NATALIE KULDELL: So we are among friends, please call me Natalie, please interrupt me as I go. Elizabeth has given a very nice framework for-- the high level questions about this next little bit of time are things about creating a scalable educational experience, and things like that. But truth be told, this is really going to be me, my dirty laundry, telling you all the mistakes I've made in developing something that I thought seemed like a good idea at the time.

How's that as the sort of tag line for this talk? It seemed like a good idea at the time.

But maybe, just so that you don't go running from the room and think this is going to be all disaster, I will start by showing you where this has ended up. Because where all this meandering and mistake-making has brought me is to something that I'm actually pretty proud of, and that seems to be reasonably useful. I don't think this is the final form of what this will take, but let's start with where it ends up, and then we'll rewind the tape and go from the beginning to get it back to here.

So BioBuilder is now a nonprofit organization that I am founder of, I have a wonderful board of directors that help protect me and my time, and help me make good decisions about protecting just thinking through the business questions, and the strategic questions, and the wisdom questions that are involved in running a nonprofit organization.

It came about because I thought that the teaching I was doing here at MIT, in the Department of Biological Engineering, was such a great way to teach and to learn. I was having so much fun drawing on current research questions from the department, and using the questions that existed to teach the engineering, and using the engineering to teach the science behind it. So I'm a scientist by training, not an engineer.

In fact, I didn't really even appreciate the distinction between science and engineering until I got to MIT 12 years ago, or something like that. I really like learning about how the world works. What I discovered when I got here and started teaching this way to the undergrads was that, by building stuff made from biology, you learn a lot about how it works. And so I really just wanted to more broadly distribute that content to students who wanted to learn this way, and to teachers who wanted to teach this way.

Pretty simple-- not that wise, maybe, but that's what I've organized this around. And so there is a nonprofit organization that is called the BioBuilder Educational Foundation which has, as I say, a board of directors, partners, we have publications and newsletters and things like that. We are a 501(c)3, and we were founded in 2011.

The funding for this organization came from the National Science Foundation. They awarded MIT, Harvard, Stanford, UC Berkeley, and UCSF-- a consortium of five institutions-- 10 years' worth of funding. From the NSF, that's really unheard of. And I thought, as the educational director on the East Coast for this, with 10 years of funding we could do something really, really cool.

And so what that started with were animations, which is why I'm here talking to you today. What those animations have been connected into is a curriculum for students that has a number of hands-on laboratory activities. So for example, this one is for students. These bubbles that are here link to the animations, but the content that's on the website is some introductory content, laboratory procedures, lab report information, and then a portal for sharing your data once you've collected it.

There's also a teacher's component to this website, so that teachers, if they wanted to start teaching this content, would have classroom materials like PowerPoints to introduce the content, videos about introducing synthetic biology-- which is what the focus of these labs are-- and then components for the lab introductory PowerPoints and things like that. So this is a website that has information about the nonprofit organization, it has curricular content for the students-- which are mostly high school students and some college students-- and then it also has a portal for teachers. We run teacher workshops in the summers to train teachers how to teach this in the classroom, and how to teach other teachers. Yes?

AUDIENCE: So one of the things we talked about yesterday was this notion of a video being something more than the experience of just pressing play and finishing it, that a video is meant to spark an ending, that is the conversation that happens on comments on YouTube-- we focused a lot on YouTube and social-media based video. What is, I guess, the ending or the goal-- or what's your vision what an ending looks like for things like BioBuilder?

And what's your user pipeline? Because for us, we're talking a lot about people who are exploring the internet and finding things that spark their curiosity or love of learning. I would imagine that something like BioBuilder, you have a very focused pipeline that's maybe more looking at classrooms?

NATALIE KULDELL: So the distinction you just made between the focused pipeline and the user exploring through the internet, is a distinction that I did not know when I started this project, but that has become really clear. So the pipeline for this is really intended to be formal education setting-- so I don't know if when you took high school biology, you took advanced placement biology or something like that, there are this series of lessons and labs. And these are intended to fit squarely into formal education settings, where teachers have content that they need to cover, hands-on labs that teach techniques as well as investigative questions, and then writing and points to communicate their work.

