STEVEN SCHAIN: So while we're waiting, I'm going to pass some things around. Everybody can sort of keep these going around. Take one, pass it down. And just take a look at these. We're going to be talking about these throughout this class, so-- and just try and keep passing them around. Should be enough for everybody to get a look at.

JERRY BERNS: Test, one, two, test.

STEVEN SCHAIN: Is yours on?

JERRY BERNS: Yeah, it's on.

STEVEN SCHAIN: Great. I think we are ready to go.

JERRY BERNS: I think so.

STEVEN SCHAIN: Ready?

JERRY BERNS: Ready, three, two, one, go.

STEVEN SCHAIN: If anybody has an Android app, this timer stop watch is the best app for presenting. So I'd like to welcome everybody. This is 3D printing and prototype development using Fusion 360. My name is Steven Shane. I'm post production supervisor and media and entertainment content developer for 4D Technologies CAD learning.

JERRY BERNS: I'm Jerry Berns, manufacturing content manager, also at 4D Technologies.

STEVEN SCHAIN: So here's a summary. I'm not going to read it but it's available in all the documentation available online. So take a look. It's in the handout. So the handout is up there. So what we're going to go through today is talk about where Fusion 360 fits into the prototype development process.

We're going to look at how we can use 3D printing in that process to accelerate our design reviews, and then we're also going to go through a little bit about using Fusion 360 to continuously modify a model. And then somewhere in here we'll also talk about the difference between modeling for 3D printing and modeling for-- or design for 3D printing and design for manufacture.

So welcome. I'm glad you could all make it to the class. Appreciate you all being here and taking time out of your schedules. So first question, has anybody not used Fusion 360 in here? So there's quite a few. Great, great. How many people have used it for a month? So sort of gotten into it a little bit. Anybody year? Anybody over a year? Like since it's been in-- what was it? Inventor Fusion was sort of the first incarnation of it.

So let's talk a little bit about prototype development and the process. By traditional prototyping, how many people in here use or develop prototypes for something? So quite a few. On average, what does it take you to get a prototype back from a machine shop? Days, weeks, months? Weeks, forever, longer than it should. Right? So the traditional process is you come up with your idea, you take that idea, and put it into CAD. Whatever CAD program, since this is Autodesk, let's say Fusion.

Take that idea, send it off to a lab or a manufacturer, machine shop, wherever you're going to get it made, and get it made. So you have your part. This is three weeks later now, you finally have your part and you can evaluate your prototype. So everything that I just passed out, those are prototypes of what we're talking about today. Then you can edit it, and if you have to send it back out you wait more time. You get sort of pushed back in the queue on getting it back. So between first iteration and second iteration, you might be talking about weeks, months, sometimes a year or more.

Well that changes with 3D printing. Now you have something that's more akin to a real time development cycle, real time prototyping. That real time prototyping allows you to take your prototype-- so you have your idea. Now your idea is sort of separate from the prototyping process because you can have a printer at your desktop, or in an office somewhere in your company that is dedicated to printing. Or you can use a print service. So you have that. Now it takes hours.

I send a part to the printer, I get it back. Maybe I know it's going to take like seven or eight hours, maybe longer. 5 o'clock, I leave. I'll send it to the printer or put it in the print queue if we have an in-house department. Get it back when I come in the morning. I can look at it, look at design, see if it works, and then move on. And I can do that day, after day, after day.

And when I finally get the part to market, the same part that I would have had two, maybe three iterations traditionally, I could have dozens of iterations of that part. I could tweak little things now, that I wasn't able to do before. So it makes a big difference. And pretty much

every aspect of what we do now, industrial, commercially, even hobby, and jewelry design-- whatever it is, you can now do something in hours that used take weeks or months, and that's a game changer for what we're doing.

So has anybody used a 3D printer? So everybody. Has anybody used one for over a year? How about over five? A couple. Just for FYI, the printer that's shown here is Fusion 3 design, F-400 3D printer, and it's got to build volume of, I think it's like 12 by 14 by 14, something like that. And these guys are at Greensboro, North Carolina. It's like a light industrial printer. Super quality. So a little bit about manufacturing versus 3D printing.

How many people in here are manufacturers of something? Couple. Anybody architecture? Product design? A couple. Anybody else something I didn't mention? Medical. You're in the right place there. So when you talk about manufacturing versus 3-D printing, you're talking about things like mass production.

So 3-D printing gives you the ability to do low runs, and I'm going to use numbers that are not necessarily accurate, but let's say a mass manufacturer you're going to do 50,000 parts. But I only need 200. I need 200 parts. I don't want to spend $10,000 to get a mold made. I need just a handful and send it off to 3-D print service or do it in-house, and I can have it in a couple of days, maybe a couple of weeks to have a couple hundred of them.

One thing that's really happening now is in manufacturing you have an enormous variety of materials. Think about everything that's made, all the materials that you have. You have a huge number of materials. 3-D printing the material range is still fairly low compared to manufacturing, but that's a continuous-- they're continuing to expand that every day. You could print in metals, plastics, all kinds of stuff, carbon fiber, even liver tissue.

The other thing with mass manufacturing is your part is really inexpensive, plus you have this economy of scale. If you're doing $50,000, and then you say, well, you know, I really need a million, your part costs go down significantly. With 3D printing, your parts are exactly the same cost whether you're printing one or 10 million of them. Doesn't matter. I don't think that's going to change anytime in the near future because they use the same amount of material, and they take the same amount of time, and they usually need the same amount of work afterwards to get them finished.

