TURNING STUDENTS INTO INQUISITIVE CREATORS

HOW 3D PRINTING TRANSFORMS REAL-WORLD DESIGN AND PRODUCTION CHALLENGES INTO LEARNING

By Stratasys, Inc.

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White Paper

Manufacturing is making a comeback in the United States, according to the *New York Times*, Boston Consulting Group and the *International Business Times*. If that's true, it's partly because higher education has been helping students learn design and prototyping work.

The NMC Horizon Report > 2014 Higher Education Edition reports that this movement on university campuses enables students across disciplines to learn "by making and creating rather than from the simple consumption of content." Hands-on learning has become "an integral part of the curriculum." The NMC Horizon report adds, "Academic makerspaces and fabrication labs have popped up on university campuses in a variety of places."

The National Science Foundation is funding research about 3D printing, also called additive manufacturing, to understand "the educational benefits of makerspaces and the transferability of that type of learning to math and science skill improvement."

This kind of education, stimulated by a hands-on mentality and manifested in places like Stanford with its d.school and Olin College with its reboot of engineering instruction, is the best recipe this country has for turning students into innovators, according to Tony Wagner. Wagner, the author of "Creating Innovators: The Making of Young People Who Will Change the World," says innovative thinkers and designers are what's needed to enable the country to become the kind "that produces more ideas to solve more different kinds of problems."

Not surprisingly, as manufacturing, making and innovation converge in education, 3D printing is becoming more crucial to curriculums. As the following examples demonstrate, giving students access to 3D printers turns them into thinkers, designers and builders — the kinds of disciplines that form the heart of higher education in the 21st century.

MERGING DESIGN AND MANUFACTURING

Traditionally, design and manufacturing have been separate disciplines. The designer would generate computer-aided design (CAD) models to pass off to the manufacturer, who would run a check on the design and kick it back to the designer for rework should the material properties of the object prove unworkable. The time-consuming nature of this process set up hurdles to realizing new ideas quickly.

Those days are disappearing. Now designers are expected to be able to frame problems and model them. The change has come about thanks to the use of 3D printing. In this process, a 3D CAD model is designed; an STL file is generated and put through "slicing" software that communicates with the printer about how to construct the object; and, finally, the part is constructed layer by layer, starting from the bottom and working up. Applications from 3D printing, ranging from prototyping and end-use parts to the medical, automotive and commercial industries, are still being explored.

CHANGING THE NATURE OF CREATION

Virginia Tech uses its 3D printers to educate students but also improve product design.

Virginia Tech has become a leader in using 3D printing to advance the breadth of student knowledge and help educators and the industry to rethink product design and manufacturing. The power of 3D printing, says Chris Williams, a member of the faculty in Virginia Tech's Department of Mechanical Engineering and Department of Engineering Education, is that, "If you can draw it, we can print it."

Williams leads the Design, Research, and Education for Additive Manufacturing Systems (DREAMS) Lab at the university. At last count, the lab contained nearly a dozen different kinds of 3D printers, including an Objet®350 Connex™ 3D Printer.

This state-of-the-art 3D printer uses a process that allows for the creation of parts or assemblies made up of different materials in a single build. As Williams explains, the printer has a "scientific way" of laying down dots (called "voxels" in 3D vernacular) to achieve a mechanical property in a consistent and repeatable way.

Engineers gain design freedom because they can access every part of a printed piece during the build process, not just the exterior faces. They can create functional parts without the need for assembly. Likewise, 3D printing allows the building of geometrics that couldn't be fabricated in any other way. Along the way, those capabilities reduce waste, minimize the use of harmful chemicals traditionally used for etching and cleaning, and offer the possibility for using recyclable materials. The Objet350 Connex 3D Printer changes the nature of design and manufacturing from the moment creation begins.

Now researchers at Virginia Tech are exploring the use of the Objet350 Connex 3D Printer to lay down "quantum dots" for use in cryptography, optical sensing and programmable matter applications.