Originally-- and maybe this is a good segue into to how this really started-- this was my notion. I don't know if you've ever seen this website-- I'm sure many of you have-- BrainPOP. This was what I thought the animations were going to fit into. This is kind of the explore the internet depending on what you're curious about kind of sense of the animations that are in BioBuilder. So cellular life in genetics-- and maybe in watching cellular life in genetics, a person would get interested in something in particular-- cloning, or whatever. And so this is a very rich library of animations that a person can self-navigate through, and learn content that they're particularly interested in.

And I imagined, when I started this project, that I would build a library of videos that looked like this. That is not where I have ended up. That was, in fact, really misguided. Yeah?

AUDIENCE: My question is-- you're in the kind of structure and giving this to students and teachers, how do you choose what to pick as a--

NATALIE KULDELL: As a topic? Right, so I work with high school teachers every summer to decide on the topics. The very first thing that the high school teachers I've worked with told me was that they did not have more time in their day to teach other stuff, but that they did feel that they could teach what they were teaching in a better way, in a more effective way. And they thought engineering was a great lens to teach biology, in particular, and these current research questions.

AUDIENCE: And they're giving you the concept that has to be covered, and you're coming up with the example that-- are they saying, it would be nice if we could use this example for--

NATALIE KULDELL: So it's more of a partnership than that, because what I'll do is I'll say, here's a really interesting system that has an ongoing question associated with it-- how do you reliably engineer a cell? How do you improve gain in a system? Something like that.

And they'll say, oh, well, you know, I don't really know much about that topic, but I have always had trouble teaching photosynthesis. So is there a way that we could teach that question and cover photosynthesis. So I'll say, well, in a plant cell, we could do it this way. So it's more of a give and take-- what they have challenges teaching, and what are the ongoing research questions in this field.

So this kind of BrainPOP kind of meandering through a library of videos is what I imagined I would be creating at the beginning of this 10-year NSF funding. What I had not appreciated was how long it takes to make each video, how hard it is to make each video, and how bad I am at making each video. So let me just walk you through the very first video that I made.

So in preparation for this conversation, I went back to some of the earlier stuff that I had done. And I'll tell you that the characters that are in these videos started with the characters that were-- these are all animated videos, they're all animations. And the characters who are in them started with this comic strip, which appeared in the journal, *Nature*, in 2005.

So this was the launch of some of the interest around the field of synthetic biology. There were some splashy papers in *Nature,* as well as this comic strip, and it shows the adventures of a woman in the lab named System Sally, and a boy who's just super curious named Device Dude, and Buddy, who is this little green blob in the middle there. And it's a really fun comic-- I like comics a lot, I grew up with Spider-man. I love comic books.

And I like this one until it gets to the really hard content. So right at the fold here, right at the midpoint, it starts to talk about engineered genetic devices. And I'll pass this around. There's a lot of content here, Boolean logic gates, ribosome binding sites-- you have to be an expert to understand what was going on in that comic. So my naive thought was, I would take these characters-- because they were very popular, people really liked them-- and I would have dialogue between them to explain these ideas, rather than have them on the page with just bubbles and question marks and things like that.

So in a very lucky way, It turns out that my college roommate's husband runs an animation company. So that's how I got connected with animated storyboards. They gave me a very nice discount on what they would do in terms of these animations-- it was still expensive. But this was the transition that was made.

So the comic book turned into this website, which was BioBuilder. This was the very first iteration of the website. And it had, on the left hand panel, the idea was there would be science animations, engineering animations, technology animations, things like that. And like BrainPOP site, you would enter that, and there would be a whole library of animations that you could explore.

In the end, I don't have enough years to live to populate the site. It takes so long to make each of these animations-- it would take me forever to really populate the site for visitors to self-navigate through the topic areas. So this was the original idea.

Then I started working with a teacher, and the website changed to look more like this-- where the animations were put into a formal context of activities, there was also a link where you could go directly to the animations, if you just wanted to watch the animations. So this was sort of the transition period, where there was both a library of animations and activities that you could do, if you wanted to teach with these animations. There were also single-page comic strips-- so returning to what was originally the unsuccessful version-- single-page comic strips that set up each of the laboratory activities.