So one thing that's really hit home with a lot of people that do manufacturing is the tooling costs involved with advanced manufacturing. A friend of mine owns an injection molding

company in Nashville, and his tooling cost for a small part could be tens of thousands of dollars. Well with 3-D printing there's no tooling. There's no tools whatsoever. You just send a part to a printer and it's done. A little bit of manual labor afterwards to clean up the part.

Another thing is the cost of changes for manufacturing, they grow exponentially, whereas the cost of changes with 3D printing are constant. So this is just a really quick graphs, sort of show you what this looks like graphed. And at each phase of manufacturing your costs grow tenfold. At each phase of 3D printing-- as a matter of fact, you don't have tooling costs. So that really should be zero there, but they just stay constant. If you update a design, you send it to the printer, there's no extra cost.

JERRY BERNS: So when you start designing for 3D printing, or know that you're going to be using a 3-D printing process, it really liberates you from some of the restrictions that you might have if you were going to have to use a mill, if I'm going to have to use a lathe. How am I going to drill that hole in there where that is located in there?

Reminds me of the first engineering firm where I worked about 30 some years ago. There was a poem on the wall and it was called the, "Successful Designer," and I won't read the whole thing to you, but the last line in there says, "He looked again and cried, 'At last, success is mine, it can't even be cast!'" Well that becomes a moot point with 3-D printing because you can do some incredible-- what seemed impossible a few years ago, what you can do now with 3D printing.

STEVEN SCHAIN: So that leads us to the project that we're going to present today. When you go to AU every year, you get your badge. So the project was to take the badge and make it useful instead of just hanging around your neck and getting you into parties. So we decided that we'd come up with some criteria that we wanted to have this accessory be.

So it said it had to fit the existing badge. So we started with Autodesk in the summertime. We verified that the badge was going to be the same size, and we said OK, it has to have at least one pen that you can hold, and then hold five to ten business cards, and it had to be something that we could print and give away to everybody in the class at the end of the class. Keep you in here.

So we had some specifications. It couldn't be heavy. If it's going to be on your badge, it's going to be around your neck. You don't want to be walking around like this the whole time going, what is that? That thing is great. We didn't want that. And for Autodesk, it could not cover a

couple of things on the badge. It couldn't cover your name, the QR code, and we didn't actually know about the RF ID. We knew it couldn't affect the RF ID, but we didn't know if it would affect it until Monday morning when we got here.

So there was a little bit of prayer involved with getting this thing approved by Autodesk, but thankfully they're all plastic and they don't really interfere with the RF ID. Autodesk just thought it was great. Needs to be comfortable to wear. We don't want it poking you in the stomach as you're walking around, and it had to be easy to print.

So those of you who have worked with 3-D printers, we did not want any support material on this. So that was the criteria. What we started with was different, and Jerry's going to go through and sort of talk about how you start working with Fusion and develop a model.

JERRY BERNS: Thanks, Steve. So for those that have not seen Autodesk Fusion, here's a little video while it plays, it's a cloud centric design tool. Designers can design, share, manage versions, it has version management in here. You can do kinematic studies, animations, renderings. It has both solid modeling as well as free form modeling built in.

So you can go back and forth between the two quite easily. Build up your sketches, constrain design, all that design information that you're used to. Adjust appearances, do, as I say, motion studies. It was the first cloud based tool to offer 2D based drawings. It's got FEA built in for both cloud as well as local solving. It has CAM capabilities built in. You can do turning, milling. It has support for 3D printing, so you can export easily out to your 3D.

Here's some more animation. So it's a great design tool. It's got that concepts tools built in. Runs on PCs, runs on Macs, runs on tablets. It's affordably priced. Go check out the prices on this. It was a great tool that we decided that we want to focus on design around. Let's use that tool, it has all those capabilities, to show how you can use that to do your 3D prototyping.

STEVEN SCHAIN: And if you're a student or an entrepreneur, I believe it's free. They've now broken out into two different levels. There's a standard and a--

JERRY BERNS: Ultimate.

STEVEN SCHAIN: Ultimate.

JERRY BERNS: So in order to start our prototyping, we needed some reference art, so Steve volunteered his badge, took a picture of it. Again, we had make sure that whatever we designed, our badge

accessory couldn't cover up the name, couldn't cover up that QR code. We verified in June. We verified that this is the size of the badge. It's not going to change Autodesk? Yes, this is the size. This is where the lanyard is going to clip. So we built that reference. Got out the calipers, took some measurements. Knew how long it is, how wide it is, how thick it is, and again, where that important lanyard was going to connect onto it.

So here let's switch over to Fusion, and show just some of the initial designing. So if we're going to build a badge accessory, we need to know what the badge is going to look like. So we'll start out here with a sketch, select my plane, start my rectangle, and we'll do some quick specifications. Let's see. One moment folks. My units here. There we go. I'm a millimeter person. There we go. We'll work with that a little better. There we go.

