Five Best Practices:

HOW INNOVATIVE UNIVERSITIES ARE INCORPORATING 3D PRINTING INTO THE CLASSROOM

By Stratasys, Ltd

3D printing has recently seen a surge in popularity in universities and colleges across the country. Educators are rushing to implement 3D printing into their curriculum and classrooms. Implementing 3D printing technology is just the first step, however. This report offers advice for helping faculty integrate 3D printing into their courses to improve student learning.

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In the 2014 NMC Horizon Report for Higher Education, 3D printing was chosen along with a handful of other trends as a major driver of technology planning and decision making over the next five years. As an expert panel reported, alongside new practices such as flipped classrooms and learning analytics, the use of 3D printing is expected to have "numerous implications for teaching and learning practice."

Although early forms of 3D printing technology first appeared in colleges and universities 30 years ago (the Horizon report notes that the University of Texas at Austin and MIT were a couple of the earliest pioneers in its use), schools are just now recognizing how they can make use of rapid prototyping to help students have authentic learning experiences that involve invention, design and production.

- At the University of Minnesota Medical School, for example, the urology department has used 3D printing to create anatomical models for students to practice surgical procedures on and to make substitutes of specialized tools too pricey for students to buy.
- The United Kingdom's Coventry University, which has won national awards for its Industrial Design program, has made 3D printing a linchpin in its automotive and product design courses.
- New England Institute of Technology has introduced 3D printing into its mechanical engineering program to help students learn the process of product development, from design through production and assembly.
- SCAD, the Savannah College of Art and Design, recently added a second workshop packed with 3D printing and other rapid prototyping equipment to accommodate the growing need for this form of experiential learning.
- An initiative at the Department of Aerospace Engineering at the University of Maryland is applying its 3D printers in research projects for the U.S. Army. Through rapid prototyping, the department has been able to reduce the amount of time and expense to reproduce experiments to tight military specifications.

In each of these cases a great amount of experimentation has taken place to help faculty learn how best to apply 3D printing in the classroom. This report shares five best practices gleaned from experienced instructors and workshop managers who have had years to effectively perfect the integration of 3D printing into their courses.

BEST PRACTICE #1.

Use The Workshop Like A Real Business

In the real world professional designers and engineers don't operate the 3D printers or other rapid prototyping equipment themselves. They hand their files over to workshop or service center personnel for final production. That's exactly how leading schools manage the work, too – with some educational twists. For example, students need a rundown on what services the workshop provides. Also, students need to learn how to communicate effectively with the technicians running the gear.

When college is in session, SCAD's lab runs two shifts of workers every day, seven days a week, from 9 in the morning until 10 at night, to service the needs of students and faculty. Just like a real business, students pay for the cost of the 3D materials used in their builds.

Although anybody on campus can come in and request a 3D print job, students typically start that process by taking a computer-aided design course in conjunction with the lab that incorporates the technology they need to understand.

As SCAD's Rapid Prototyping Operations Manager Justin Hopkins explains, students are assigned projects that fit within a given set of parameters. For example, for 3D printing, they may be told to design a flashlight no bigger than a 1-by-4-inch rectangle.

"The students will prepare the files and submit them and we'll make sure they fit inside the build envelope and that everything – files, file extensions and paperwork – is correct. If everything fits, we print them. If not, we'll tell them what's wrong with it and then they keep fixing the files until everything is correct. It just goes on and on until they understand how it works."

Once students have passed that class, he adds, "It's free range. They can come in whenever they want, no matter what they're doing – as long as the file is correct for our setups and they're ready to go."

That practice also helps students learn how to

communicate with an operator and understand the lingo – “STL file,” “inverted normal,” “bad stitching,” and similar in-depth terms. “If we can teach them now to know what that lingo is and understand what’s wrong with their designs and what’s expected when they leave, hopefully we’ll be able to get a perfect model next time and not have to have that conversation again,” notes Hopkins.

BEST PRACTICE #2.

Iterate, Iterate, Iterate

Design is an iterative process, and that’s a lesson every student needs to learn. What may look “perfect” on the screen won’t necessarily come out that way when it has been printed. “It might be fatter, it be might thinner; it might be too edgy; it might just have the wrong proportion. And you can’t really see that until you see it finished,” says Coventry Head of Industrial Design John Owen.

The idea that a designer can “sit down, make a sketch and expect someone to print a nice copy is just a fallacy,” he observes. “It’s part of a process really. You start with one thing. You change it, look at it, you have another idea about it, you change it again.”

On top of that, there may be flaws in the file as well. When the student submits an STL file for 3D printing at SCAD, the operator will quickly check it over for errors. A common mistake, says Hopkins, is bad stitching, where there are little gaps in between the surfaces of

Part of Coventry University’s industrial design curriculum includes working with 3D printers, like this Objet 3D Printer.

parts and the machine doesn't know what to do with them.

While the operator will show students where the problems are in the file and explain how to fix them, he notes, "We don't typically fix a file for them. The idea is that they have to keep doing it and doing it until it's correct because they won't learn it otherwise."

That hands-off philosophy applies to post-production work too, such as clean-up like sanding and painting. Students "have to get their hands dirty at some point to understand the process in general," Hopkins explains. They'll also learn the value of the various techniques they can use for prototyping – whether it's worthwhile to print a cylinder in 3D "as opposed to going to the shop and using a lathe and turning it because it'll take less time and be more accurate if they possess those [machining] skills."

Faculty can help guide the iterative nature of the design by asking students leading questions that can get them thinking about how their part should be built, advises Hopkins: Do you want the part to look cleaner? Do you want it to be stronger?

