

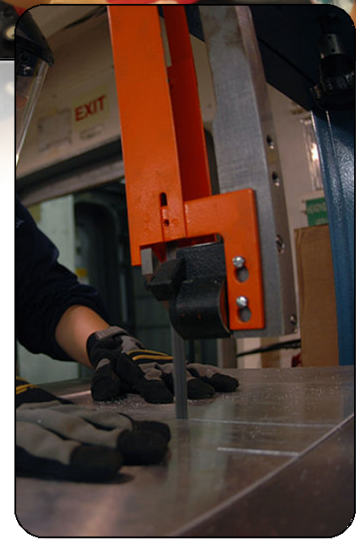
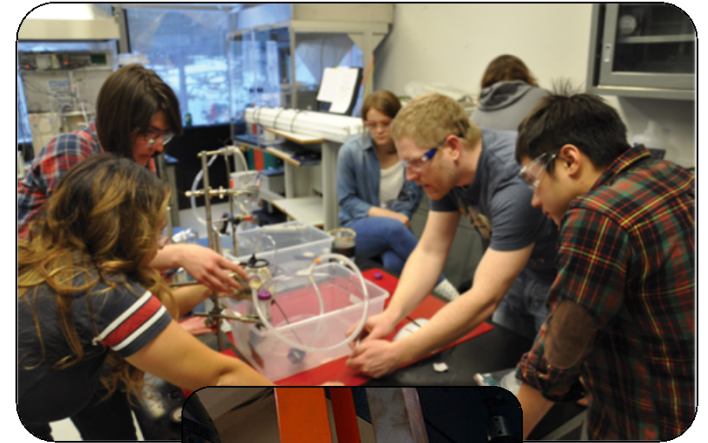
INCORPORATION OF 3-D PRINTERS & LASER CUTTERS INTO CHEMICAL ENGINEERING CURRICULUM

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University of Utah, Department of Chemical Engineering

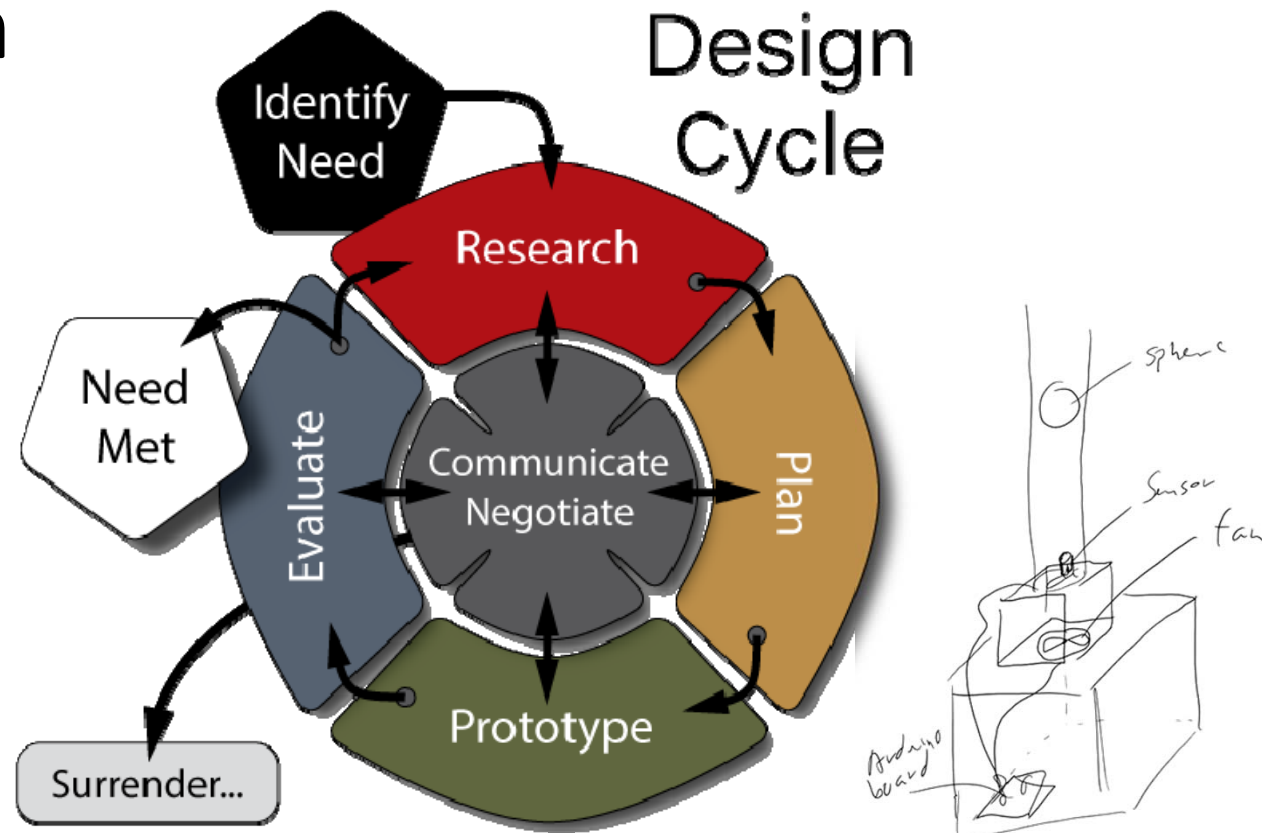
Motivation

- New freshman lab.
 - Open-ended design projects.
 - **“BUILDING CHEMICAL ENGINEERING STUDENTS FROM MISCELLANEOUS PARTS & VAGUE INSTRUCTIONS”**
Tomorrow, 1:34 PM, in Room M102
- Have you seen the average Chem E freshman handle power tools?



How to get our freshmen from an original plan to an authentic prototype?

- Avoiding cookbook labs.
- Keeping it safe.
- Maximizing creativity.



Maybe a Laser-Cutter & 3-D Printer?

- Covers both additive and subtractive manufacturing.
- Submitted a College of Engineering equipment proposal.
 - Got funded...
- Now what?

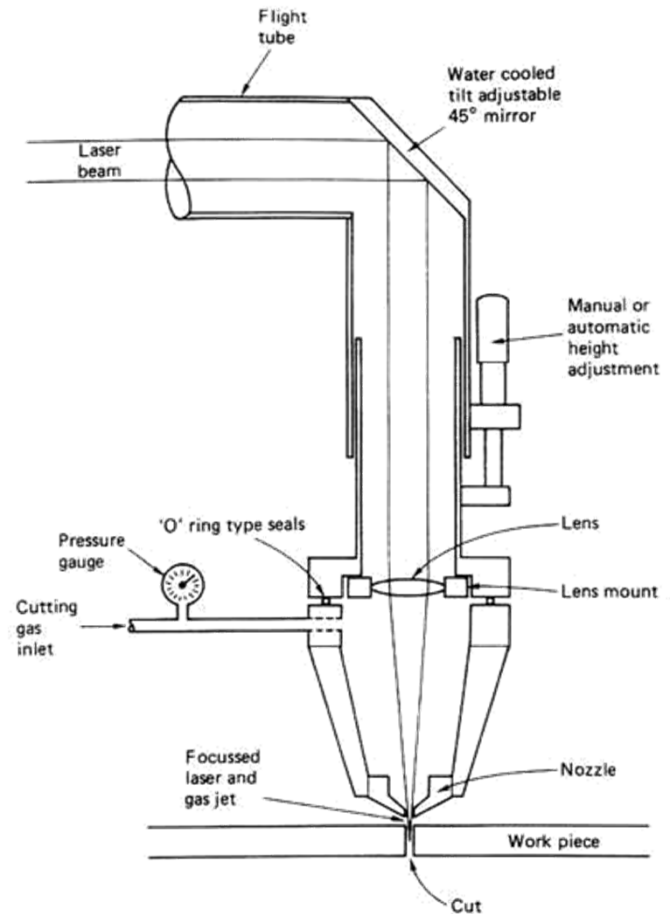
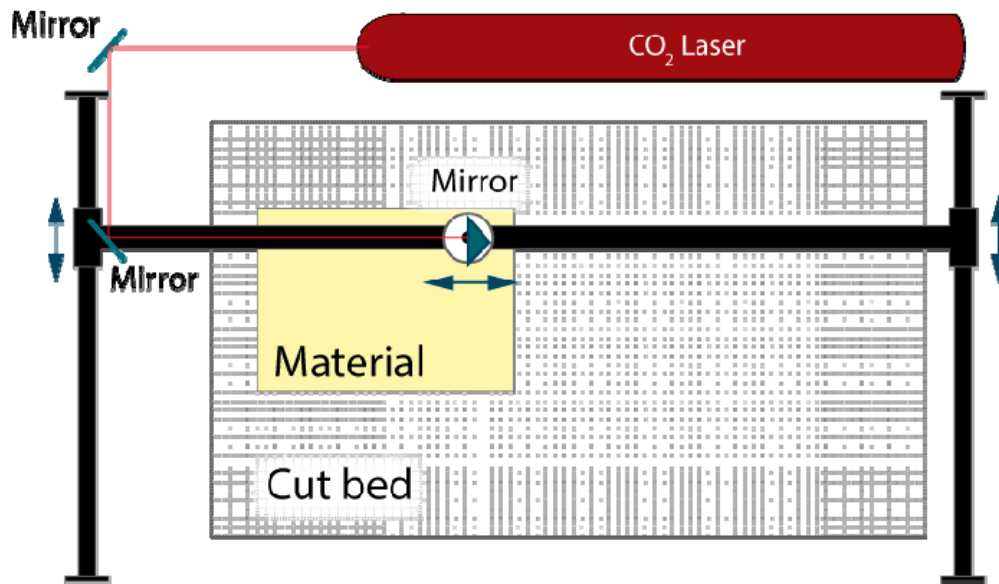
Our Choice of Laser Cutter