All right, so I know my numbers. I know that this was 139 millimeters long. I know it's 88.5 millimeters wide. Finish out my sketch, and we're ready take that and give that a quick extrude. Put in the specifications. We knew what that thickness was. So there's the shape. Next, need to know where that lanyard's going to clip on. So again, continue with the sketching process. Select it, create a sketch. All the common stuff, lines, arcs, circles, rectangles.

It's got slot capabilities in here. Specify where the slot's going to go. There we go. Then we can add in some dimensions in here. If I know my center to center distances. There we go, put that in. I know that's 1.5. Nice. And then from the top down, I'll put that in there. Whoops, let's try that again. From that edge, to that center. You're going to be stubborn, aren't you? There we go. And it was six millimeters down. Not quite centered. Not a problem. We'll get that lined up here.

Throw in a point. Oops, let's try that again. Come on tools. There we go. Lock on midpoint, and we'll get that lined up in the center of our badge. There we go, nice. Spin that around, grab the area. There we go. Drag down. Understands I'm dragging down. Probably not adding material, automatically switches to a cut operation. I can specify a distance or just tell Fusion, look, cut all the way through the material. I don't care how thick it gets in the future. Make sure it cuts all the way through.

Of course, if we're going to be putting this into a-- design the badge accessory, we need to know all the details. So I'll start my fill in command and make sure that I get all those corners rounded. I like that window capability. Quick select all those edges there, and we got a 3 millimeter radius on the corners. There it is. Quick badge. Couple minutes. Again, we have

make sure that we don't cover up the name. Don't cover up the QR code.

So with that picture that Steve took, I can add in that as a decal. I'm going to put it onto that face. Go and select the badge picture. Specify the rotation, get that oriented correctly on the face, put it on our scale factor, and then line up that all important picture of the slot and get it lined up with where we've modeled the slot. All right, looks great.

So now I know where's the name, where's the QR code, design around that. Start some more sketching. Pick right on top of the badge itself. Start sketching in a rectangle. Close enough. Add some projected geometry. Again, if anybody's got some Inventor experience, you're familiar with perhaps adaptive, how I want one part to adapt to another. Fusion has that similar. I can project edges from one body to another. I can project from one component to another.

Add in some reference dimensions so that I know that the distance from there to there, 1.5 millimeters, and I can link these dimensions together. When I'm telling it the distance from the top, I can reference that dimension that I already use. So keeping it parametrically tied together. If I need to go back and make a change later, I don't want to edit three different dimensions. Here, I can just have them all link to one. Finally tell it the overall length of what that badge accessory is going to look like. Great. Looks good.

STEVEN SCHAIN: Hey, Jerry can you go back into that sketch.

JERRY BERNS: Sure. What would you like to change?

STEVEN SCHAIN: We have the sides are 3 millimeters. I changed them to 3.

JERRY BERNS: You changed them to 3. So, I go in, change that to 3, and watch all those sides update. Whoops, missed one. Let's make you link over to that. There we go, all fixed. Any other change?

STEVEN SCHAIN: That's it.

JERRY BERNS: OK. Then we're ready to extrude. So again, select the areas that's going to get extruded, and we have to have build material that's going to be in the front of it. There's going to be build material that goes behind it. Instead of making two separate features, Fusion has this wonderful tool called two-sided. Inventor users, you may know it as asymmetric. So I'm going to tell that the top of it's going to go up 1.5 millimeters, and the bottom, maybe that needs to

go down 8.

I'm seeing red on the screen. What's going on there? Well, it's trying to do a cut operation. It's trying to cut into the badge. Well, I want to do a badge. Again, this is Fusion. It can seamlessly switch between working with bodies and switch to assembly modeling. I can go over here to the side and say, well no, you're not going to do a cut. I want you to create a new body. Or I can even tell it to start a new component, and all the features that I put into it are going to go into this component. Keep them separate from this component.

So very friendly design flow. You don't have to think about oh, I got to make all my parts first, and then going to put those parts into this assembly. It can switch. So we'll select the body mode. Now it's going to be its own separate body, and it's in. So I've got a problem obviously. The QR code is blocked. So let's take care of that. Start a sketch.

Again, I can reference where is that important badge? Where are those edges? There they are, projected it from one body into the other. Create my rectangle. Drop that in. Again, add some more dimensions. Tell it how far it is from those sides. Again, I could go through and specify all of those distances, again. We'll just go a little quick on this, and I think I'll just eyeball that one. Say yeah, right about there. Close enough.

Again, we're prototyping. Finish out the sketch. Start my extrude. Select that. Let's see, how far up did I go? I don't remember. Don't worry about it. How far do you want to go to an object? Fusion, you remembered that I want to cut to that badge face. Sure, I can do that for you. I don't have to memorize numbers and such, or go look up parameters. Just say, look, cut to whatever that face is. All right. There's that shape.

Next, we've got to make room for the lanyard. So I'll start in the back here and start a sketch. Close enough. Again, taken some time out not putting in all of those dimensions here. Selecting that. Again, just cut it all the way through. But wait, I'm still in body mode. I don't want to be interfering or cutting through my badge, I just want to cut only through the badge accessories. So I can tell Fusion, ignore the badge. Don't cut through that body. OK, Sure.

So there it is. Well, I need to do a little bit of alignment there, but there's my badge, not cut through. The other criteria? We need room for business cards. Again, after all this was going to hold business cards, hold in pens. So from here continuing on, I could start on another phase here and start sketching in where that rectangle is. Cut it down through. Start building the prototype for our badge accessory.

