Applications of 3D Printing

The Design Technology Pathway at Pasadena City College, **SALOMÓN DÁVILA** (Career and Technical Education, Pasadena City College, 1570 E. Colorado Blvd, Pasadena, CA 91106-2003; sgdavila@pasadena.edu).

The Design Technology Pathway in the School of Career + Technical Education at Pasadena City College is now in its third year. Students are achieving strong results as the innovative program continues to lead the way by integrating academic, professional and technical skills in a meta-major focused on career exploration. Designed for recent high school graduates with an interest in design and technology related careers the Design Technology Pathway (DTP) at Pasadena City College offers a fully supported college transition into a full two year program in Design Technology leading to certificates, degrees and transfer.

The pathway features coordinated high school transitions, priority enrollment, dedicated resources including coaches, counselors and tutors, state of the art fabrication and computer labs, and access to all college services. Using a broad range of technologies from CAD to laser cutting, 3D scanning and printing, robotics and social media production, students develop design prototyping techniques. The meta-major approach to college education allows students to critically evaluate their career interests through exploration of Career Clusters, groups of convergent or related careers within an economic region. Real time Labor Market Information and career development support give students an understanding of life long learning strategies for long term career planning. Understanding that the jobs of the future have yet to emerge, Design Tech Students are poised to take advantage of opportunity through a highly developed sense of entrepreneurship.

3D Printing as a Curricular Tool in Design and Engineering for the Secondary Curriculum, **SIMON P. HUSS[1]*, REGINA RUBIO[1], and JOAN HORVATH[2]** ([1]Science Department, Windward School, 11350 Palms Blvd., Los Angeles, CA 90066, shuss@windwardschool.org; [2]Deezmaker 3D Printers, 290 N. Hill Ave, Pasadena, CA 91106, joan@deezmaker.com).

Over the course of an academic school year, Deezmaker 3D printing technology was used to facilitate and augment design instruction in a variety of curricular and extracurricular settings at Windward School, an independent 7-12 grade school in West Los Angeles. Three distinct examples are detailed in this presentation: a 3D printing middle school elective course, an individual 3D design project for a Principles of Engineering survey course, and an independent campus-wide engineering application. In all cases, successes and challenges in incorporating readily available 3D printing technology into the curriculum and the anecdotal learning outcomes are discussed. Expansion of the program to include 3D scanning technology and the development of a prototype maker space are also detailed.

Open-Source 3D Printing Projects as Multidisciplinary Learning Tools, **KRISTIAN WITTMAN** (Mechanical Engineering Department, Shiley-Marcos School of Engineering, University of San Diego, 5998 Alcalá Park, San Diego, CA 92110; krwittman@sandiego.edu).

Open-source projects involving filament deposition modeling 3D printing offer rich and diverse learning opportunities for students. The assembly, set-up, and use of a 3D printing kit can provide a broad range of educational opportunities relating to several prominent STEM topics. These include: manufacturing, assembly, electronics and circuits, programing, vibration, mechatronics, heat-transfer, plastics and extrusion, modeling and design, and most importantly, critical thinking and troubleshooting. 3D printing, as a teaching tool or learning module, can create an engaging, multidisciplinary environment for students to expand their knowledge and skills. From Fall 2012 through Spring 2013, presenter Kristian Wittman worked with a team of 4 other mechanical engineering seniors at the University of San Diego to build and design improvements for an open-source 3D printer. Through this endeavour, each member of the team developed skills involving all of the above topics. The fall semester was spent assembling and analyzing an open-source 3D printer purchased online. The team focused on designing improvements for this printer, while simultaneously seeking to bring the original model online. In the spring, the team attempted to build a second 3D printer based on their designs. In addressing the many technical obstacles and frequent setbacks of the project, the team was provided with a rich and challenging learning experience.

3D Printing Nautical History at the MIT Museum, **JOAN HORVATH[1]*, DIEGO PORQUERAS[1], KURT HASSELBALCH[2]** ([1]Deezmaker 3D Printers, 290 N. Hill Ave, Pasadena CA 91106, joan@deezmaker.com, deezmaker@gmail.com; [2]MIT Museum, 265 Massachusetts Ave., Building N51, Cambridge, MA 02139, kurt@mit.edu).

The Hart Nautical Collections at the MIT Museum contain many drawings of historic ships and their components. However, plans on aging paper can be difficult to visualize. This paper will describe the process used to go from drawings in the Hart Collection to 3D printed versions using a small consumer-level fused filament fabrication 3D printer. Items replicated include an 1890 cleat from a ship designed by the legendary nautical architect and mechanical engineer Nathanael Green Hereshoff and a hull by yacht designer William Hand.

Translating the drawings into a 3D-printable computer aided design file required some interpretation and some knowledge of the assumptions that a shipbuilder would have made when reading the drawings. A presentation of the drawings, the resulting 3D prints, and a live demonstration of printing some of the historical objects are all planned to occur at the MIT Museum during the April 2014 Cambridge Science Festival. The authors will discuss the visitor reactions, the lessons learned, and future plans for making history rise from the page with small consumer 3D printers.