- 80 W Laser.
- 40 cm x 50 cm cut bed.
- About \$10k*.
- Will cut:
 - Plastics**
 - Acrylic
 - Wood
 - Fabric
 - Paper
- Will etch:
 - All that...
 - Glass
 - Anodized Al



Laser Cutter Basics

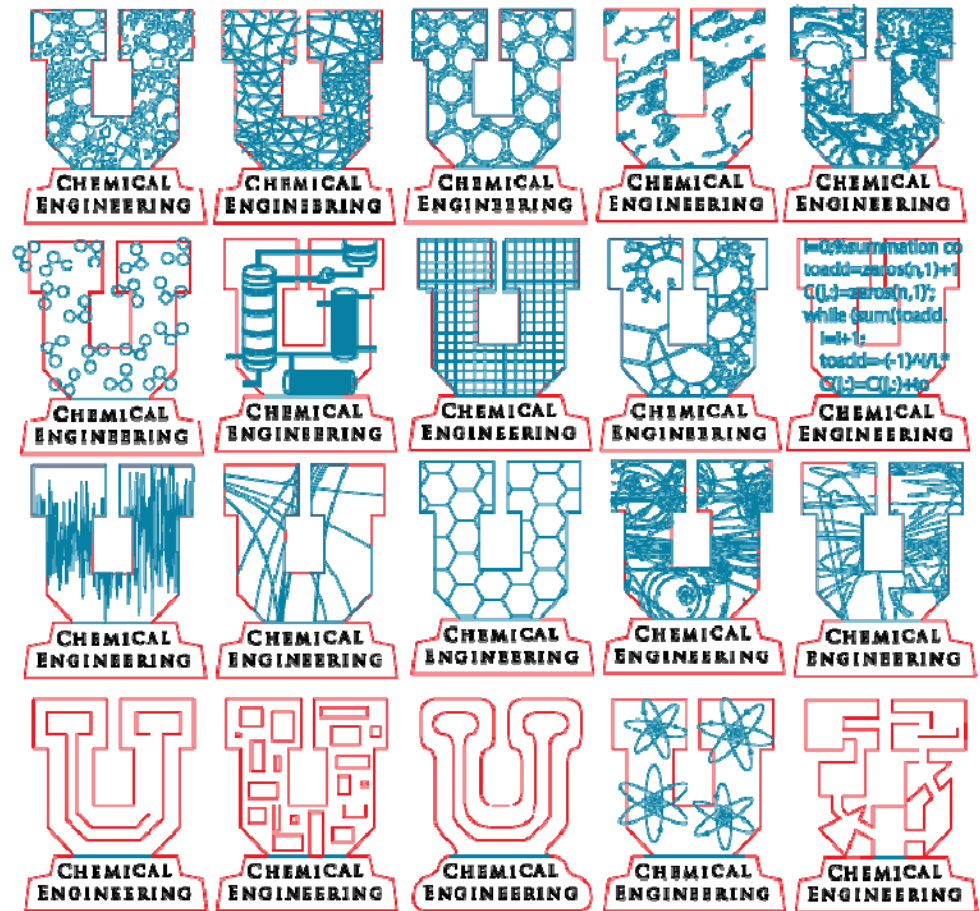
- Water-Cooled CO₂ Laser reflected and focused onto material.

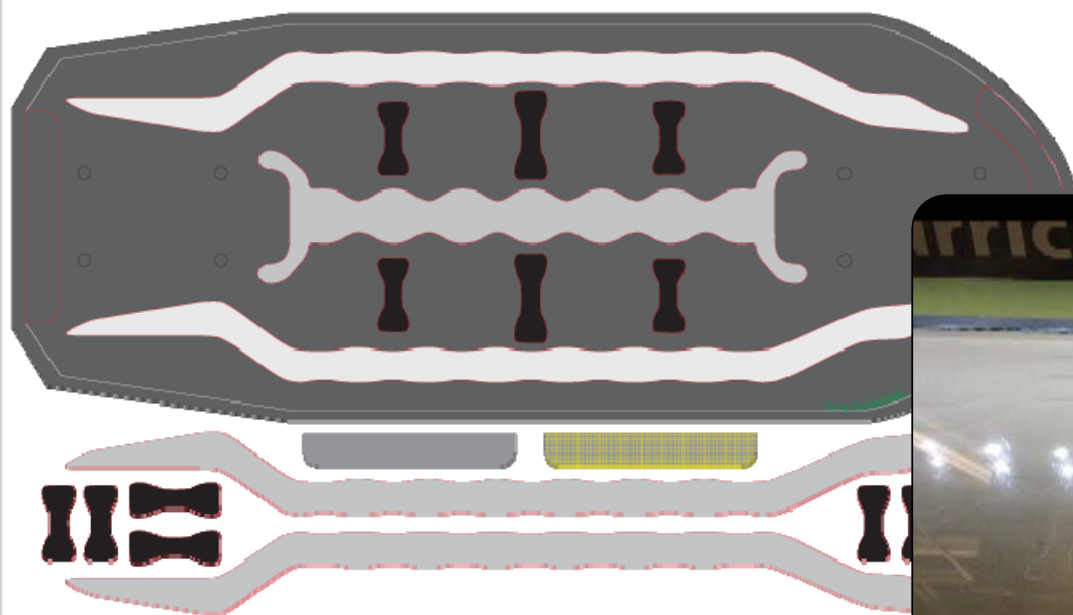


<http://upload.wikimedia.org/wikipedia/commons/1/1d/LaserCutter.jpg>

Design Software

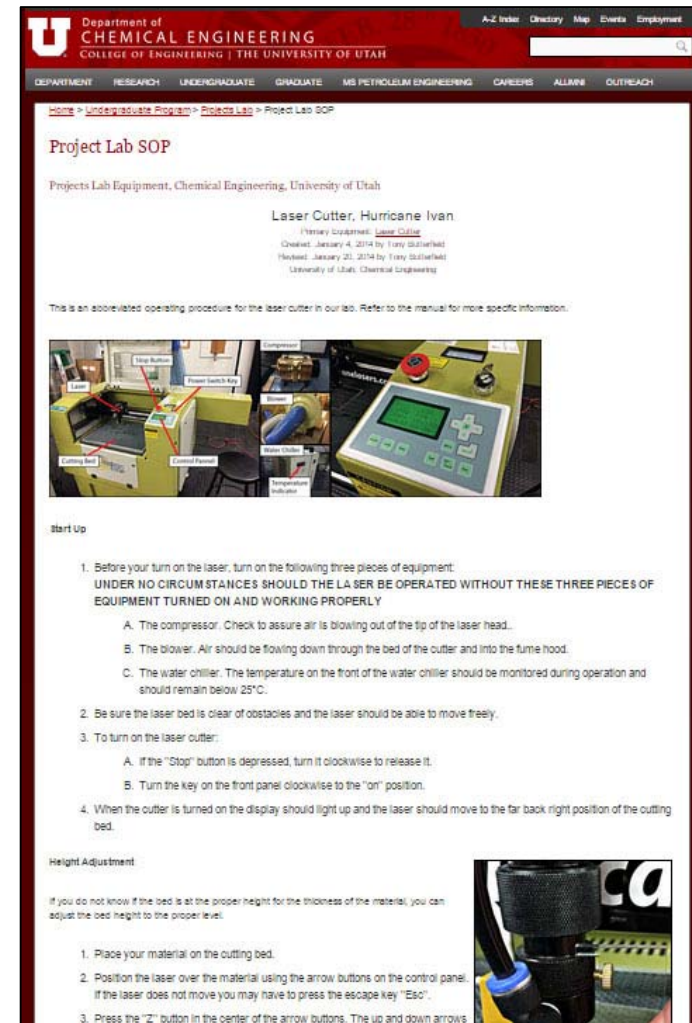
- Typically: DXF files.
- Any CAD program.
- Adobe Illustrator.
- Inkscape.
 - Free...
 - <http://sourceforge.net/projects/inkscape/>
- Different line colors control:
 - Laser speed.
 - Laser power.
 - Gradients.
 - Cut vs. etch.