So continuing on with this. Show you some of the prototypes that we did come up with. Here's the first one that came up with, and it was going to be just a hook style. It was just going to hook over the badge. Lanyard would clip there. Here's what it looks like with the badge in place. Nice. It's got a pocket on the top, business cards visible in the back. We came up with another one, again, still using the hook style.

This one used a little bit different design on the back. We were going to have to use pressure or tension to hold those business cards in place. Well maybe that's using perhaps a little bit too much material. Trying to cut down on the amount of material we're going to use. How about we switch over to just three tabs or three fingers holding those in place. So that was walking through the process, coming up with some initial prototypes. Notice we didn't have any pen holders in those first three. That came on as a later requirement. We wanted to see that pen holder capability. So our first three initial prototypes.

STEVEN SCHAIN: Great. Thanks, Jerry. So I want to talk a little bit about the design process as it's focused around 3D printing. It's really a traditional design process. What happens with 3D printing is everything is greatly accelerated. And now with all the collaborative tools, and the ability to 3D print in remote locations, I could send a part to somebody in California. We can look at the same part, do the same kind of testing. Whether it's fit form and function, whether it's putting an assembly together and trying to make it work, and we can collaborate through Fusion and through A 360, and really get something together that works really nicely.

So we started out with a plan. Come up with your plan. Figure out what your idea is. Do your design work, and again, whether it's all in one office or remote, doesn't really matter. Take that and then 3D print it. This is where the changes is for this process. It's a traditional design process. 3D printing enhances it in a way that we've never been able to before by really speeding things up.

Then we can test it, and we can go back and look and see. Well you know, did this work right? Did it fit right? We discovered quite a few things on this that we'll talk about in a little while, and then we can present it. So Jerry and I went through these steps, and basically presented these to each other and said, what do you think? What do you think of that? What do you think of this? We were able to iterate the design and really come up with something that worked.

And then we can develop it. Right, so each of these is sort of a process in of in itself, but that development part is well, do I develop it further? Do I continue that prototyping process? Or do

I now branch off into another type of development? So now that I'm done, I've got to do something else, whether it's marketing or production. Jerry is going to talk a little bit about how we evaluated the prototypes.

JERRY BERNS: So once we had the designs made, we printed them out of course and started looking up over, comparing them to the criteria that we had set up earlier. How well do they fit onto the badge? Is it easy to assemble? OK again, this was a hook style. It's going to hook on the side. Is it going to be easy to hook the lanyard to it? Am I going to be able to get the business cards in there conveniently? Are they going to be able to get them out conveniently?

So we started looking at that and evaluating. Some of the designs were a little bit too fragile, made the walls a little bit too thin. Beef those up a little bit, make those a little thicker. Could we make the pocket a little bit bigger? Hold more business cards. Those first three, there was no pen holder, so we need to make sure we go back and redesign for a new way of how we're going to hold a pen or add a location for a pen holder.

And that first one-- let me back up here real quick. This one needed a lot of support material in the middle here. So that again, kind of went against our criteria. We're trying to reduce or eliminate.

STEVEN SCHAIN: And you'll see as those are going around-- has everybody had a chance to see all of those? The orange ones are the original version. You can see where the support material is, and if we're printing hundreds of them, we didn't really want to sit there and like peel out the support material on every single one. As it is I'll explain the work I had to do on them anyway.

JERRY BERNS: So, back to Fusion. Went in and said, OK based upon what we discovered after we printed those out, what was missing? What features we liked, what features were missing, what do we have to improve in here? Well, first big thing, there was no pen holder. So we needed to add pen holders onto this.

So a pen holder was built onto both the left and right. So we made it left-hand, right-hand friendly. Whatever's convenient for you. Made it more secure so that when it hooked onto the badge, it wasn't as likely to slip off. If the lanyard wasn't holding it for some reason, some change we didn't anticipate, we wanted it kind of locked in. So we made this pocket style for the badge accessory.

Just to walk you through the process, let me back up here. I'll start stepping through. Whoops,

not that button. There we go. Again, having the badge in there. Stepping through, building up the box, putting in the cut-out for the lanyard, creating the pocket for where-- be able to see the name and the QR code.

Spin it around over here to the side you can see some of the pocketing going on in the back. Putting in where the business cards we're going to be held. There we go. You can see the pocket's in place. Adding in some fill-ins, rounding out the corners. Didn't want sharp corners in there, and continuing through. What I'm doing here is I'm stepping through that timeline. Fusion has a timeline.

Again, for those that may have Inventor experience, have you ever moved the [INAUDIBLE] up and down? Same kind of concept. I can go back in time, fast forward, back up to here, go to here. Steve, you mentioned that-- I noticed in here in your design, some of these are grey. What's going on there?

STEVEN SCHAIN: So these are grayed out. How many people have used Inventor? So a couple. So Inventor has a feature where you can suppress a feature if you don't want to use it. Sometimes when you delete a feature it affects things that are down the timeline, further down the timeline to the right. So you need to suppress it, and not delete it. It works differently. I'm not a programmer, so I'm not sure how it works, but it works differently. So you can suppress a feature that you don't want and have it not affect other features down the timeline. So it's a really nice feature of Fusion also.