Designing DNA Nanosystems through 3D Printing, **MATT GETHERS[1]*, SI-PING HAN[1], LISA SCHERER[2], JULIAN VOSS-ANDREAE[3], WILLIAM A. GODDARD III[1]** ([1]Materials and Process Simulation Center, California Institute of Technology, Pasadena CA, 91125, mgethers@caltech.edu, si-ping@wag.caltech.edu, wag@wag.caltech.edu; [2]City of Hope, 1500 East Duarte Road, Duarte CA, 91010; lscherer@coh.org; [3]Julian Voss-Andreae, 1517 SE Holly St., Portland, OR 97214, info@JulianVossAndreae.com).

DNA nanotechnology has proved to be a powerful approach to nanoscale engineering by self-assembly, the ability to adopt varied geometries, and precise arrangement of molecules by utilizing the natural spacing of DNA bases. This has stimulated interests by a large number of researchers from disparate fields. However, the small size of DNA makes it difficult to visualize the structures being designed. This is unfortunate since visualization is critical for design, especially for systems with many components and complicated geometries where the mind's eye is insufficient. Computer modeling provides an indispensable tool in addressing this challenge, but it too has limitations, typically requiring specialized and expensive software, and limiting the designer's creative expression to whatever functionalities were included in the software. We proposed that 3D printing can help the critical visualization of design in a number of ways. 3D models are not hampered by the limitations of the computational interface, so the designer can freely and rapidly test new ideas. Further, by physically handing the model, the designer gets an intuitive feel for the relative shapes and sizes of the system. Importantly, a physical model of the target system also facilitates collaborative discussions. In this presentation, I will present some of the DNA systems being studied by our group and will show how we have used 3D printing to aid in the design of those systems. Financial support of this ODISSEI project was provided by the National Science Foundation (EFRI-1332411).

3D Printing Protocols for Tissue Printing in an Academic Setting: A Strategy for Printing a Human Cornea, **ANDREW BARAJAS[1]*, KEVIN KIM[1], LEEOR ZIBERMINTZ[1], PAUL SCHUBER[2], JOEL WEST[2], and ANNA HICKERSON[1]** ([1]Department of Biomedical Engineering, [2]Department of The Business of Bioscience, Keck Graduate Institute School of Applied Life Sciences, 535 Watson Drive, Claremont, CA 91711; abaraj14@students.kgi.edu).

The objective of this project was to devise tissue printing protocols, that utilized commercial 3D printing technology, in order to artificial print and grow a cornea. This research includes strategies in converting an open source 3D printer to allow for cell scaffold printing, as well as procedures in growing tissue and establishing focal adhesion onto printed scaffold structures, in an academic setting.

A machined aluminum mold was developed in CAD that contained various cornea sizes simulating the basic curvature and form of corneas seen in humans and various types of animals. A specially formulated poly(ethylene glycol) diacrylate (PEGDA) hydrogel was developed, that was extruded using a syringe pump, to create cell scaffolding within each mold to all allow for cell growth. Cornea cells were then implanted on each scaffold and allowed to grow digesting the scaffold and taking the shape of the mold. The optical properties of the artificially grown corneas, as well as the cell viability, where then tested in comparison with naturally grown corneas.

Utilizing these protocols, the Keck Graduate Institute (KGI) hopes to further develop its 3D printing program with its focus on medical applications. It is the belief that such a program would allow KGI students to continue to pursue research in the area of regenerative medicine and develop new, innovative uses for 3D printing technology in a biological setting.

Development and Initial Porcine and Cadaver Experience with Three-Dimensional Printing of Endoscopic and Laparoscopic Equipment, **MICHAEL DEL JUNCO[1], RENAI YOON[1], ZHAMSHID OKHUNOV[1], RAMTIN KHANIPOUR[1], SAMUEL JUNCAL[1], GAREN ABEDI[1], ACHIM LUSCH[1], JAIME LANDMAN[1], and BENJAMIN DOLAN[2]*** ([1]Department of Urology, University of California, Irvine, 333 City Boulevard West, Suite 2100, Orange, CA 92868; [2]RapidTech, 445 Engineering Tower, Bldg. #303, Irvine, CA 92697; dolanb@uci.edu).

Introduction: Recent advances in three-dimensional printing technology have made it possible to print surgical devices. We report our initial experience with the printing and deployment of endoscopic and laparoscopic equipment.

Methods: We created computer-aided designs for ureteral stents and laparoscopic trocars using SolidWorks. We developed three generations of stents, which were printed with an Objet500 Connex printer, and a fourth generation was printed with an EOSINT P395 printer. The trocars were printed with an Objet30 Pro printer. We deployed the printed stents and trocars in a female cadaver and *in-vivo* porcine model. We compared the printed trocars to two standard trocars for defect length and area.

Results: The first two-stent generations (7Fr and 9Fr) could not be printed with the lumen required to pass a guide-wire. The third generation 12Fr stent allowed passage of a 0.035 guide-wire. The 12Fr diameter limited its deployment, but it was introduced in a female cadaver through a ureteral access sheath. Fourth generation 9Fr stents were printed and deployed in a porcine model using standard Seldinger technique. The printed trocars were functional for the maintenance of pneumoperitoneum and instrument passage. The printed trocars had a larger superficial defect area ($p<0.001$) and length ($p=0.001$) compared to Karl Storz, and Ethicon trocars (29.41mm², 18.06mm², and 17.22mm², respectively and 14.29mm, 11.39mm, and 12.15mm, respectively).