And this was the transition to, then, the third version of the website, which I showed you at the beginning. So let me show you, since you're working on animations of your own, let me show you some of the detail, some of the things that went into building that very first-- well, let me show you the first animation I did. How about that? I'll show you what these animations look like, and then I'll show you some of the fun and the choices that went into making this animation in particular. Does that sound like a reasonable plan?

AUDIENCE: This would be a great review, because on Thursday, Josh from [INAUDIBLE].

NATALIE KULDELL: Great, great.

[VIDEO PLAYBACK]

[BUBBLES]

-Dude , no running in the laboratory.

-Sorry, Sally-- but have you heard about this competition? It's called iGem, and I think my bacterial bubble could totally win this year.

-I thought you were done with bacterial bubbles. And what do you know about iGem?

-Um, not much, except that there's going to be a bunch of losers and me.

-I don't think you understand the nature of this competition. iGem-- the International Genetically Engineered Machine Competition is a way to get young scientists and engineers working together to engineer biological systems.

-Working together? Where's the competitive spirit in that? The dude works alone, that way the dude gets all the credit.

-You need to be a member of a team to join iGem, and you need a professor to lead it.

-But I heard it was a student competition.

-Well, yes, the competition started in 2004, based on an undergraduate class developed at MIT in 2003 for their short winter session. And it continues to be an undergraduate experience-- but not without guidance and support. Last year, there were more than 30 teams who competed from all over the world.

-So that's my competition? That's a lot of people.

-A lot of people all asking the same question-- can simple biological systems be built from standard interchangeable parts, and operate in living cells? Or is biology simply too complicated to be engineered in this way? What do you think?

-Biology is not too complicated for me.

-The goals of this competition are to enable systematic engineering of biology, promote open and transparent development of tools for engineering biology, and help construct a society that can productively apply biological technology.

-OK, I got a lot of work ahead of me. If we're not going to use my bubble idea, what else is possible?

-Maybe a better question would be, what isn't possible?

-OK, so first off, what's your standard interchangeable part be? Actually, what parts exist? Do we have to make those?

-You'll probably need more than one, but the registry of standard biological parts is a great resource, with lots of parts already designed. And if we make parts of our own, we should add them to the registry, in case other teams can use them, too.

-And help other teams? What kind of competition is that? Of is that how so many teams got cool projects going last year? Pleasant-smelling bacteria, a bacteria nightlight, a DNA drug delivery system-- I heard one team even made up bacterial freeze tag. To beat those, we should get started right now.

-All right, well let's brainstorm for a little while before I have to get back to work. How does that sound?

-Great. Can you show me this registry? Maybe we can find some good parts to use.

-Good idea, Dude. Let's start there. This is where you'll be able to search.

-Oh, wow!

[END VIDEO PLAYBACK]

NATALIE KULDELL: All right, so that, for better or worse, is probably the best video that's on my website. And you know, it was done several years ago, it still holds true. So in some ways it-- it still very accurately describes iGem. It has some old screen shots of the registry and things like that, but you know, it was done five years ago and I think it holds up reasonably well.

It was fun to make, so let me show you some of the fun things that were involved in making it. One thing was the script. So the script was written by a former undergrad of mine in biological engineering, and she did a summer UROP with me, and wrote some of these scripts. And then it was edited by a woman who's on my board who is also a screenwriter.

And this just shows you some of the edits that were involved in that short script. "Dude, no running in the lab. Sorry, Sally, but have you heard about this competition? It's called iGem. I think my bacterial bubble could totally win this year." And she deleted, "I don't much about it, but someone gave me a flyer for it." So there were a lot of deletions and edits on the text, itself.

And if you like writing, and if you like this kind of sentence level work, this is actually pretty fun and creative. I'm not very good at it, but I think it's fun.