JERRY BERNS: So here I'm going through the timeline, moving around, and I say, you know what? Right about there, maybe I want that accessory to be a little bit longer. Using the press pole tool I don't have to think about-- let's see, what sketch is that? Where's that coordinate? Where's that sketch dimension that's controlling the length of it? I can just grab the press pole and say maybe I want to add another couple thousandths onto the bottom of that. Hit OK, and it's in.

Continue moving my timeline along here, and seeing what's going on. Moving that on in. Did you notice a problem there, folks? Steve, didn't you drill some holes in here?

STEVEN SCHAIN: Yeah.

JERRY BERNS: What happened to that hole? Oh, I changed bottom of it, right?

STEVEN SCHAIN: Yeah, you moved the bottom of it and you didn't--

JERRY BERNS: Well I can come back and reorder that press pole instruction that I added, that I dropped in there in the middle of it, well, I can reorder it. Maybe I want that to happen after that.

STEVEN SCHAIN: Now I can get my pen in there.

JERRY BERNS: So that's going to be a little bit easier to put a pen in there. We don't want to have a bottom out in there. We want it to be able to slip and hang up the bottom there. So again, being able to reorder, giving us that flexibility to say, you know what? Let's change that, let's change that, and how does that affect the downstream features in here? We'll just go ahead and fast forward all the way to the end. See the finished model, and we'll turn our badge back on so you can see what it looks like in place there. All right. So modifying the CAM model. Let's switch back over.

So we printed out those after we redesigned it, adding in those new pen holders. Giving them the capability to hang the pen on either side. Adding in some more fillets, improving the pocket for how it was going to connect to the badge itself.

STEVEN SCHAIN: Right, and some of the design changes-- just like in the real world-- they're not noticeable. So the design changes here from three to four, the badge is a little bit longer. It's a little bit taller, actually. From one to two, the pen hole is bigger to accommodate a larger pen. We notice that there's a lot of different pens you get it at Autodesk University. Some are over a half inch in diameter. So we wanted to accommodate as many as we could.

The other thing is, the changes between two, three, and four are really dealing with the depth of this slot, and how that part is handled. Because when you think about design for 3D printing, you have to think about how the print is made, and what printers it's printed on.

JERRY BERNS: And even the orientation comes into consideration. How am I going to put this on the print bed? Is it going to lay down? Is it going to stand up? All those things you have to take into consideration. So here, taking a look at this redesign, from five to six, we noticed that when you're wearing it, we thought, well maybe we don't really need to have to pen holders on there.

How many people are really carrying around two pens, or need access to two pens at one time? So could we again, let's go back, see if we could save some material. Let's move the pen holder to the bottom, and then it's still left, right-hand friendly. You can load your pen in from left to right, your choice, but it holds one pen, instead of having to worry about two and

cut down on the printing time.

STEVEN SCHAIN: And that prototype was pretty wide. It was easily an inch and a half wider than the badge. So it was a little cumbersome. So I want to talk a little bit about the printers that we used. And I saw a raise of hands, a lot of people have used 3-D printers in here. The printers that we used to print these are the Craftunique Craftbot Plus. It's like an $1,100 printer, and the print quality is amazing. So these are consumer level. We use the MakerBot Fifth Gen and the Replicator Plus printers. And then we used a couple that were sort of the commercial level, low end industrial commercial level Fusion 3 Designs F306, and then Stacker 3D's Stacker.

The unique thing about the Stacker that's kind of cool is you can have four independent print heads going at the same time. So you can actually print four parts. They're the same part, but they can be different materials, the print heads could be different temperatures, and you can print four at a time. So you multiply or you divide the amount of time it takes you to print by four.

So the first part of that is to export the STL file. Jerry's going to walk through exporting the STL file from Fusion 3 design, and how that STL export process works. It's actually a 3D printing process inside of Fusion.

JERRY BERNS: So here is our redesign, and we want to take that out to our 3D printer. Of course, need to send that out to an STL file. Well built right into the ribbon is the 3D print command. So they got that forethought, but this is going to be a tool. We're going to be using this type of technology. Why not make it convenient to build that STL file. So I hit my 3D print command, select what I want to have printed, and it calculates the number of triangles that are going to be exported. And there's a control in here called the refinement.

If I zoom in here on some curve faces, how smooth do you want your arcs-- those curved surfaces-- to be? Do you need to have a high refinement? Do you need a low refinement? Again, as you start lowering it, you're going to print potentially faster. Not faster, excuse me, but the quality-- how smooth is that surface going to be? So there's controls in here as to the refinement. There's even a custom control in here. If you need to go in and tweak the number of the normal deviation, the surface deviation, you can really go in and fine tune that refinement for what your print needs are.

STEVEN SCHAIN: So I want to ask everybody a quick question. Of those of you who are using 3D printers, have you ever gotten a print out and it's faceted? Yeah? That's the reason why you see the facets.

One of the misconceptions about 3-D printing is you could feed it any file, it's going to smooth it out. You have to have a file that's smooth enough to be able to have the printer print a nice smooth curve because it's discrete facets. If you use a non CAD program like 3DS Max or Maya, you're working in polygons, and that's essentially what this is doing.

JERRY BERNS: Like the old plot rosin in AutoCAD. Well, it's still an arc or circle, but how smooth do you want it be when it goes to the plotter. Same concept.

STEVEN SCHAIN: I remember watching my pen plotter work.

