infinite number of universes after you have all these different decisions and different chain of events occurring

And this particular timeline concept has legitimately explored many times as well. It's been featured in the recent regular *Star Trek* movies. It's also been featured in recent *Fringe* series, which kind of I hate because JJ Abrams right now remind me of something. And yeah, this multiverse series is actually quite popular because it's the easiest for producers to just show the solution, and then they'll say, oh, we actually spawned off a new timeline. So that's when you get sloppy and lazy.

The third theory you have is what we call the dynamic timeline theory. It's also the theory which induces all the paradoxes. Which, you often hear about these paradoxes, such as the grandfather paradox, where you go back in time and you kill the grandfather, and because you kill the grandfather, you won't exist. And because you won't exist you can't go back in time and save the grandfather, and that's where the whole paradox comes in. Who kills who? God knows.

The third theory we have is called the dynamic timeline theory, which is also where all your grandfather paradoxes come in. Let's say your grandfather is a really, really evil man-- Hitler-- and you have to go back in time to kill him. And you go back, you do the deed, and then you realize that, oh no, after I kill him I can't exist. And because you can't exist, you can't go back in time to kill him. And because of that, he comes back. And then after you have to come back, and you have to go back in time again [INAUDIBLE].

That's where the paradox starts. It's an infinite circle of never ending events, and that's how the grandfather paradox came about to be in the first place. And I think you may have seen it in *Back to the Future.* And I can't really think of any other film right now. So, this is a brief history of time travel and the three theories associated with it, as well as a quick touch on the grandfather paradox.

[END PLAYBACK]

ELIZABETH CHOE: All right, come on up, Kenneth. So of the four values-- I don't know if you all remember, but there's spark, there's clarity, there is thoughtfulness, and there's challenge, right? Kenneth obviously is not lacking in spark whatsoever, which is awesome. As soon as you see this video-- and this was the very first thing you did-- and you have some video experience, right?

KENNETH: Yeah, I have. And if I had known this would be shown I would have put on more clothes. Yeah, I have had some.

ELIZABETH CHOE: So the video technique was there, and the enthusiasm for the subject matter was definitely there. So how did you go from this pitch, which is basically it's own video-- it's kind of like a mini SciShow video, basically, on all the theories of time travel. How did you go from this to the video we're about to see?

KENNETH: So this was talking about the three main theories of time travel, and this happened right before we saw the sixth graders. And when I started talking to the six graders, I realized that most of them haven't seen *Interstellar* or all of these new *Star Trek* movies. Funnily enough, they have seen *Back to the Future*.

So yeah, I realized what really intrigued them about time travel wasn't all these paradoxes, or all these theories, or the timeline. They were more interested in how is it possible-- is it even possible, and other questions. So it wasn't-- they were interested in time travel, just not my scope that I initially planned. So I decided to change it up a bit. Maybe talk more about the science of time travel itself, which is where I went to at the end.

ELIZABETH CHOE: I mean, something to emphasize too-- we talked about on the first day that this space is so hard to work in because what is good is not defined by anyone. So just because the sixth graders wanted you to talk about the exact science of time travel, and we encourage you to do that, that doesn't necessarily mean that this video is bad, or that people wouldn't really be into a video about the science behind *Interstellar.* That's not true at all. So part of the challenge of working in this space is knowing who to sacrifice-- what audience to sacrifice when you decide to make your video. What were some of the new or unexpected things that you had learned that you didn't know about production?

KENNETH: Sound is important. Sound is really, really important. Yeah, if I had more time I would re-shoot some of the scenes because the sound was just so bad. Other things-- I realize my writing and my speaking is really, really, very different. My initial script when we first wrote it out, I think it was about seven-- six to seven minutes long. My final cut is short of four minutes. So I think while filming it's really a big difference to how we bring things-- how I brought things across. It feels a lot more natural to speak just ad lib to the camera.

ELIZABETH CHOE: Awesome. Any final thoughts before we show yours?

KENNETH: Be forgiving.

ELIZABETH CHOE: Thanks, Kenneth.

[VIDEO PLAYBACK]

-Imagine holding a party and then sending out invitations after the party. Wait a minute, that doesn't make any sense. Are my friends going to be able to time travel back just to attend my party? In 2009, Steven Hawking actually conducted such an experiment to disprove time travel. But what exactly is time travel, and how does it work?

It actually has a lot to do with speed. A lot of what we know about time traveling actually comes from Einstein's theory of special and general relativity. We are actually time travelling right now, but not in the manner that sci-fi films have depicted it. We are, in fact, time travelling at a pace of one hour per hour. In other words, every hour I experience, the world around me experiences a singular hour, too.