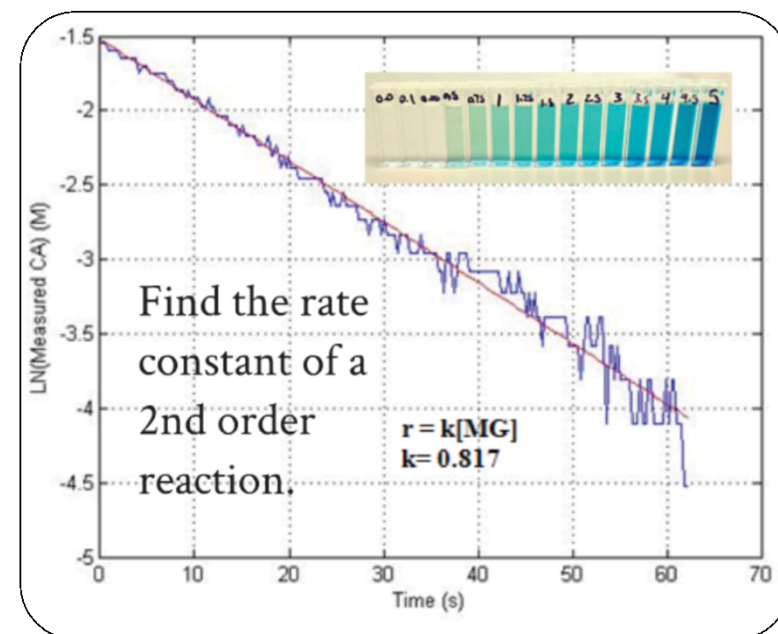
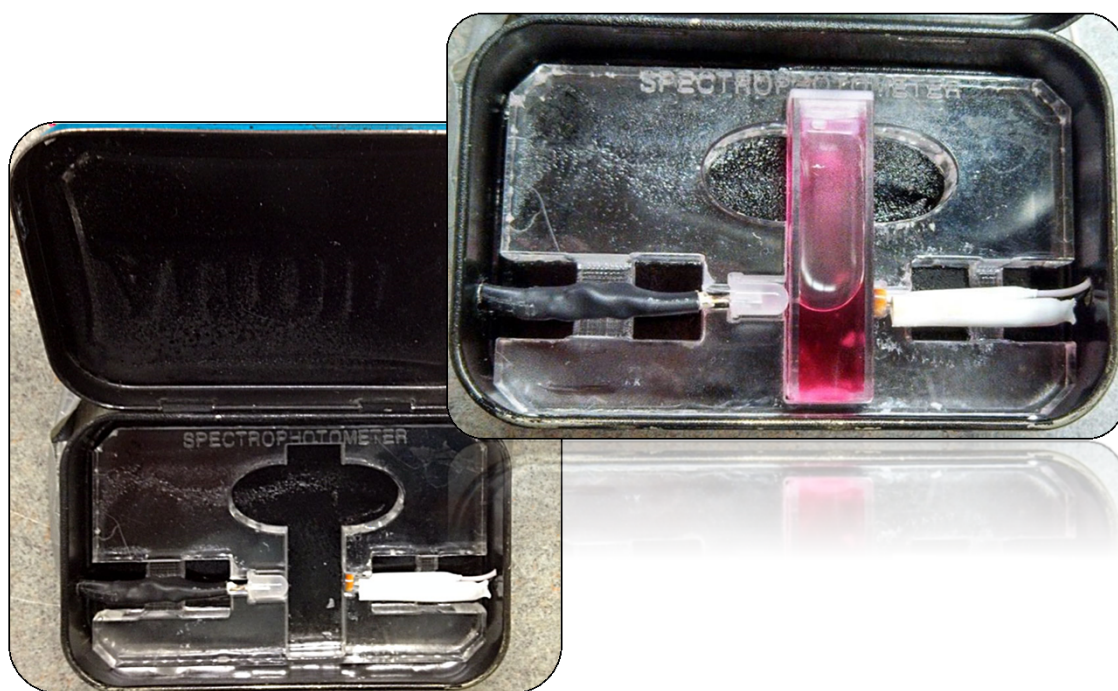


But How Do Our Students Use This Tool?

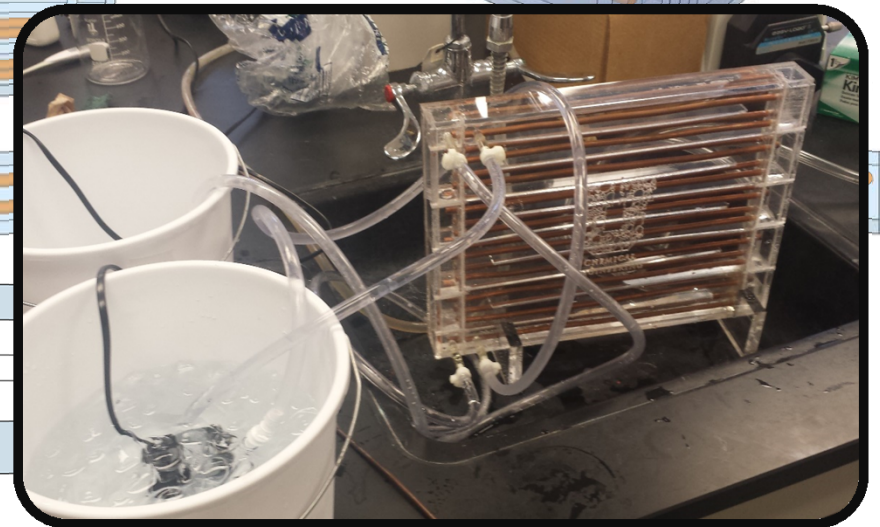
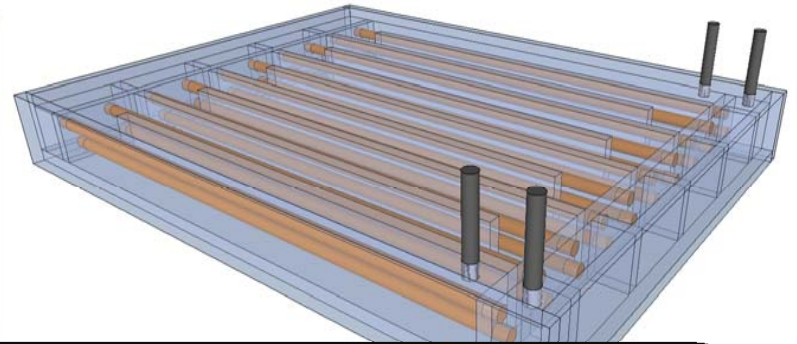
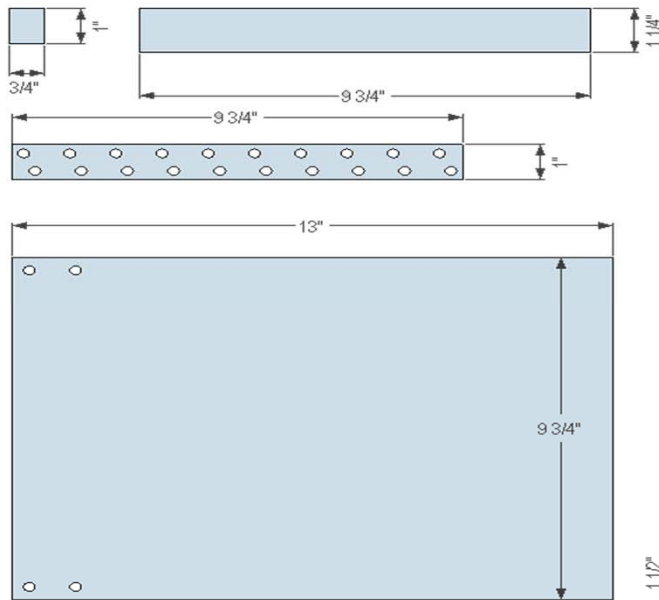
- Students familiarize themselves online SOP.
 - http://www.che.utah.edu/undergraduate/projects_lab/sop/?p_id=26
- Use with faculty supervision.
- Then it's all up to their creativity.
 - Course or personal use.



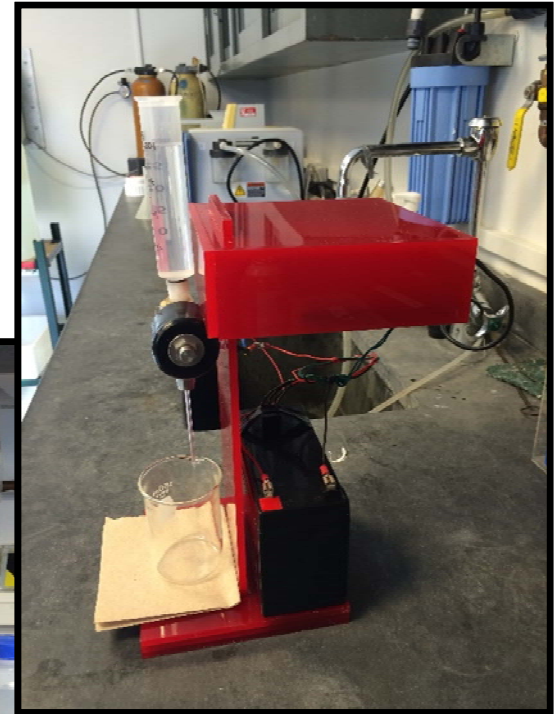
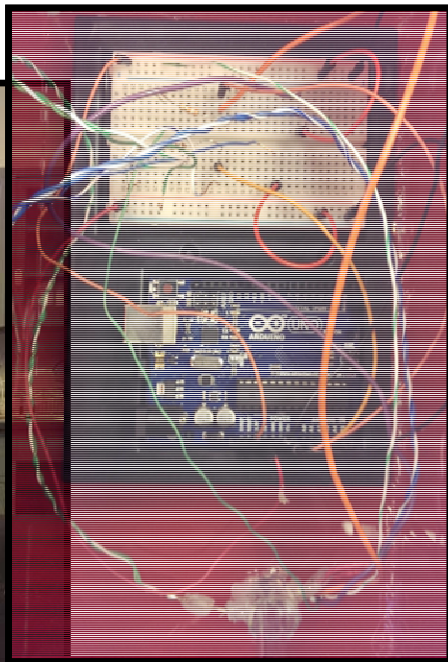
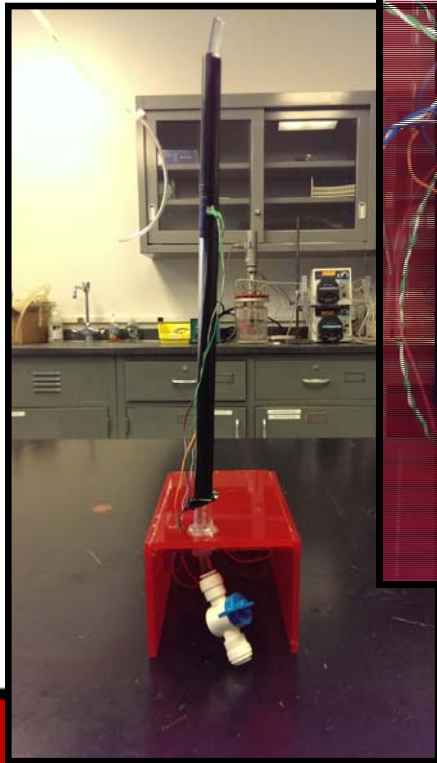
Spectrophotometers