"Typically the student wants it as fast as possible. Usually the fastest way is not the best or cleanest way. It depends on how much of a hurry they're in."

BEST PRACTICE #3.

Faculty And Workshop Staff Work As A Team

The best results for students come when faculty and workshop staff collaborate. Hopkins advises the instructors he works with at SCAD to talk to him as they're designing new curriculum to make sure they understand the capabilities of the workshop. The benefit of doing that, he points out, is that the workshop will commit a specific 3D printer to a given class project based on the nature

An architectural student at the New England Institute of Technology used the school's Dimension 3D Printer to design a four-foot skyscraper.

of that lesson. “That way we can keep the flow going all 10 weeks as opposed to everything getting crammed in at the very end of the quarter.”

While that practice holds true for the first seven weeks, the final three weeks of the term are first come, first served If a faculty member assigns a class project during that period, he notes, “students have to get in line.”

When Hopkins meets with faculty, he emphasizes the need for them to teach their students how to set up files properly in the design software. He also reminds them that his operators have the right to reject incorrect or frivolous files. “If we’re really full and the student wants to print something that’s really silly, like a sphere, when they could go buy a ping pong ball to make the same thing, we still reserve that right of saying, ‘All right, this is a waste of time.’”

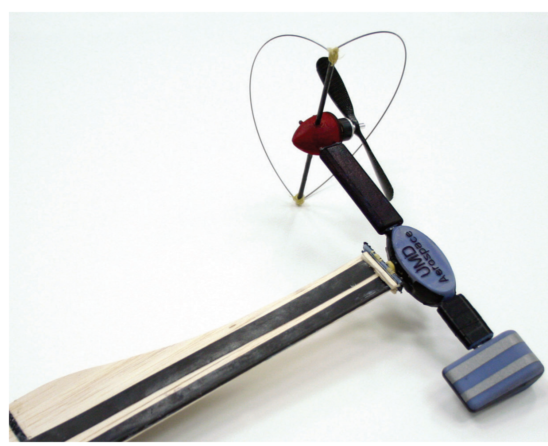
BEST PRACTICE #4.

Choose The Right Tools For The Job

Just as design programs try to integrate the use of software that’s prevalent in the jobs their students will pursue, the equipment they choose for doing rapid prototyping and 3D printing should be professional-grade as well. The use of industrial-caliber hardware and software gives students experience and confidence in the tools they’ll eventually work with on the job.

So the selection of 3D printers used by the college or university must fit the purpose. Hopkins continues championing the investment into commercial-grade equipment as opposed to hobbyist-level 3D printers. “It’s fun for the person who wants to tinker with it,” he explains, but “the hobbyist machines don’t produce the parts the industrial machines will.” Plus, he notes, the high-end equipment “lasts a lot longer and they’re more bullet proof.”

Fortunately, he adds, pricing for industrial-level equipment continues to come down. The latest



The University of Maryland has improved aerospace research by using PolyJet technology to compress the prototype development cycle.

The University of Maryland's funding from the U.S. Army helps analyze alternate modes of flight for potential military applications.

3D printer SCAD purchased was close to half the price of the first version of that model the school acquired.

There's also the question of what type of 3D printer to acquire – extrusion or resin. The extrusion variety (or fused deposition modeling – FDM®) heats thermoplastic to a semi-liquid form and deposits it in a tiny thread along the path defined by the design software. Where support is required, the 3D printer lays down additional threads to act as scaffolding. During the clean-up process, the user breaks away that support material or dissolves it in detergent and water and does final work on the printed parts, such as gluing or fitting them together.

PolyJet™ printing works like an inkjet printer. The 3D printer sprays a complete layer of droplets of liquid photopolymer onto the build tray, and that digital material hardens with exposure to UV light. In places where there's an overhang or a complex shape, the printer sprays a gel-like material that's removed during the clean-up process.

Choosing one type of 3D printer over another is a matter of "give and take," Hopkins points out. One model may be faster in producing the printed piece while an alternate model may promise faster clean-up. SCAD runs both types of printers for different purposes. Printed parts may require a certain level of detail that's better suited for production by one printer than another, he explains.

When Hopkins is asked by other institutions how to go about equipping a new lab, he recommends starting with an extrusion type machine. He's a long-time fan of FDM technology models, such as the uPrint®, Dimension® and Fortus® lines of 3D printers. However, his two workshops also run Objet® printers, which use resin-based PolyJet technology.

"They're workhorses," he declares. "Service on them is very inexpensive and they just don't break down."

Another plus: the software that runs on the Stratasys® 3D printers will pre-check the basics of a design and let the operator know via the console whether there's something wrong about it that will prevent the print job.

BEST PRACTICE #5.

Seek Continual Improvement

The most responsive schools are always looking for better ways of doing what they do, whether that's in academic or operational areas. Pursing a philosophy of continual improvement requires participants to seek out colleagues within other institutions to share lessons learned and to borrow good ideas from other industries.

For example, when SCAD's Hopkins has the chance to interact with managers from other schools, talk will turn to what equipment they have and what they like about it. "That's the only way to get a judge of what's good and what's bad and what fits into your program," he says. "Another technician will tell you the truth about those things."

As a speaker at 3D printing and related industry forums, he has also met and talked with a number of operators who run workshops for major manufacturers. What he's learned from them is that the challenges his team faces in working with students are the same ones they face in working with professional engineers.

“We’re all fighting the same fight,” Hopkins says. That’s why he’s determined to help students learn foundational skills – how to provide a file that’s ready for printing, how to tweak the work when something’s wrong with the design, how to choose the right approach for building a part or doing rapid prototyping.

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