JERRY BERNS: Here I can send it out to a 3D print utility, if necessary. I could send it to MakerBot, Print Studio, if I wanted to send it directly to another application for some further refinement. If the tool that I'm going to use isn't on that list, then I'm just going to uncheck the 3D print, hit OK, and I'm just going to make an STL file. From there, I can decide what post-processing tool I want to use with that STL file. [INAUDIBLE] makes the STL file, and from there.

STEVEN SCHAIN: So how many people have used a 3D print service? A couple. So if you're using Fusion-- and Autodesk has done this in other programs as well, but if you're using Fusion, the nice thing about it is you never have to export an STL file. You can connect directly with some of the providers that Autodesk is working with to get a quote on the cost for your print.

So if you have a printer, export your STL file, use whatever software you're going to use. But if you don't and you want to get a part made, these are the ones that are there now. I believe they're continually adding new. Don't quote me on that though, I have no idea. But this has grown since I've seen it. In the beginning I think they had like one or two on, now there's a handful of them.

So you can get a quote for your part and the one thing I want to talk about really, is once you get that done-- does anybody you Simplify 3D? No. Doe anybody use MakerBot? A couple. So these are slicing programs. How many people are familiar with what a slicing program is or does? So there's a few. So I'm going to show you Simplify 3D, which is a slicing program that's commercially available, and it is a program that you can use with almost any open source, and several close source 3-D printers.

So this is the cardholder, and you can see the design. We've modified the design. We haven't talked about yet. But this allows you to create what's called a process, and a process is nothing more than the parameters you're going to send to the printer. So if I want to send a

part to the printer and I want it to print quickly, I can tell it to print at a low-- or actually in this case, it's a high layer resolution, 0.3 millimeters, 0.35 millimeters, 0.4. That's a thick layer.

So if you think about your part, what a slicing program does is it literally slices it into layers that are that thick, and it sends that out to a G-code file, which allows you to send that to the printer and print. You can also do things like set the speed for those layers. And you'll notice here I have three processes. Well these three processes--

There's a tool that Autodesk has that I think they just sort of talked about it recently, called VariSlice. Anybody heard of that? VariSlice allows you to automatically determine the quality of the print based on the part itself. So where you have curvature or high detail, it will give you a higher resolution print. Where you have straight parts and low detail, it'll go ahead and give you a lower resolution. Sorry.

[CLEARS THROAT]

Long day in a hot desert. Ah, thank you. So if you look, this is a layer resolution of 0.3 millimeters. This process is 0.2 millimeters. The nice thing about this software is it allows you to specify where the layers-- or where that particular process begins and ends. So if I process this, you'll see what this is doing.

What VariSlice is doing automatically, this is manual, but it allows me to go in and set the resolution differently for different parts of the model. And I just determined this by actually saving out a G-code file first, and seeing where all the layers were. And I can actually look through the layers and see how this is going to be built. I can see here that this is the in-fill for the model. This is the support structure on the inside. The dark blue is the outside layer.

I can look at it by speed. It will show me how fast the printer is going at different points in the model, with red being the fastest, and green to blue being slow. And you can see as I go through, it's going to change and print at different speeds based on my parameters for the model. So that's just a really quick overview of a slicing program, and that's sort of like the post processing for 3D printing models. So your STL files are processed afterwards. Yes?

AUDIENCE: How does it work with generating the sign if you have-- and I guess, well two questions. One question, Fusion 360 will generate a design, and second question, in manufacturing when you're trying-- or [INAUDIBLE] design has the limitation of not as easy to print. How do you have [INAUDIBLE]?

STEVEN SCHAIN: If we can hold that till the end. We can talk afterwards. I want to try and get through everything and get the badges handed out. But Yeah, we'll catch up after the class because there's nothing going on afterwards. So definitely I can talk to you about that. So let's switch back over to the presentation.

JERRY BERNS: Oh, presentation? Whoops. There we go.

STEVEN SCHAIN: And so Jerry is going to talk a little bit about the redesign of the badge.

JERRY BERNS: So here this one, after we got done we discovered that since this was the orientation, that it was going to be using-- see if we can't get it there. Come on, Fusion.

STEVEN SCHAIN: That's close enough.

JERRY BERNS: That's close enough. Since it's got this horizontal area in here, there was going to need to be support material, and the hole itself is now aligned horizontal instead of vertical. I see some heads nodding. Yeah, you're going to have support material in there. Steve, what did you have to do with that?

STEVEN SCHAIN: I had to drill that out.

JERRY BERNS: And who's going to how to do that a little over 100 times?

STEVEN SCHAIN: And here's the problem. My drill was a half inch, and that hole was 0.55 inches. So it didn't actually work all the way. So that was not fun.

JERRY BERNS: Time for redesign. Take a look at this. We got rid of that rectangular pocket, and changed it over to this Chevron shape. Because it was built at a 45 degree angle, no support material required. Take a look at our pen holder. Let me get this spun around here. We went from a hole to a teardrop, because again, it's being built at a 45 degree angle. Spin this and turn it so you can see it a little better.

STEVEN SCHAIN: Yeah, I think that's actually a 35.