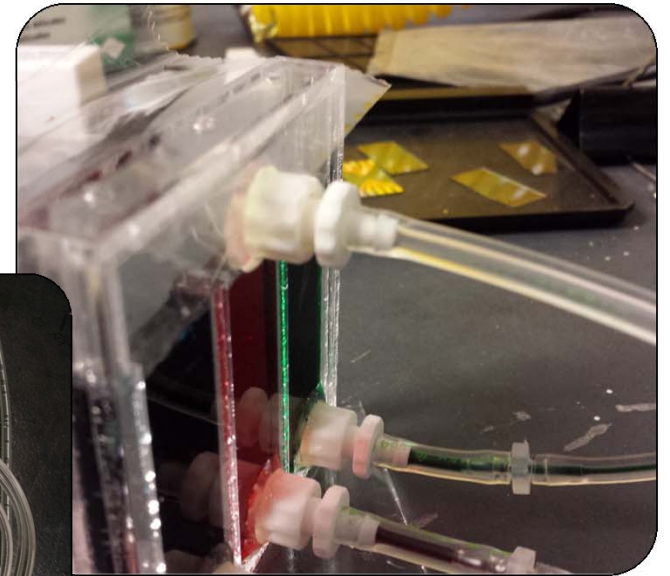
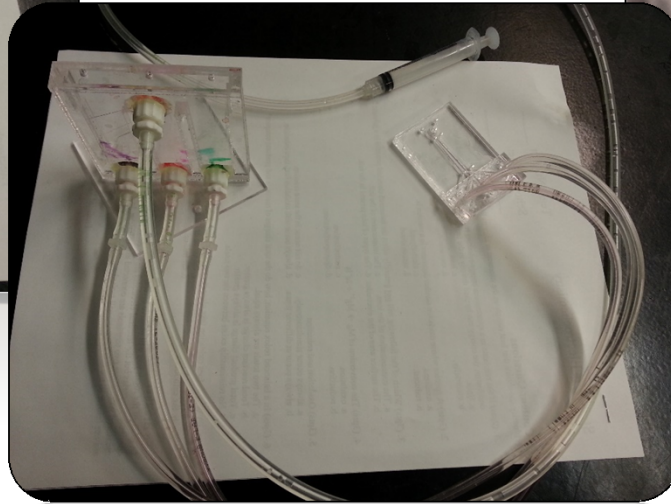
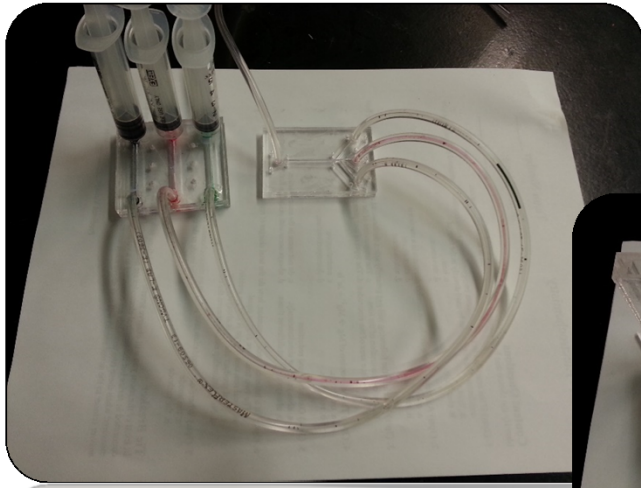
Heat Exchangers

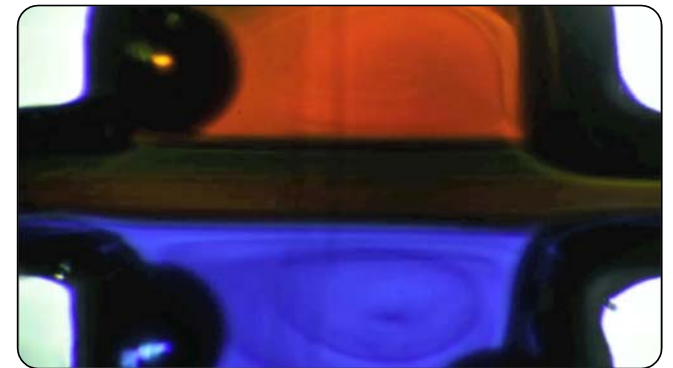
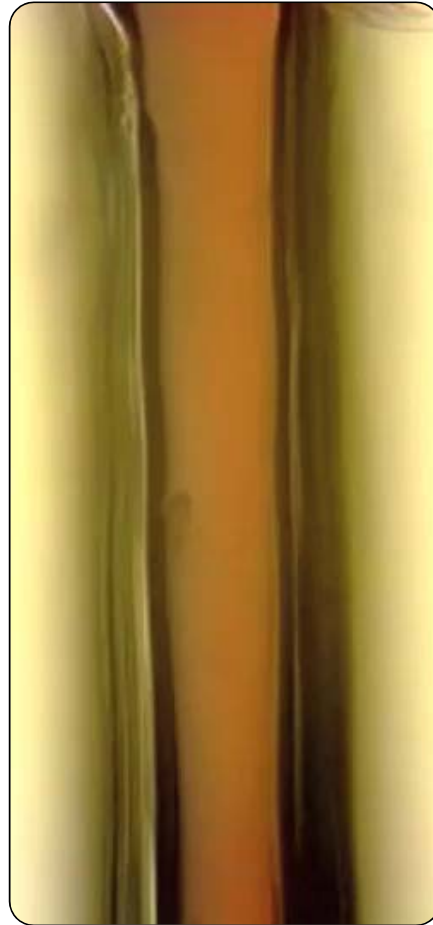
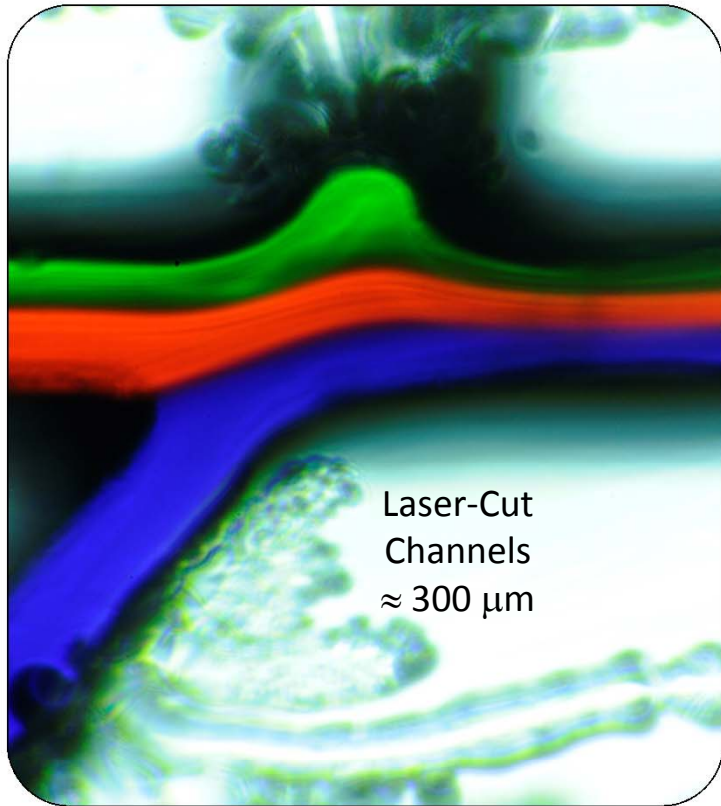


Viscometers



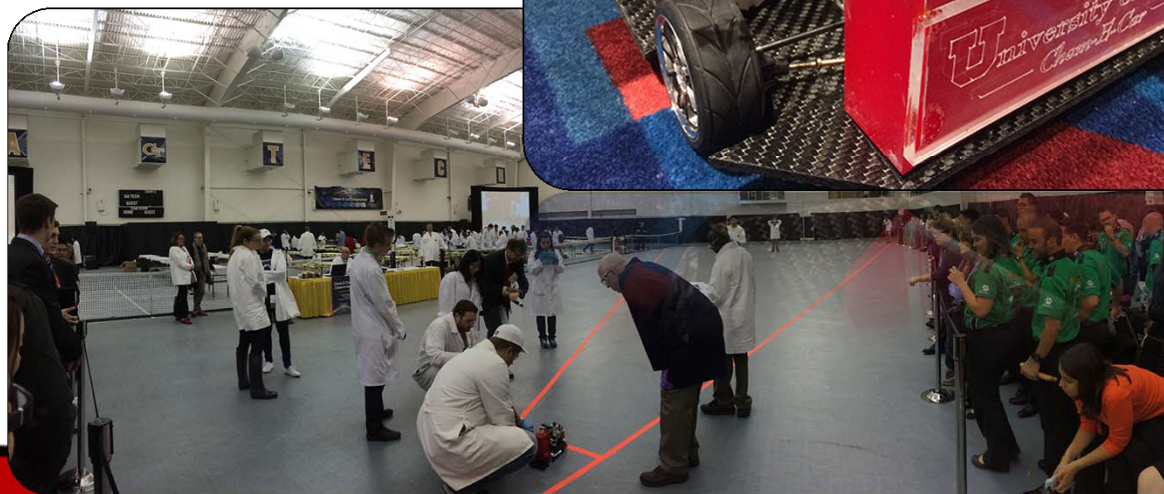
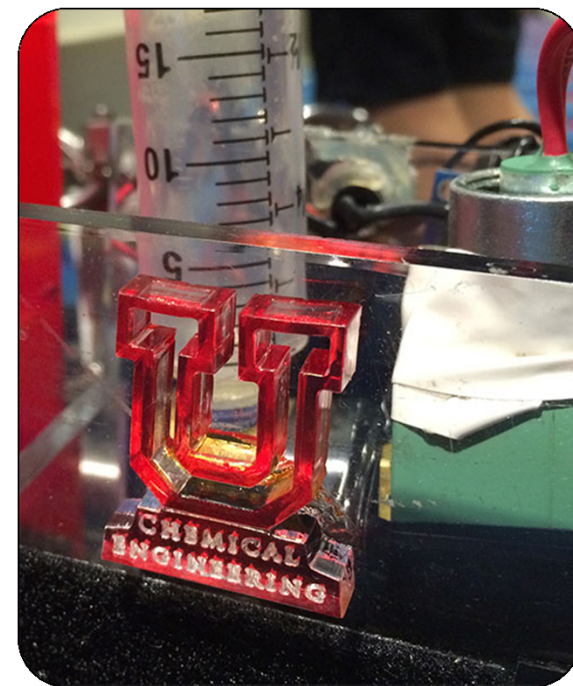
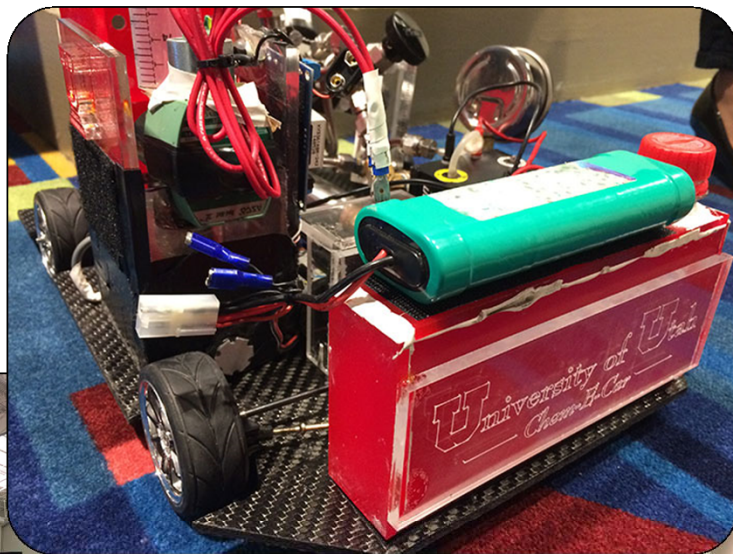
Cheap & Easy Microfluidics