The other part that I would say was pretty fun was-- oh, before we did the storyboarding actually, we did-- where are those pictures? Maybe it's here. Yeah, so the company that did these animations sent me pictures of people who were posing in ways that they thought they would be using in this animation. And I got to choose which little boy I wanted to be Dude in these comics.

So I don't remember which one I chose, but these are all shots of actors that they have who come in and pose in ways that they would think might fit the script, and then you get to choose which one they're going to base the image on. I also got to choose voices, and I have an early read-through here that--

[AUDIO PLAYBACK]

-My bacteria bubble could totally win this year.

-I thought you were done with bacterial bubbles. What do you know about iGem?

-Not much, except that there's going to be a bunch of losers, and me.

[END AUDIO PLAYBACK]

NATALIE KULDELL: So that was a quick read of one of the candidates for the voices and stuff like that. So that was kind of fun to work with them to choose actors who were doing the still shots, and the voices, and things like that.

And then they did the storyboarding for this animation, which I had never done before. They were very talented at-- they knew where to break it up and which shots they'd use. And in watching that video now, and honestly I don't watch these videos regularly, so it's interesting to see a couple things that I think still work reasonably well.

I think it's short enough, it doesn't go on and on-- so could be a little bit shorter, but I think it's pretty interesting. I think it zooms in and out of a reality scene and a non-real scene. And it covers the questions they have. There's a little bit of lingo and secrecy to it that's not as easy to understand, if you don't already know iGem a little bit. But I think it answers most questions that people would have about iGem. Yes?

AUDIENCE: Why did you choose to do animations rather than film a real woman with a boy?

NATALIE KULDELL: I think I was misinformed, that I thought animations would be quicker and easier. And then I also had that BrainPOP idea in mind, and this comic strip in mind, which had Buddy, this sort of bacteria thing, as one of the characters. And so I didn't think a puppet or something would make sense.

But that does lead me to a mistake that I made. And again, if I knew then what I know now-- who's my audience for this? I mean, would high school students watch this? I don't think so. I think it's too young for high school students, and too old for middle school students. It kind of doesn't have-- frankly, I show it to my undergrads, so I was like, I'm OK with that. So maybe it's OK for MIT undergrads, but then it doesn't really have a great audience mark.

And the high school teachers who are now using them, it's pretty rare. I mean, they may assign them to people to watch the night before they come in and start the discussion on synthetic biology, or start their iGem team, but it's not something they show in the classroom. Yeah?

AUDIENCE: So what was the intent behind making it? Because we talk a lot about what is going to be your what, why, and how questions before you make a video. Was it to make something that was instructional for people who were already interested in iGem? And if so, what you made you want to do a video over a comic book, for instance? What was that initial interest?

NATALIE KULDELL: I thought-- why are there all the words listed in the dictionary? My goal was to actually make like a Wikipedia of synthetic biology, covering the relevant topics through animation. So I wasn't being selective-- I had to choose something to start with. iGem was my first, because it seemed to really capture some of the unique features of synthetic biology, and was explainable in a way. It's a discrete entity, not too technical or anything like that, that I could cover.

But it was really intended to be encyclopedic, not targeted to an area that I wanted to cover-- except synthetic biology. When I started this project, people were coming to me for learning materials about synthetic biology, and some of those people were people in government and policy, some of them were biologists wanting to learn engineering, and some of them were engineers wanting to learn biology. And I was not going to make a comment book, or a different way for each of those populations to learn.

I guess my thinking was that through self-navigation through animations, people could learn what they wanted to learn. But what it requires is a really rich library of animations to look through. And this took me a full summer to do, and I just don't have that much time. I mean, I would need hundreds of animations, and I just didn't have time.

Then, to top it off, when the teacher finally came to me and said, I can't teach this way. There's no narrative to using these. I need a hook, I need a something that introduce to my students. It has to fit into a framework. That's when starting with the research questions in the field, and using these animations to support the background that you learn to do the investigation, just seemed to make a lot more sense.

So if we look back to the website, and we go to the student side, we can look at this one-- what a colorful world. So now the bacterial growth curves animation is here. I did, I will say, introduce another character, Izzie the iGemmer-- she's Latina, somebody said you should have a little diversity. Anyway, again, it has all kinds of probably rookie mistakes that you guys will never make, thanks to your course that you're taking now at IAP.