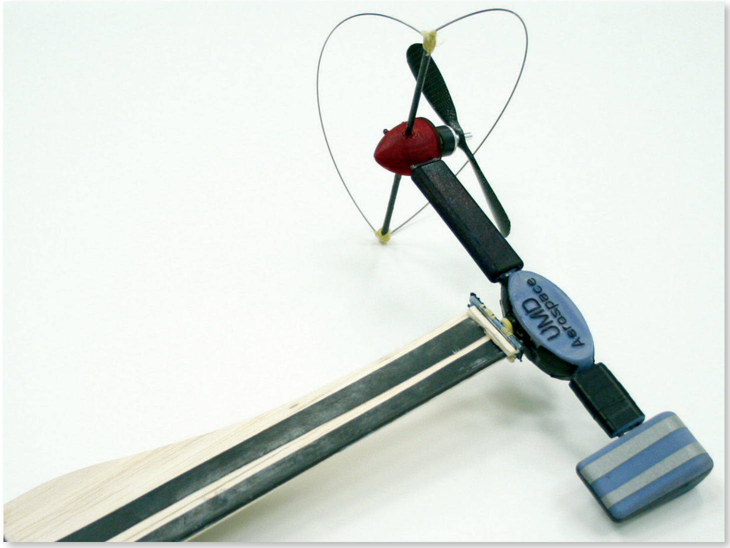
DESIGN, PROTOTYPE, REPEAT

Beyond use in institutional research, 3D printing is well suited to student projects since it enables learners to prototype ideas and bring their projects to life quickly and repeat the process until the results are what they want.

For example, in a second-year mechanical engineering course at Virginia Tech, students had an idea to create a Swiss army knife-like device to hold their keys. They created a "beautiful" CAD model, Williams recalls, with a lot of modularity built into the design and quickly moved to the printing of the object. It was only after they could try it out in real life that they discovered their mistake: It didn't fit well in a pocket; it was too bulky. "It wasn't until they held it in their hands that they realized they needed to redesign it," says Williams.

In a more sophisticated application, students and faculty created and tested a mini wind turbine the size of a soda can and capable of charging small electronic devices and powering remote sensor networks. "Before we had additive manufacturing, there was no way to make that product a reality," Williams says.

3D printing has also been applied at the university in "biomimicry" projects, in which the study of designs in nature leads to design breakthroughs in other fields. Students have used 3D printing to create a robotic typing hand that would previously have been



The University of Maryland has improved aerospace research by using 3D printing to compress the prototype development cycle.

machined out of aluminum, a time-intensive, wasteful process that doesn't allow for quick iterations. They've created flexible models of horseshoe bat ears to help a researcher conduct acoustics testing. They've created parts for soccer-playing robots and master patterns for statues of the university mascot. And they've made a silicon jellyfish with embedded actuation.

The use of the 3D printer and other 3D printing technologies have also helped Chelsea Cook, a physics major with a goal of becoming an astronaut – who also happens to be blind. A full load of courses included multivariable calculus, a tough class to pass if the student is unable to see the shapes and shadings of paraboloids or hyperboloids. The answer: create 3D objects that she could feel.

HIGH TURNOVER PROTOTYPING

At the University of Maryland, aerospace and other engineering students have used 3D printing to enhance their overall testing cycle and design processes.

For years the Department of Aerospace Engineering has sought the best way to produce large volumes of highly accurate prototypes for its work in designing aerospace components, vehicles and systems. The U.S. Army, for instance, funded research related to alternate modes of flight. That kind of repetitive experimentation called for the construction of numerous completely identical prototypes.

Darryll Pines, dean of the University of Maryland's Clark School of Engineering, was convinced that 3D printing technologies could be used in this application. After evaluating several choices, the department selected an Objet® Eden350V™. "The Eden350V 3D Printer was selected based on its exceptional resolution, accuracy and detail and durability," says Pines, who oversaw the acquisition.