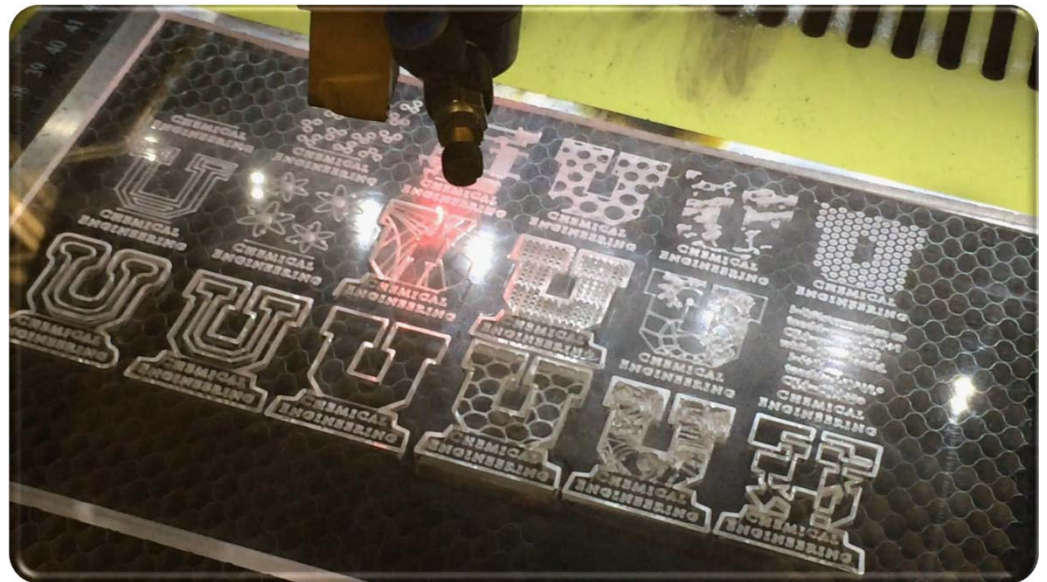
Video of Attempt
at Low Re Mixing

AIChE Chem E Car Competition

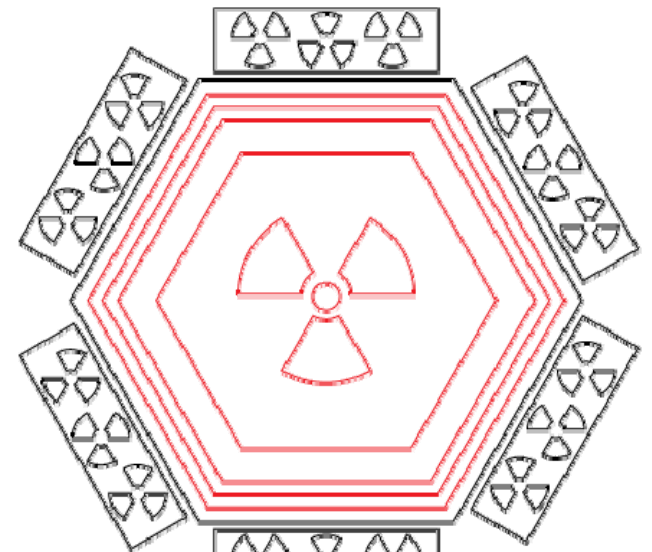
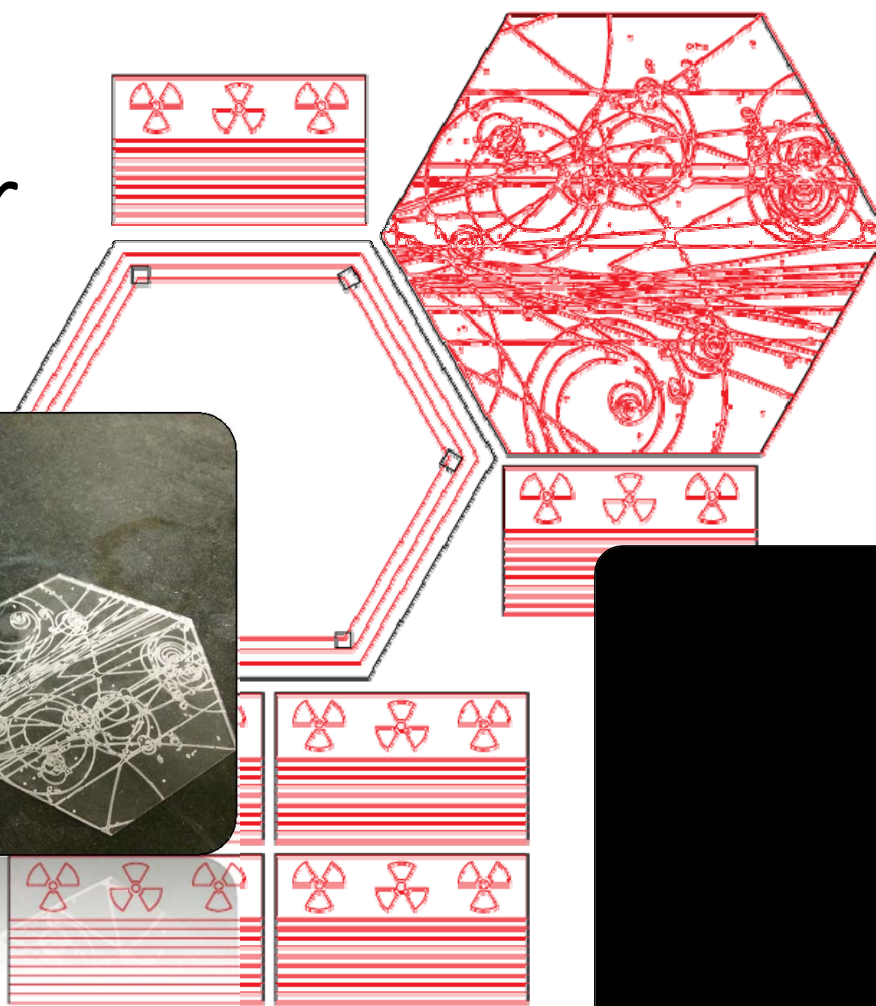
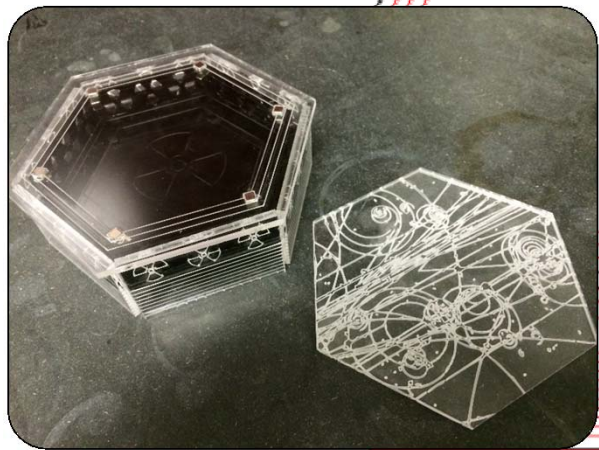


