The MEAM department recently introduced the MakerFleet. This is a fleet of six MakerBot Replicator 2 three-dimensional printers. The aim is to have them available and open to students to support their coursework and explore the growing field of three-dimensional printing. This presents the challenge of finding the best way to accommodate the large number of students wishing to use the machine. For the summer of 2014, the Jacob M Abel Internship was used to help set up the new MakerFleet for student use throughout all levels of coursework. Some courses that were focused on were MEAM 101, EAS 024: Summer Academy of Applied Sciences & Technology Robotics, and EAS 102 but this work will be beneficial to all courses with design-based projects along with MEAM research labs. This summary of progress will cover the three main areas needed to be address in great detail: day-to-day usage, teaching about the capabilities of the machines, and machine maintenance.
Usage

The first aspect to cover is usage, including how students access the machines, become trained, acquire materials, and post-process their projects. The first step was to create an efficient training method for new users to become adequately prepared to use the machines and software, MakerBots and MakerWare respectively. The two-part training method was created to have students first watch two videos outlining MakerBots usage and complete an online quiz. Next, they would come to training where they were instructed to prep the MiniMrJaws file (seen to the right) and print it to show their understanding of both the software and machine operation. Once completed students would be free to rent filament and print.

This leads to the next area; filament and SD card lending. A lend out station was created in the Rapid Prototyping room, Towne 167. Here students will be able to check out filament spools for 24-hour periods during staffed hours. Filament spools are the material the MakerBots use to print. As a fun and creative addition, many different colors were purchased and the color sample, Crayon Box, was created to show off the selection. Unfortunately, the SD card lend out system was also tested this summer but did not seem to have the same success. It appears that due to their small size they are easily lost and forgotten. Upon discussion, it was decided that it is best for students to supply their own cards or purchase them from the department.

The final aspect was setting up the maker space in the Rapid Prototyping lab. The layout of the room was set up to best incorporate the laser cutter, MakerFleet, and two new sections for RP staff and post-processing. The RP Staff will be in charge of lending outs and training. The Staff station included the computer and filament cabinet and a post-processing station for pieces was organized. This included supplies such as scrapers, pliers, and other assembly tools, as well as securing these items to prevent the tools from being lost.
Teaching

Having a tool is only useful if you know how to use it; for every student to get the most out of the MakerBots, several teaching materials were put together. The first aspect was to print sample pieces to showcase what the MakerBots can really do. Several resources were used to build this showcase such as Thingiverse, GrabCAD and past student projects from IPD 501. Some of these pieces include Jumbo Lego Man, Chess Machine Jig, and RoboHand (seen left).

Once students see the possibilities, the next step is to introduce them to the specialized jargon and how to optimize their prints. This was a sticky point in the 101 Locomote projects, which lead to multiple 12+ hour long prints to finish only realizing that the support could never be removed. A few presentations were created to cover topics to explain support placement, infill’s strength-time relationship, and the MakerWare tools. In addition to the presentation, hands-on demo pieces were created to assist in student’s understanding of the capabilities of the MakerBot. Some sample pieces are:

- **Cantilever angle size**- Show the printer capability with over hangs in prints
- **Infills/ Shells/support/raft** - show what each of these aspects are in respects to a print
- **Press-fitting kerf/ Finish in different directions**- Test and calculate accurate numbers for use when trying to make piece snap together
- **Print in place** - Demonstrate proper spacing for gaps and snap together
- **Layer Height** - Demonstrate how different layer heights affect time and finish

The final aspect was to review current three-dimensional projects and create some new projects. Two MEAM 101 projects were reviewed, Derby and Locomote. The considerable reworking mainly focused on teaching the aspects outlined above and improving filament check out. A new project created was MatchBox Derby. Matchbox Derby was a miniaturized and modified version of Derby used for EAS 024. For this project, students were given axels and wheels and instructed to design a car around them with the challenge of having a
print time maximum of thirty minutes. Students have to utilize what they learned from the presentation to get the most design into their time limit.

**Maintenance**

To accommodate the high demand, the MakerFleet will receive a rigorous maintenance program that has been created to keep the machines running at top condition. This required getting to know the inner workings of the machines, including fully disassembling a machine to learn as much about it as possible. In addition, much was learned from debugging errors that arose during summer usage. This helped to create better understanding of repairs leading to faster diagnosing and correction.

The first line of defense is a weekly preventative maintenance schedule. The aim is to keep the Bots at the top level of cleanliness and to catch small bugs to prevent them from becoming large problems. A standard operating procedure and preventative maintenance document was created to outline a day-to-day schedule of cleaning and minor upkeep with detailed step-by-step procedure. The Rapid Prototyping staff will be trained on each of these procedures and will have the document as a useful reference. They will be a great attribution to keeping the MakerFleet running smoothly and will make each Bot last longer between major repairs.

However, things will go wrong and large repairs will be needed. For these occasions, a repair shop was created in the experimental station of the AddLab. A knowledge base has been built and documented by repairing several of the MEAM, ESE, and GRASP MakerBots over the summer. In addition, a lot has been learned from repairing and rebuilding both a MakerBots Replicator 2 and a Replicator 2X. The Replicator 2X is a specialized MakerBot that has a dual extruder head that allows two filaments to be loaded for a print (this allows for configurations including 2 colors, color and a dissolvable filament, etc.)
Conclusion

This internship provided the opportunity to learn about the MakerBots and prepare for the incoming semester. The Rapid Prototyping staff will be assembled and start implementing the above plans. Along with MEAM 101, other courses throughout MEAM and SEAS will begin to incorporate the teaching materials.

I am excited and eager to continue this work throughout the year and face the new bugs that will definitely arise. Furthermore, I am looking into other areas, including investigating flexible filament, more about the Replicator 2X, and possible dissolvable filament. There is still more that can be learned to expand the availability and creative options of the MakerFleet.

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