Immediately, the Objet Eden350V 3D Printer reduced the prototype development process by a "full year" and generated savings of about $80,000 a year, reports Evan Ulrich, a former graduate research assistant who is now an embedded system applications engineer at the Aerospace Corp. The 3D printer "eliminated the need to pay for homemade prototype material such as aluminum and plastics that outside vendors marked up by nearly 1,000 percent," Ulrich explains. Even more important, the use of the 3D printer enhanced the validity of the department's research findings by ensuring that test objects were always precisely identical.

According to Ulrich, all aspects of the testing apparatus are now constructed with the Eden350V 3D Printer. "There's no waiting on other people, as we can produce our models in-house at a much faster speed than ever before," he says. "This machine has fundamentally improved our overall process, completely revolutionizing our ability to do research on this scale."

In his own dissertation research, Ulrich used 3D printed prototypes to study the flight patterns of spinning plant seeds, which led to the invention of the first (and patented) at-scale robotic maple seed. This in turn led to the launch of RoboSeed, his startup company that develops small drones for surveillance and reconnaissance.

Pines believes the use of the 3D printer's PolyJet™ technology "can help engineers and those who train them to better execute some of the most sophisticated and technical research studies in the world. It represents the future of aerospace studies and will surely help our best minds achieve the next generation of scientific breakthroughs."

PROMOTING THE ART OF DESIGN

STEM-oriented students aren't the only ones focusing on design capabilities. Towson University's Object Lab allows art and design majors to use the Objet30 Pro™ 3D Printer and other 3D printers to apply their creativity in multiple ways.

Lab director Jan Baum recruits off-campus clients to offer up real-world challenges. When a local manufacturer sought a way to improve its car spring-making process, students working in the Object Lab came up with a more efficient design. They've also collaborated with the university's occupational therapy program and with biomedical engineering students at the other Baltimore institution, Johns Hopkins University, to create the housing for a device that enabled a girl with muscular dystrophy to use a sewing machine.

"The applications are endless," Baum says in a campus magazine. These applications can range from production of tools to bespoke machine parts used in health care and art.

SETTING UP REAL-WORLD EXPERIENCE

Students at the Art Center College of Design use 3D printing to work on transportation design, like this Ford model.

Students at the Art Center College of Design in Pasadena, CA, have learned how to enhance the design process in the transportation industry. Every major automobile design organization in the world has come to the Center to meet with students and sponsor projects, says faculty member David Cawley.

Besides teaching courses in 3D printing techniques, Cawley runs the rapid prototyping and model shops. This is where students bring their designs to create the 3D models for their projects. The shops have multiple printers from several vendors, each of which excels in specific ways. For example, the budget-oriented uPrint® SE Plus™ 3D Printer comes in useful for the production of remote-controlled cars, which need to stand up to rigorous testing at high speeds. When the project requires extremely high resolution, intensely smooth surfaces, thin walls or tiny moving parts, students are directed to the Objet30 Pro 3D Printer, a small footprint printer that can print in extraordinary detail in up to seven different materials, including high-temperature photopolymers.

As Cawley recounts, Jaguar executives brought their newest vehicle to campus, allowing students to scrutinize it inside and out. When students asked, “How much of this was developed using 3D printing?” the visitors replied, “Almost everything in that car is created with 3D printing.”

Cawley notes that when visitors “see we have the Stratasys 3D Printer, it makes a difference. It gives us an edge.” Because that line of 3D printers is the same one used in the industry, he explains, “We’re setting students up for real-world experience.”

NURTURING THE “EXTRA” IN LEARNING

The use of 3D printing in colleges and universities is helping to nurture creativity and satisfy intellectual curiosity among students. Just as important, the fast-paced prototyping cycle made possible by industry-grade 3D printers is preparing students for the real world. They can develop their ideas rapidly, bring their designs to life quickly, integrate combinations of materials that may never have been tried before, and create amazing objects that model the innovations with high accuracy, fine detail and moving parts.

Nobody can predict the overall impact of 3D printing on higher education. But if the transformation taking place in these schools and others like them is any indication, learning will never be the same.

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