K-12 Outreach

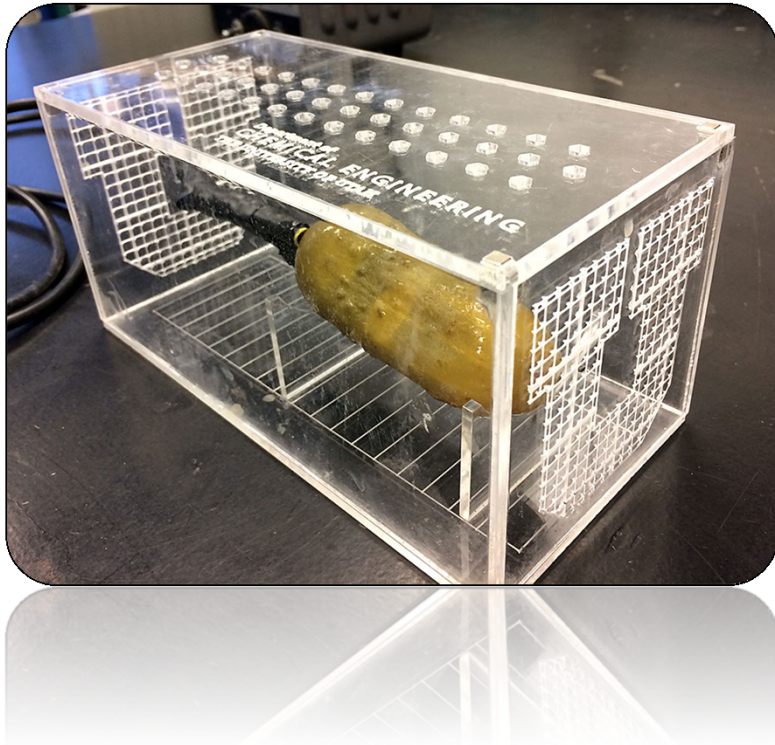
- We reach over 3,000 students directly each year.
- Five K-12 Engineering Camps in 2013-2014.
- Laser cutter has opened up new avenues for module creations.
 - http://www.che.utah.edu/outreach/teaching_modules/



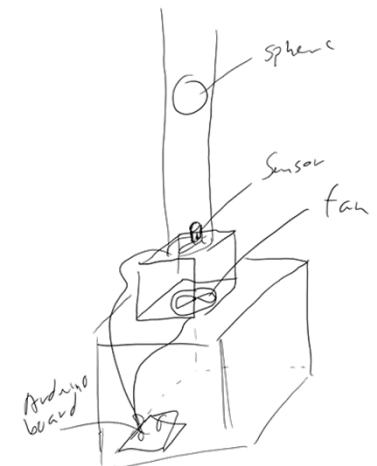
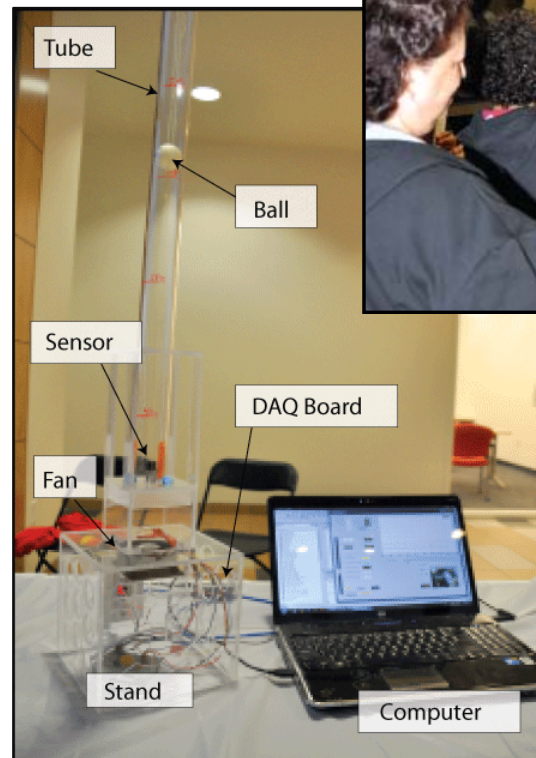
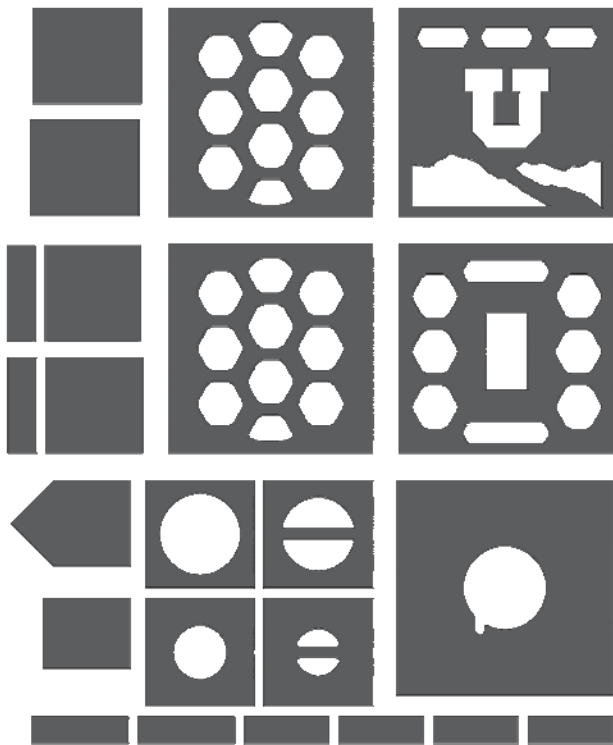
Cloud Chamber



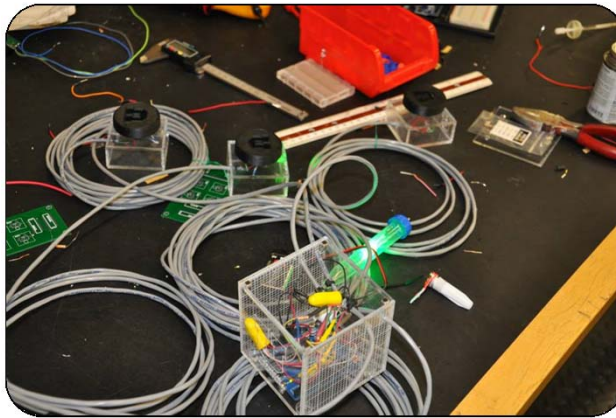
A Safer Glowing Pickle



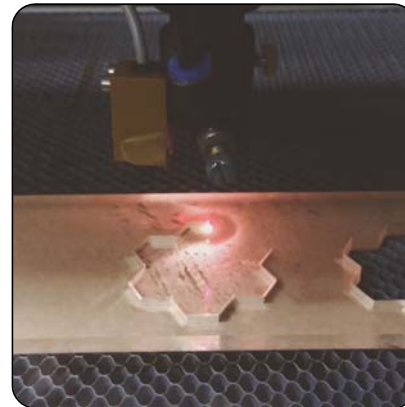
Ball-in-Tube Device



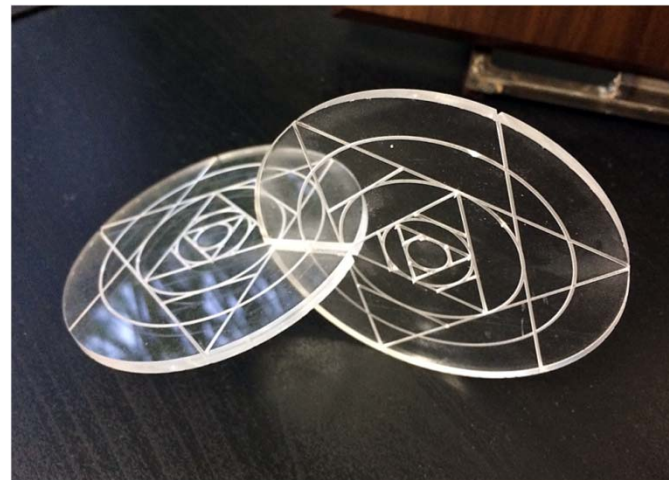
AIChE Jeopardy Buzzers



Miscellaneous



Lab Tools
stands,
tweezers,
& hooks



Furthering Research

Cold flow model of a chemical looping combustor for research, and a new project for our senior capstone lab.



Laser Cutting Lessons Learned

- An 80W laser is just right.
 - Can cut up to 1 inch acrylic... at 1 mm/sec.
 - Primarily use 1/8th and 1/4th inch material.
 - 1/8th acrylic = 24 mm/sec.
 - 1/4th acrylic = 12 mm/sec.
- A 40 cm x 50 cm bed is adequate.
- Saved \$10k going with a new company.
 - Two years on, company litigated out of business.
 - Had to replace power supply.
 - Would probably spend the extra cash up front.



Laser Cutting Lessons Learned

- Easily incorporated into lab courses.
- Can aid in demonstrating a wide variety of core concepts.
 - Teaching.
 - Research.
 - Service.
- Students are particularly enthusiastic.



Subtractive



Additive

Our Choice of 3-D Printers

Stratasys OBJET30



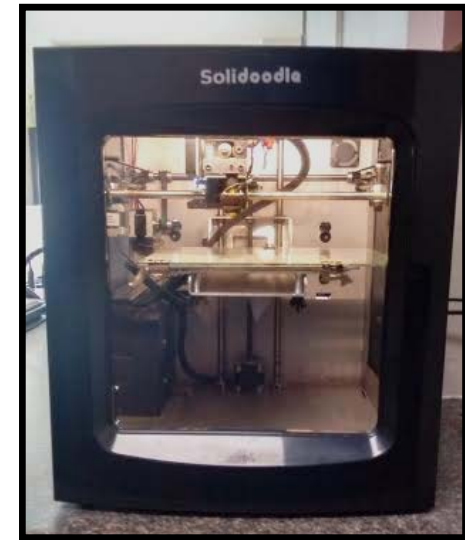
Light Polymerization
Resolution: 0.028 mm
≈\$40k