Now, it may sound simple and trivial, but stay with me. This is where it gets interesting. Now, a [INAUDIBLE] of Einstein's theory of special relativity is actually a phenomenon known as time dilation. Effectively, this means that the faster you travel the slower time passes around you. It potentially means that I could travel at maybe more than one hour per hour.

This phenomenon, however, is only noticeable at really, really high speeds-- speeds near the speed of light. This rocket here, not even close. Say I do have a spaceship now that travels at 90% the speed of light, and I have a pair of newborn twins. I bring one of them with me on this journey for 10 years. When I return, one of them will have turned 23 years old, while the one will me will have only tuned 10 years old. While we have experienced 10 years on the spaceship, 23 years have actually passed on earth.

This amount of time actually increases exponentially as we get closer to the speed of light. So, we could have potentially travelled forward in time, but what about backwards in time? That's a loaded issue. Now, remember our previous draft. The time that it took [INAUDIBLE] to the speed of light. Some scientists think maybe the secret to time travel lies on the other side of the line. In other words, we may have to travel faster than the speed of light just to be able to travel back in time.

Now, when you do travel at speeds near the speed of light, something called relativistic mass comes into play. In other words, as your speed goes up your mass increases. As your masses increases, you require more energy to move the same object. This might mean that we need an infinite amount of energy just to move [INAUDIBLE] beyond the speed of light. However, the more energy you put into an object, the more likely you are to increase its mass rather than to increase its speed. Therefore, to gather [INAUDIBLE] quite impossible at this point in time.

So, why are we still so obsessed with time travel? Time travel does come with it's own set of problems. Take, for example, my party before. If I were to send out my invitations after the party, my friends would have come back in time to attend. And if they did come back in time to attend, I wouldn't have to have sent out my invitations. And if I didn't send out my invitations they wouldn't be at my party. Doesn't make any sense at all that they are both at my party and not at my party. This is what we call the grandfather paradox. It's one of three time travel theories that we currently have. Now, so it seems that we may not be able to time travel yet, based on what physics tells us at least. For now, if you are planning a party, be sure to send out the invites first. Your friends can't time travel yet.

[APPLAUSE]

[END PLAYBACK]

ELIZABETH CHOE: We have one more video. Joshua, I'm going to show your day three blog. This was the day after that we had our hosting and script writing workshop.

[VIDEO PLAYBACK]

-I thought what really stood out for me was the one of looking at a member of your audience like your family member or a professor behind the camera, so it's not just a camera. So yeah, but the funny thing is, speaking of this tip, I kind of forgot it and I've been looking at the camera thinking of the camera. So it's a bit ironic. I guess many if these things require a lot of practice, and that's kind of like why you do, and get out of the zone of thinking I'm in front of a camera.

Usually, every time you press a camera there's this red button. Sometimes I think maybe if that red button was eliminated that a lot of things would be different. Yeah, so I guess one of my questions I would like to ask as well is, what kind of face-- what would be a perfect member of the audience that I would like to put there? I mean, if I put someone who is very respectable, like my professor, then I guess that the whole tonality in my voice, the whole choice of my vocabulary would try to be more serious.

By the same time, I guess if I put someone like a two-year-old in my imagination in front of the camera, I'll probably not talk in the same tonality. So I guess, what would an appropriate member of the audience be in front of the camera, or some of--

[END PLAYBACK]

ELIZABETH CHOE: So that's a very hard question. You can come on up. And the thing that's hard when you're hosting is that there's a difference between talking to and for your audience, which is a point that George brought up during the workshop. But being able to actually implement that, as you mentioned, it's really hard. So what did you think of when you were hosting?

Because I think that the way you talk in this blog is totally appropriate for sixth grader, for your professor. But being able to distill like who you are as an individual, and having the self-awareness to process, like, this is how I really-- this is who I am at my core. That's actually a really hard thing to do. So how are you able to do in your final video?

JOSHUA: I guess the most important thing is remembering a script. So you at least you know what you're going to speak, and then you probably just want to focus on being yourself. Because at the end of the day, we don't want to be Bill Nye. Still we want to be ourselves, but we must be clear. So you have to balance those two objectives. And this is just me just talking off my head, but I had no objective coming into these reflections.

Yeah the question was interesting, because it was just-- it was the day after-- am I right to say it was the day after the students came in? And if you saw my first day picture it was extremely embarrassing. Thank God for not showing it.

ELIZABETH CHOE: It's not bad-- it's really not that bad.

JOSHUA: I was explaining like hashing, and it was like some security concept that's so hazy that--

ELIZABETH CHOE: It's actually-- it was quite a good video. Very clear and succinct. I now know that my password is safe on Facebook just as long as I update it every now and then.