JERRY BERNS: Is that a 35? OK, 35. Couldn't remember which angle we were using in there. No support material again. Didn't have to do any drilling. Again, saving time at the end of the process. And because there's a larger hole, it's able to accommodate a greater variety of those pens. I don't know if anybody saw one of those Autodesk pens from years ago, you can come up later and take a look at it. It fits, so great.

[CHUCKLES]

AUDIENCE: What about inside the [INAUDIBLE] Couldn't that have support material if you put it in upside down?

STEVEN SCHAIN: The way that we printed it, the top part of the pen holder or the cardholder, the gap was able to be bridged by the printer without using support. So the filament didn't sag, and if it did sag just a little bit, even if it was just millimeters, it really was inconsequential to the design of the part.

AUDIENCE: Did you identify that in the process step? Just said no support material?

STEVEN SCHAIN: Yes. Yeah. That was part of the criteria that we wanted, and I just knew just from experience-- I've been 3D printing now since 1994, and with all the FDM printers that we were using, I knew just from experience with the FDM printers that I could bridge the gap without having sag there. So I didn't really have a problem.

JERRY BERNS: So here during the fit testing, making sure in that Rev 5, I believe it was, making sure that the pens did fit, we could put in the business cards. It didn't cover up the name, didn't cover up the QR code, it slid over the pocket, received it very well. We could clip on the lanyard here in the middle without any problems.

After we changed and got rid of that support material, again, during that final assembly, making sure that a variety of pens would fit, the badge would slip in there, we could hook on our lanyard, and it worked well. So we figured we are all ready for Autodesk University to come present this design.

STEVEN SCHAIN: Stop the printers! Does anybody notice a problem with this design?

JERRY BERNS: Oh, what would that be?

STEVEN SCHAIN: Single hole design. So about a week and a half ago-- or well, we've been working with Autodesk. About two weeks ago I said, let me send this to them. They can see what I'm doing. So send it to them, and she goes, well the badge is the same size, but I hate to tell you that part in the back is not going to work because now we have two holes for the badge. Two holes? Slots, holes? We had no idea. We have no idea, just there's two of them now. No idea. And we said, all right, so how do we do this?

So essentially we went into Fusion and all we did was enlarge the Chevron on the back of the badge in between the badge and the card holder slot. And said, OK, so if we expand that and make it almost as wide as the badge itself, we've got to be within the margin of error, at least for this thing. Unfortunately, we had to scrap about 40 prints. And because they take about an hour apiece I was like, that's a lot, and now I have two weeks before AU and I've got to print a hundred of these things.

Thankfully, we've got access to about 11 printers, and we were able to get them printed. But this was the design change that we came up to say, sometimes it happens. That never happens, right? Has anybody had that happen to them where they've got a design and they're like, it's not 45 degrees, it's 47 degrees. Or maybe you don't know an angle, you don't know period, you don't know an angle, you don't know a distance. So that was a discovery that we were like, doh! That's not good. But we were able to recover.

And just to recap, we're ending a little bit early because we want to be able to get everybody the badge accessories. So just to recap, we talked a little bit about prototyping. Went through and discussed just a brief idea of the difference between manufacturing and 3D printing, and a little bit of design for manufacturing design for 3D printing.

Just a note about design for manufacturing, you have to build a part that can be manufactured. 3D printing, you now-- and it comes with that iterative design process. You're free to build things that you couldn't build before. We went through, and Jerry was able to go creating and modifying parts in Fusion. How many people had never seen stuff happening in Fusion before? Oh, good.

JERRY BERNS: Quite a few, OK.

STEVEN SCHAIN: And then going through and exporting something to be 3D printed. So I want to thank you very much. Again, my name is Steve Schain.

JERRY BERNS: Jerry Berns.

STEVEN SCHAIN: And we are bribing you, so please give us a good review. Don't forget, south by booth 2804, and you can sort of win a 3D printed, Big Brain On Campus award, as well as I believe, $100 gift card.

JERRY BERNS: It's a hundred dollar prize. Yeah, if you can take it.

STEVEN SCHAIN: And a full year to CAD Learning Online.

JERRY BERNS: And there are six tests, so if you want to take AutoCAD, Inventor, Fusion-- or not Fusion, excuse me. Got Fusion on my mind. Revit. There's six different--

STEVEN SCHAIN: 3ds Max and Maya.

JERRY BERNS: 3ds Max and Maya. So we've got three different tests that you can take.

STEVEN SCHAIN: Six.

JERRY BERNS: Six. Civil 3D also.

STEVEN SCHAIN: Yeah, Civil. And a big announcement by CAD Learning is Fusion, their online Fusion course will be free starting December first. So if you want to learn it, it's a really amazing tool. It's great for creating even the simplest design, but it's also really good for creating very complex designs. Any questions? You had a question about the-- can you ask that again?

AUDIENCE: My question was does you have generative design, and how does it work with Fusion 360? And the second question was, if you do make the generative design, which could be quite complex, how do you go about simplifying it in your process and can you print it in a better way than the actual model that you end up generating in Fusion 360, if you can generate a model in Fusion 360?

JERRY BERNS: Generative design is not in Fusion 360.

AUDIENCE: So there's no [INAUDIBLE] or anything like that that works with Fusion?

JERRY BERNS: I'm the one with 360 experience. I am not aware of any generative design tool inside of Fusion 360.