But this is the idea, is that now these animations don't stand on their own the way like BrainPOP does, and you sort of meander through them. Now they're part of the background material you can look at and read and understand, in order to do some biodesign, or some experiments about transformation of bacteria to different colors, and things like that.

Were there are other-- tell me what would be relevant for your work here.

-OK, I was thinking that since you work so well with the high school population, if you could orient these guys a little bit, since you work so well with teachers and the students, understanding that age range. Right before you work with them, which is our target audience, what are some science concepts that those kids-- like what do they know? It wasn't that long ago that you were that age, but you've done a lot since then. You probably forget.

Meeting with the sixth graders would probably be very informative to think about, oh, what do they know, what don't they know? But maybe it would be helpful, since you have a better understanding of what's taught when, for them to have a sense of-- say sixth grade is kind of our target, what do those kids know, and what don't they know about science?

AUDIENCE: Sorry, if I can add one more thing, it's really important because even if-- I mean, I had you guys meet with the sixth graders today, but that doesn't mean that your videos should be talking to a ten-year-old, right? Because that's really the basic knowledge base of the average public view, that they're not really going to remember the science that they learned beyond middle school or high school.

So don't mistake understanding an audience of sixth graders as thinking that it's an audience of ten-year-olds, that you're talking to them like they're 10. Because the person who watches Myth Busters, and the person who goes to vote on certain policies, they're going to share a knowledge base. So that's why I think it's important to orient yourself to that audience.

NATALIE KULDELL: So in terms of what folks know and don't know, where this content currently is positioned is to fit into the formal frameworks that most high schools teach for biology. In particular, the advanced placement biology classes. And the reason for that is that, because their laboratory based, you really kind of need particular equipment, you need time in your day to do this kind of stuff with them-- if it's a hands-on lab activity-- and so the advanced placement curriculum has that built in, and you can make some presumptions about what's available, and what isn't, what sorts of basic knowledge they have.

At the high school level, generally speaking, there's good abstract thinking. You can think about things that you can't see and understand what's going on with them, without actually having to either manipulate them directly, or visualize them, have them right in front of you. At the middle school level, I don't know that that's true. And I will say there is a BioBuilder junior site that's quite fledgling, and not as robust as this, but that there's great interest in it.

I mean, you can see the in sixth-- they're awesome, these middle schoolers. They're so curious, and they really want to do stuff, and they're not, oh, I don't like science, and oh, I never got that. Or they're not already turned off in some ways, they're very open to new ideas. What's hard, I think, is the abstract thinking.

So when I tell, in this lab in particular, that's here, which is an experiment which brings DNA into a cell and turns the cell different colors. And the scientific question here is, does it matter what cell type you're using to get different levels of color expression? So like the chassis in which you're running this genetic program, what's the impact of that? It's a very important question in the field of biological engineering-- what cell are you going to choose to run your program in, and how do you choose it?

This is a typical transformation experiment that many schools do with their students, but usually schools are doing it just as a demonstration. What are you going to do with a middle schooler when you say to them, well, when you add salt to the cell, the membrane gets porous, there are tiny holes in it, and the DNA can sneak through? They have to buy it. So some of the middle school teachers are doing acting out-- they have students stand in a circle and hold hands, and say, OK, now salt's added, and have some of the kids let go.

And so I think working with teachers who know their audience has been, for me, critically important in making this any kind of success that it is. And I continue to really value their advice. They know what works with their students and what doesn't. And these animations, some of them use them, but I think they mostly use them as homeworks, not as ways to have students discover what they want to know about synthetic biology.

AUDIENCE: That's going to be really important, because some of you guys have authentically more concrete topics than others. Because ships are something that you can see. Computer programming is not. So you guys, some of you will have more abstract concepts, are going to have to really work hard to figure out, how do you make that concrete enough so that a kid, who developmentally can't grasp an abstract concept as easily as someone a bit older-- how do you make that with metaphor, with acting, with all these different things? How do you use your communication tools to make something that is maybe a reach outside of their developmental conceptual ability, but is still accessible to them.