JOSHUA: Yeah, but I've now understood my audience. And so the point of this video-- and hopefully what I wanted to show was something very accessible, something you use everyday. And it goes deeper and deeper until it goes to a concept that you're not very familiar with. But because you started off at the very familiar point, it lead you there. And so I guess that's the exciting part of the K-12 videos.

ELIZABETH CHOE: Awesome. That was a point Chris [? Babel ?] brought up a lot, was taking the familiar and making it unfamiliar, or taking the unfamiliar and making it familiar. And I think this video that we're about to see does a great job of taking something that's familiar to all of us and showing sort of the unfamiliar side of it. Any other final thoughts before we show it?

JOSHUA: Ugh. Don't cringe, but I better hide under the table.

ELIZABETH CHOE: No, no.

JOSHUA: OK.

[VIDEO PLAYBACK]

-Hi. Do you find it particularly difficult to find a specific item in your house? Let's say you're looking for a pair of gloves, but you just can't find it and you spend your entire afternoon looking for it. Well, you've just encountered the same problem that companies like Google or Microsoft encounter every single day, and that's the problem of search.

Just like your house, which stores a thousand different items, Google stores 45 billion index pages of information. What if every page was a sheet of paper, and we stacked them up real high? We would create a tower 600 times taller than Mount Everest. Well, how can Google find a result so quickly when I find it so difficult to find a pair of gloves.

Well, searching on Google is kind of like looking for a person in a big school. Let's say I'm looking for James in a row of classrooms. One of the easiest method would be to go to every classroom next to you until you find James. There is a better method called binary search.

Now, let's say the students were arranges from A to Z, one in each classroom. We would then go to the middle room first and see if James is there, and if James isn't there we would look at the first letter in the name, and if the letter is before J, we head to the right. If not, we head to the left.

We would then approach the middle room in the newly sectioned area. Eventually, we will repeat the process over and over again until we find James. Now, this is just the first method, but it's at a much, much faster rate. How much faster will that be? Well, that depends on the number of students in the school. Let's say there are 500 students and we are looking for one. It will take about 80 minutes in the first method, but one and a half minutes with binary search.

But let's say there are 1,000 students in the school. It will take 160 minutes with the first method, but 1.6 minutes with the second method. Now, that's a whole lot of difference. So a name is just a word, but Google searches a combination of words, making it a little bit more complicated. So just like how we identified the first letter of each alphabet of the name, Google identifies 200 unique factors making the search terms faster.

Well, if you recall, the effectiveness of binary search depends on the pre-arrangement of data, and that's why computer scientists are actively looking for ways to sort, manage, and eventually retrieve data faster and better. In the same way, the TV remote goes near the TV, the shoes go to the shoe rack, the coats go into the cupboard, and the winter gloves go into the winter jacket. Aha! So that's where my gloves are.

[APPLAUSE]

[END PLAYBACK]

ELIZABETH CHOE: OK, so like I said, given the incredibly small amount of time and the small amount of resources they had, I think that these videos are pretty impressive. It's pretty impressive what they were all able to achieve in such a short amount of time. We didn't even really hit music, which is like an entirely separate, time consuming thing. But well done everyone.

[APPLAUSE]

I wanted to thank all the teaching staff who made this class possible. Sarah, you're an awesome TA. Jamie, the co-instructor. We had George [? Ziden ?] come and teach hosting. We had the guys from Planet Nutshell, Josh and John, come and teach script writing. Chris [? Babel ?] taught a lot of how to make the camera techniques advance your narrative, so it was really a collaborative effort to make this class happen. Just like hopefully you guys realize how much of a collaborative effort it takes to make a video. So big thank you to everywhere who made this class possible.

So all of these videos and everyone's stuff is up on our Tumblr if you guys are interested. I don't know when we're going to offer this class again. We'll see what happens. But in the meantime, best wishes to all the students from Singapore who are going back tomorrow, and then the remaining students-- I've talked to most of you guys but waiting to hear back from one person-- we'll be producing their videos for Science Out Loud season three next week, in addition to a few more that we've been developing in parallel to this class.

So maybe when the spring semester rolls out you'll not only be able to see their progress from pitch, to script, to second script, to rough cut, to final project, you'll also be able to see their final product in the videos that we produce for them, which is going to be really exciting. And that big thanks to Opencourseware too, for helping document this class. It will be interesting to see that roll out this summer as well.

But feel free to take-- if there's food left, feel free to take it. There's plenty of salad left, which is unsurprising. But other than that, thanks so much for coming out. Feel free to-- I'm going to volunteer the students, if you want to ask them about their experiences, you can. But other than that, have a great evening, and thanks again, everyone.