STEVEN SCHAIN: I don't think there is. As far as the 3D printing generative designs, they're complex designs in of in themselves. It's very hard to simplify those. Those designs are really good for printing with powder based materials. So if you're using like an SLS process, or selective laser melting, or something like that that's powder bed, because the powder will support the part and you don't need separate support material.

The disadvantage of using something like FDM for those parts is the amount of support material you've got to clean up afterwards. So a lot of that is the process that you use, versus

trying to simplify it. I don't know if that answers the question. Anybody else?

JERRY BERNS: I will add, Fusion 360 just added support for handling meshes. About a month ago a release came out. So now you can import meshes. So if a generative design tool generated a mesh for you, can bring that into Fusion 360, and I believe you can actually turn that into a solid and start doing some things with it. There may be some smoothing tools. Again, it's solid modeling as well as free-form modeling. Maybe there's something you can take it into the free-form modeling area.

STEVEN SCHAIN: You want to that box?

JERRY BERNS: I'll grab that other box.

STEVEN SCHAIN: So you had a question?

AUDIENCE: Yes, [INAUDIBLE]

STEVEN SCHAIN: These are all PLA, and the reason why I use PLA is they're just easier print. So one of the things that with printing with FDM, anybody who's done it, is materials like ABS tend to warp. And since all the printers I had were open framed printers, I didn't want to use anything that was going to warp.

Color Fab has some great material. How many people that are printing are using FDM machines? So has anybody used the Color Fab NGEN, XT? They have a PLA-PHA blend that's super. Some of these are PLA-PHA. Some of these are just PLA, and you can see the difference. You can tell the difference.

The PLA-PHA from NetFab is just flexible and it's a little bit more durable. NGEN is a great material. It's easy to print. It's easily as good as ABS plastic. And then they have HT, which is a high temperature, and then XT, I don't remember what the XT is for. Is there another slide? I left this slide clicker up there.

AUDIENCE: [INAUDIBLE] for instance, with ABS some of us had the issue for actual prototype purposes, the shrinkage of it causing issues with their designs, and how can they start to account for that in their design, [INAUDIBLE]

STEVEN SCHAIN: That's really hard, and the reason why is it depends on the printer. It's entirely dependent on the printer. So we have a U-Print SC plus in my office, and I can print a part in that. It's ABS,

but it's in a temperature controlled chamber. So the shrinkage is controlled. So when I get the part out of that chamber, it's identical to the part I put in, the STL file I put in.

The Fusion 3 F306 is open, and I can print ABS, but I know that there's going to be a little bit of shrinkage. Now you could probably do is measure it. So come up with-- make a 1-inch cube and test what the shrinkage is.

AUDIENCE: Well, sure, but if it's not [INAUDIBLE].

STEVEN SCHAIN: Exactly, and your in-fill is going to change that as well. So lower in-fill will have less shrinkage than more in-fill. Thicker layers will have more shrinkage than thinner layers, depending on how high your bed is, and if you enclose it. Oh, one thing I did want to mention about these. So these were printed on different printers, and I tried really hard to accommodate the thickness of the badge across all the printers that we used.

And this falls right in line with what you're talking about. I spent a good hour and 45 minutes last night sanding a lot of these down in the middle because the badge from last year is literally like a couple of mills thinner than this year. And I don't know whether it's the coating that's on the badge that's different or whatever, but it's just minimally thicker.

So some of these little snugly fit on. Some are loose. I noticed that from the MakerBots, they tended to have a little more material that was printed out, and on the Craftbot there was a little bit light on that material. So it really makes a difference. The printer itself is going to vary your parts. You almost have to settle on one printer and say OK, we're going to do some classwork to figure out what the shrinkage rate is for that printer, and then we'll use that rate to figure out how to adjust our model.

AUDIENCE: But there's nothing like that built into Fusion already?

STEVEN SCHAIN: No, no, no. There's nothing, and there's really nothing built into the slicers either. Because the slicers are universal. If you're using open source ones like Cura or the Slice-3R, they have to accommodate so many different printers. All they do is set up the parameters for you, and then you have to figure it out. If you're teaching, it might be a good class project to take the printer that you're using and try and figure out what that shrinkage rate is based on certain parameters.

So if you're doing like 10%, 20% in-fill at a 0.2 millimeter layer thickness, what's the shrinkage rate on a wall that's 060 thick? And do that as a class project. I taught for years, and taught a

Fusion class that's based around 3D printing, and that never really came up, but it would be something interesting for the students to do I think. Figure out how to even measure it.

AUDIENCE: Yeah, I mean, we did do something similar to that, but that's where we ran into the issue of printing solids and [INAUDIBLE] that's more specific and has more holes in it, then it's [INAUDIBLE]

STEVEN SCHAIN: Yeah, and I had the Fusion F306 in our old office right next door. And this was the funny part, if I was printing ABS, you could tell when the door opened because there was a line in the print where cold air came in and blew on the model.

I want to give these out to everybody. So what we're going to do is Jerry and I are going to stand on either side of the doorway, and as you guys leave if you can grab one. Any other questions before we break?

AUDIENCE: What booth did you guys say you were in?

STEVEN SCHAIN: 2804.

AUDIENCE: 2804, [INAUDIBLE]

STEVEN SCHAIN: So no other questions? Thank you everybody. I really appreciate you coming.

[APPLAUSE]

STEVEN SCHAIN: Thanks.