uPrint SE plus



Extrusion
Resolution: 0.254 mm
≈\$20k

Solidoodle 4



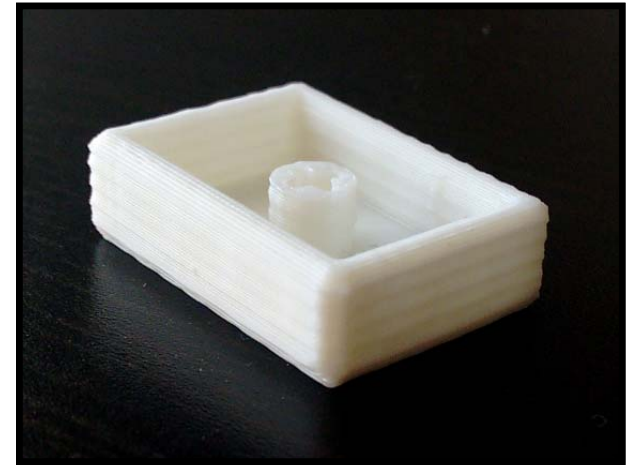
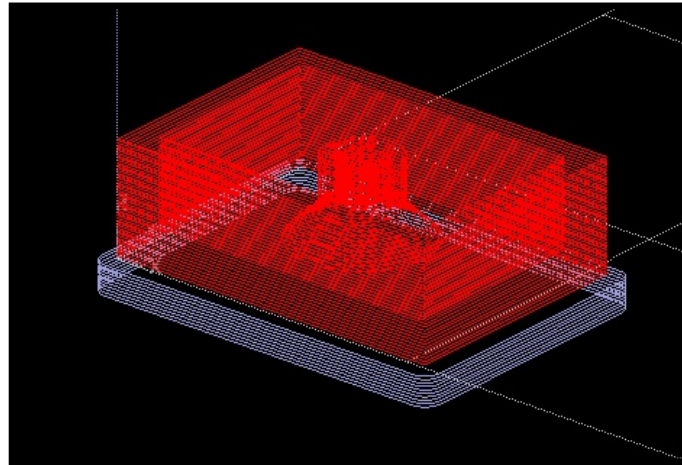
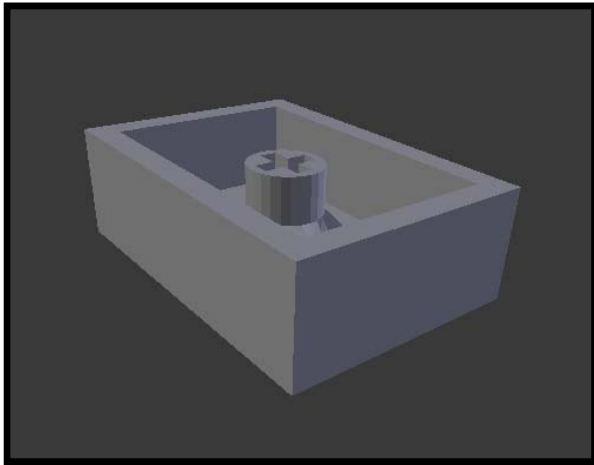
Extrusion
Resolution: 0.4 mm
≈\$1k

How They Work



How to Use 3D Printers

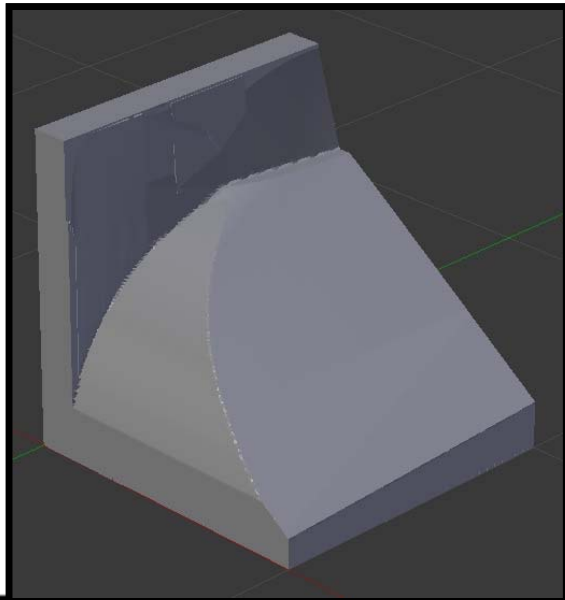
- Create object in any 3D CAD software.
- Export as an STL file.
- Upload and print file.



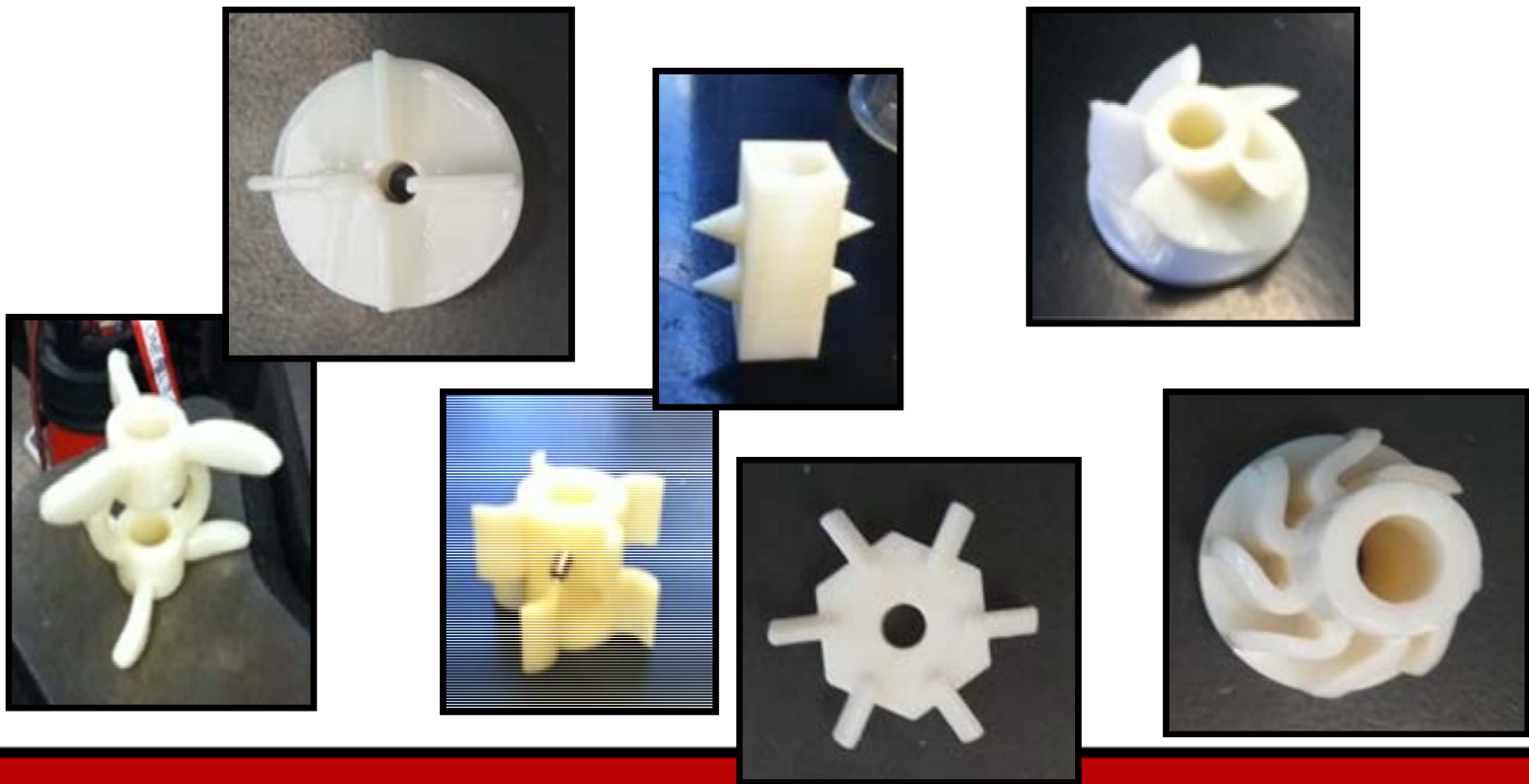
K-12 Outreach



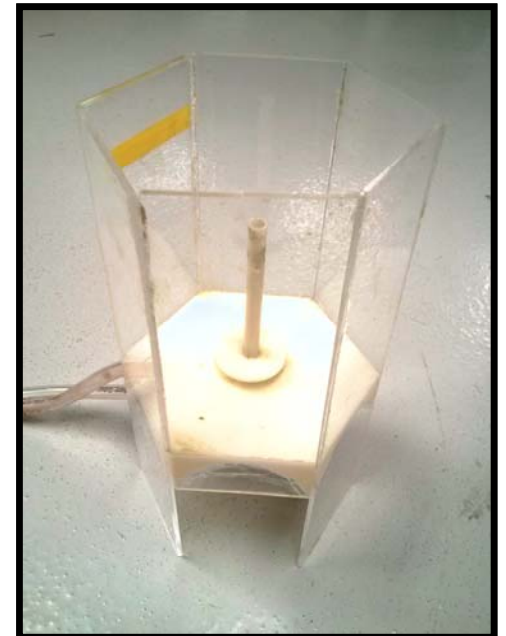
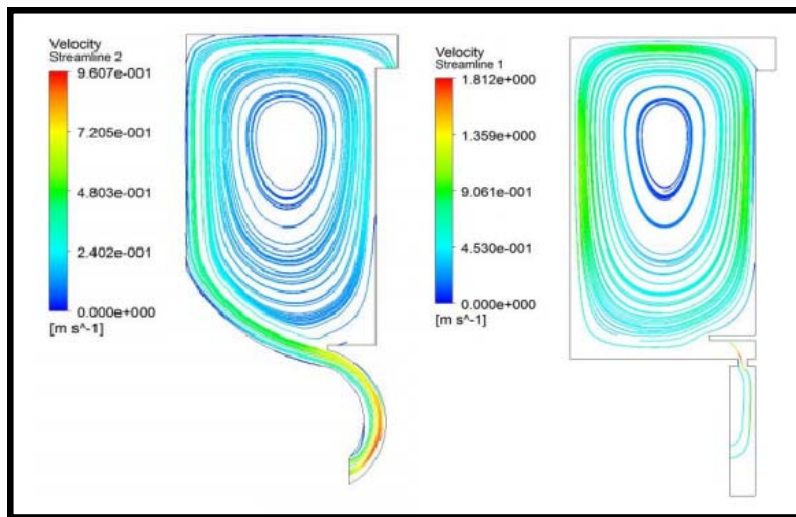
PVT of Water