AUDIENCE: And I will say it's that, as a case study it's very interesting. So when the MIT K12 Videos program started, it was originally allowing students to create full videos on their own without production. And I'll have to show you this slide, maybe after Natalie's talk, but when you let MIT students decide what they want to make, just let them do it free-reign, almost 70% of the videos were physics. It was alarming, the overwhelming majority.

And it's because physics is a very visual, very tangible topic. And when you go online, a lot of science videos and a few are physics-based. Maybe one was on electrical engineering. And the electrical engineering ones were about circuits, so again, you could see the parts.

When we started producing Science out Loud, the one video that went as popular-- in order of magnitude, at least-- and the view count [INAUDIBLE], that's a different discussion. But the one that did the best on its own was the one that I marketed the least. I literally just posted it to YouTube, and sent one Tweet about it. And it was one on how computers work.

And I don't know if you've been in the Stata Center, but there's this machine called the [INAUDIBLE] which explains how switches count in binary, as the fundamental component of the computer. And people loved that video, and it showed this desire and this innate need for a way to visualize these super abstract concepts. And the fact that things that fulfill that need just don't exist right now.

It's very hard to find a good video on programming. It's very hard to find a good video on biology, actually. Anything microscopic-- it's hard to create something that's visually engaging, to where you really justify making a video out of it. If you ask yourself, why would I make a video about microbiology, when it's so much more clear and so much more engaging to write a blog post about it?

And so are the challenges that come along with it. And these are very good questions. They're very good mindsets to have when you approach those ideas.

AUDIENCE: And Elizabeth had a really-- we had a really interesting conversation with those girls about what computer programming concept was actually most interesting to them. What we realized was that all of these ideas were really big ideas. The binary is such a narrow topic, that is allows you to flesh it out in great detail to show-- for the different types of learners who are out there-- different ways to access that information.

So the challenge is to pick a topic that's narrow enough, that in five minutes, you can really unpack it and pack it back up again. And really targeting our audience to figure out what do they know, and what don't they know, so that we're hitting that sweet spot where it's interesting, complicated, but not so complicated that I can't-- it's too much for me.

AUDIENCE: Jaime's original pitch was almost six minutes long. And it was about how does a computer work? That was his original idea.

And so it hit upon switches. It hit upon talking about binary and on semi-conductors and all these things. The switches part is literally less than a sentence of his pitch, and that is what we ended up exploring for five minutes. We had so much to say about it. I do think the more focused a video is, it can be a lot more powerful. Somehow it makes it more dense.

Having worked with this age group myself, I remember sixth grades learning basic biology-- just so you guys can orient yourselves. Seventh grade is learning basic structures, typically, like how to build a bridge, and how to keep something physically standing. Fifth grade is-- I'm trying to think backwards. Eighth is-- chemistry.

So just so that you guys have a sense of where they are in their learning, they're really sticking with physical things until they get a little bit bigger, and can conceptualize chemistry. They're not even ready, yet, to think about that until about eighth grade-- is like 14.

NATALIE KULDELL: So maybe in the last just minute or so, I'll show you another video that's not very good. But that does really speak to this question of how I'm trying to visualize something that is microscopic, and what we did with animation to try to accomplish that. And we won't look at all of this. But we'll get to the microscopic part.

[VIDEO PLAYBACK]

-Dude, I like what you built there. What's it do?

-Oh, hi, Iz. This is a cool bug-- I made it using in an electronics building kit that Sally got me. She wanted to get me a genetics kit, but nothing's available yet. Eesh-- I don't get it. Why is it so easy to turn on and off the lights for this electronic bug, but so hard to turn things on and off in biology?

-What do you mean, Dude? The arsenic sensor that we built in bacteria a few years ago works pretty well. If there's arsenic in the water being tested, the sensor turns on. And when arsenic isn't in the water, the sensor is off. And we built that sensor with natural biological parts.

-So arsenic works like this switch? How is that possible? How does the cell know?

-We used parts from the ArsR operon to program arsenic inducible expression.