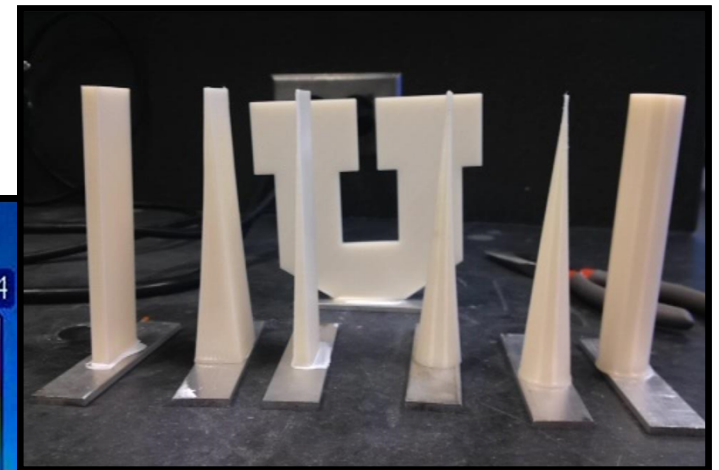
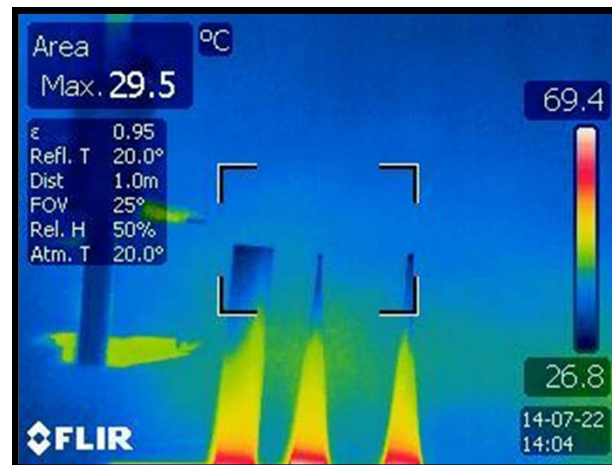
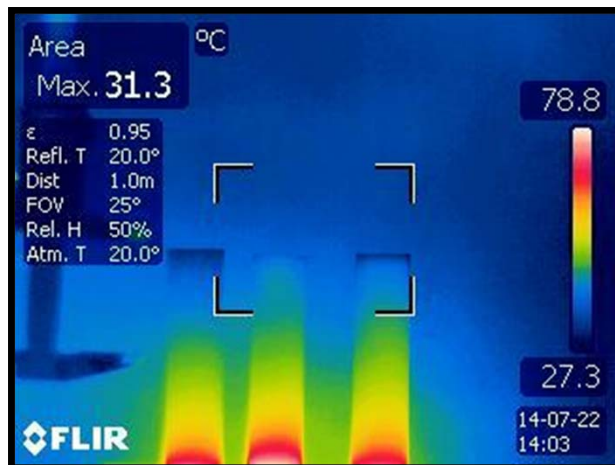
Impeller Designs - Degree of Mixing



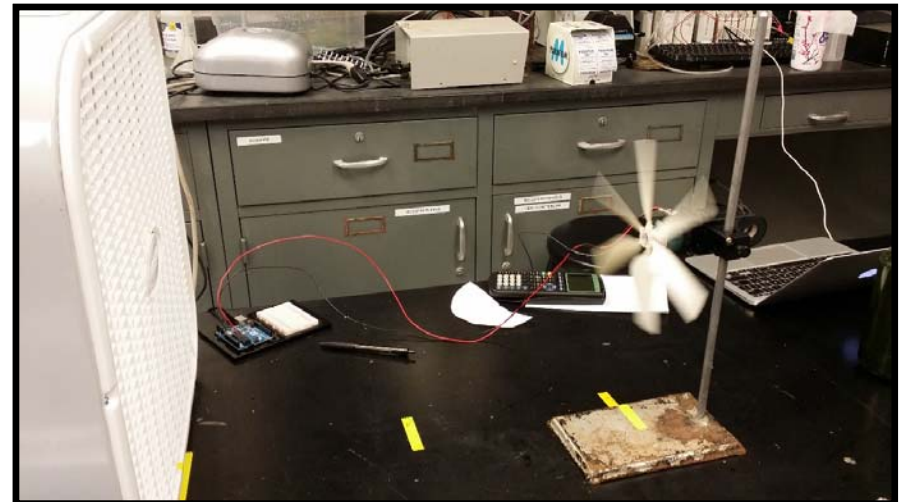
Photobioreactor Design



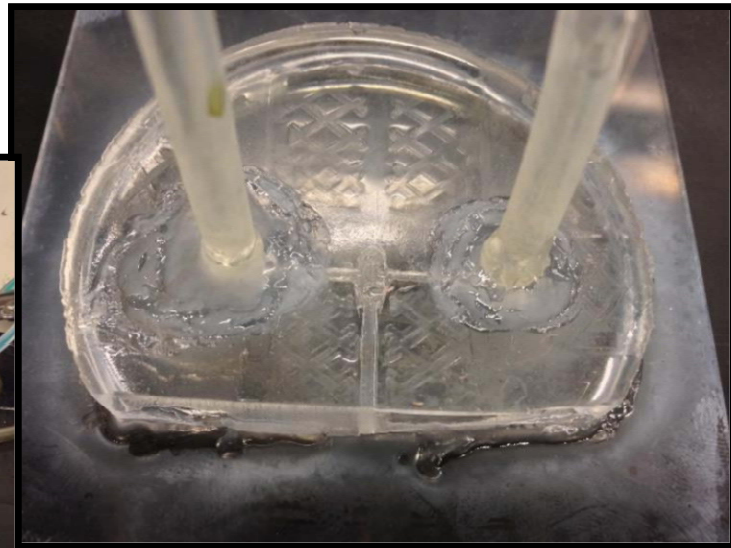
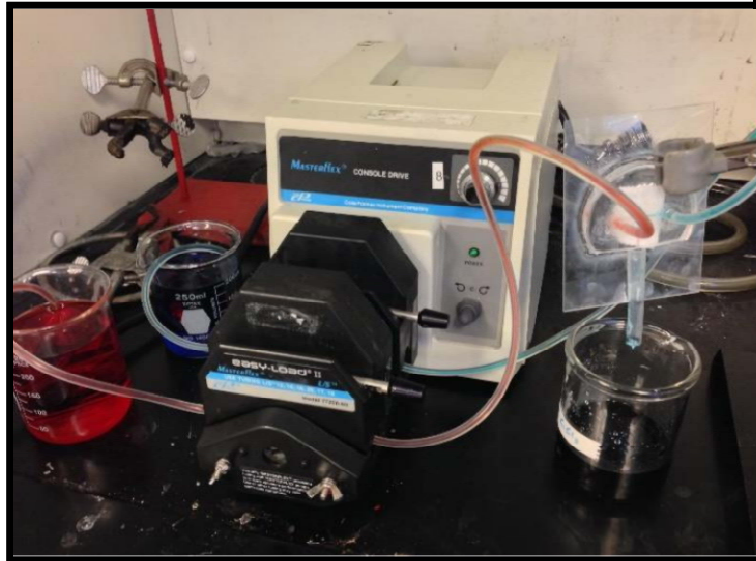
Temperature Profile Across Pins and Fins



Wind Turbine Efficiency



Research – Impinging Jet Mixer



Research – Chemical Looping Combustor

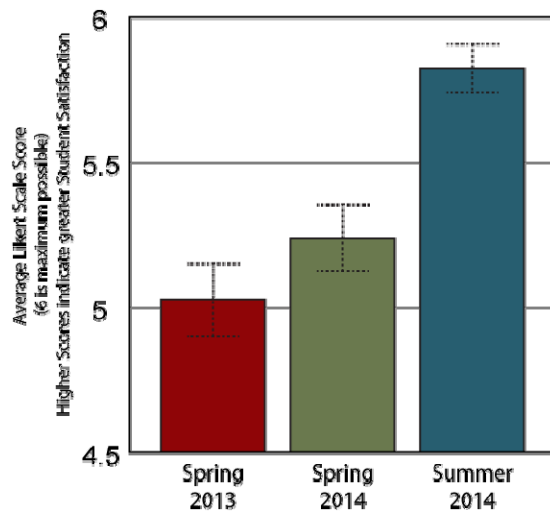


3D Printing Lessons Learned

- Creating the STL files can be difficult for beginners.
- 3D printing is relatively slow.
 - Usually print overnight.
- Inexpensive printers require significant setup and maintenance.
 - May still produce high quality parts.
- Check the cost of printing plastic.
- A heated print bed reduces warping.



Student Response



"The way the class is presented as the students being engineers and collaborating on projects and presenting reports to the teacher as a business would be fantastic. The very open-ended projects were a VERY educational and eye-opening experience. Working with people you don't know and solving problems with group ideas (not pre-generated guidelines) was something that is sure to come in handy after graduation."

"An excellent course which affords the students the opportunity to apply engineering principles and get them excited to be participating in engineering early on in the major. Also the open endedness of the projects was very refreshing when compared to the heavy theory and rigidity of the rest of the courses that we take up until senior year."

"Very fun and useful class. Do more!"

"I absolutely loved the class, it made me feel more confident in the choice of my profession. Very hands on, the instructors are great. Overall, regardless of the grade I get, it was a great experience."

"I thought the hands-on design and prototyping aspects of this course were awesome. The online simulations we did for individual homework were also generally helpful."

"The design of the course really forced students to take initiative and not rely on instructors to tell them what to do, it really helped me be more confident in coming up with and developing my own ideas."

"You constantly have us answer questions in class that help everyone stay engaged. The simulations are very helpful for conceptualizing problems."

"This was my absolute favorite class and I really enjoyed every week of it. The hands-on experience was invaluable and the lab experience cannot be replaced."

"It was nice to finally get some hands on engineering in the curriculum."

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