-Hold up, arsenic inducible expression? What's that mean? All I know is that arsenic is toxic. Don't the cells just die when you poison them?

-Cells have to come up with a bunch of clever ways to survive. In the case of arsenic, the cells make a pump to get the poison out as soon as any comes inside the cell.

-So asser is the pump.

-Dude, be careful how you say it. The protein is called ArsR, since it's the arsenic repressor protein. And ArsR isn't the pump-- it just tells the cell when to make the pump. The operon has a promoter, which is where the cell's RNA polymerase binds. And at least three genes, ArsR gene, which encodes the repressor protein, and the ArsB gene which encodes the pump, and the ArsC gene, which encodes an enzyme that reduces arsenic in the cell, so it can be pumped out.

-Oh, OK, right.

[END VIDEO PLAYBACK]

NATALIE KULDELL: OK, so you get the idea. It just goes on from there, and it talks about how you build an inverter by moving the repressor and the promoter in different spots, and manipulate the DNA. But you can see with this one, you know there was some physical object that we were trying to use to illustrate what a switch does. But then when you get down to that DNA level, and you're talking about proteins binding to DNA, and names of open reading frames and stuff, it's just deadly. I mean, I can't even watch it and I know this stuff.

So I guess it's a real challenge-- it's a hard thing to think about making tangible, making evident, things that are not. But I do think there's a great power through storytelling, through animation, through video that you have, and when it's done well it's really very, very effective, and very memorable, I think is the big part of it.

Are there any other quick questions? Yes?

AUDIENCE: What is the criteria element of the idea is too big? When you're brainstorming, trying to find out ideas. Is there communication of when-- because I think, after today, we won't get to see the sixth graders anymore.

AUDIENCE: Well, you have us and each other.

AUDIENCE: I think the litmus test that I used when producing Science Out Loud-- I didn't mention this yesterday, but it was probably the first thing I should've said. Because there are no best practices established in this field, take everything that we present to you in class with a grain of salt. And [INAUDIBLE]. So what I've found with distilling a big idea is that when I'm scripting with a student, and we start to go down a rabbit hole, so we're saying, well what is a computer made out of? Well, I have to talk about a switch. Then I have to talk about binary. Then I have to do this.

And we have somehow found ourselves down a rabbit hole that is tangential to the core topic at hand. That's always been an indication for me that the core topic is too big. And you examine the branches that are possible from that core topic, and start looking at, well, what can I do from a branch, itself. We can talk about this more-- because I know Natalie has to leave. Does anyone have any final questions for her? Her email address is on the syllabus.

NATALIE KULDELL: I'd be happy to talk.

AUDIENCE: Yeah, I was curious, I guess you worked with the sixth grade, and many different teachers. Are they conflicting advice that is being given you?

NATALIE KULDELL: Yes, but I think that's because teachers teach in many different settings. And so what is true in one setting is false in another. There are some schools that won't show YouTube, that have that site blocked. There are other teachers that teach every day with YouTube.

So it's just every teaching setting is really-- there's a wide range of--

AUDIENCE: Somehow you never get to make a decision--

AUDIENCE: Standards are the same.

NATALIE KULDELL: Yes, right, so what they have to reach.

AUDIENCE: It may be different where you are, but at least here, in public settings, and in some private settings, the teachers have uniform goals that they each have to achieve in each academic year for each student. And it's a national standard in public schools that all sixth graders must do these big topics. And so within that, how to teach those, that's the common thread in that.

NATALIE KULDELL: Yes, right. But in terms of using animation-- so the question I thought was more related to the tone of the video that you're making, and that is hard, because teachers have very different students, and teachers are very different people, one from the other. Some are very comfortable teaching with animated characters, some think that it undermines their authority. And I've heard both.

So it really-- for better or worse, I tend to just make a decision and go with it. This goes back to if I knew then what I know now. I think small, smart steps is really the only way to figure this out.

Anyway, and with that, I really do have to go. And I'm sorry, but I'd be happy to talk with you guys offline, OK? Thank you.

AUDIENCE: Thanks.