Successful Implementation of a Cross-Institutional Training and Credentialing 'Passport' as a Shared Common Makerspace Standard

6th International Symposium on Academic Makerspaces

ISAM 2022 Paper No.: 32

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Introduction

Training and credentialing programs have grown in popularity within academic and community-oriented makerspaces [1], [2]. They are often the primary means by which a makerspace safely trains users and provides access to equipment. However, the wide and varied nature of what defines the term "makerspace" often means that skill-building and training ecosystems frequently exist in silos. These programs are typically unique and site-specific, designed to service a single makerspace or network of spaces and the associated machines, protocols, and policies.

Such siloed training and credentialing programs can create barriers between makerspaces, discouraging the free exchange of makers and ideas. In these scenarios, makerspace administrators and educators must invest significant time developing new training programs and resources to ensure safe and responsible access. This, in turn, can slow the deployment of new makerspaces, create unnecessary redundancies in equipment training, and make it challenging or discouraging for makers to access out-of-network resources. Imagine instead that training resources were democratized, open-access, and shared freely between spaces.

We maintain that core makerspace skill competencies – such as operating a Prusa 3D printer, Epilog laser cutter, or SawStop table saw – should be taught the same way regardless of where the machine is housed. And yet, no standardized, collaborative makerspace training program currently exists. A shared standard would allow makers to access a wider range of makerspace technology and tap into a broader network of participating makerspaces with minimal barriers to entry. In addition, with the assurance that makers are being trained safely, responsibly, and uniformly, administrators could focus less on time-intensive curriculum development. Instead, they might be able to invest more time laying down the critical foundation of any successful makerspace: hosting workshops and outreach, building engagement, and growing a robust maker community.

Here we propose creation and adoption of a shared standard and collaborative operational infrastructure that any community or academic makerspace could adopt with ease. We highlight the implementation and lessons learned from a successful cross-institutional training program in the Rocky Mountain West (Fig. 1). Finally, we end with a call to action to establish a Makerspace Curriculum Review Board (MCRB) to coordinate further curriculum development.

Background

The Maker Access Pass (MAP) program was developed in late 2018 to standardize training and create a common makerspace standard that could be adopted by any creative space that might espouse 'making for all.' In particular, the MAP was designed to be student and community centric, focusing on fostering safety and personal responsibility among members while minimizing barriers to entry across spaces. The program's overarching purpose is to share resources and curriculum across academic and community makerspaces, and establish a makerspace 'passport' that could be recognized by all participating spaces regardless of institution or affiliation.

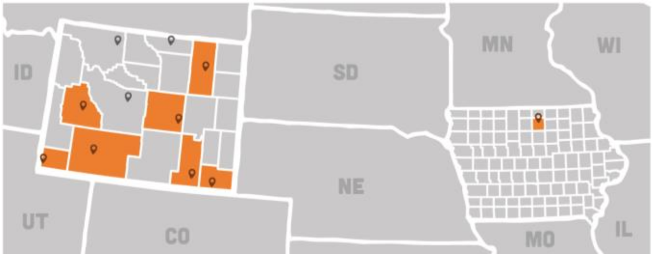

Fig. 1 The MAP is a cross-institutional digital training program shared by eight makerspaces (orange) and serving eight counties. Gray pins indicate additional interested makerspaces still to be brought onboard.

Guided by the Higher Education Makerspace Initiative (HEMI)'s principle that there is no one-size-fits-all approach to makerspace policy and operation, special care was made to design this system as a collaborative, centralized system independent of any specific institution's administrative policy and regulations. The MAP was designed to be a complete learning ecosystem, with self-paced online curricula that could substitute for or complement in-person workshops. Focus was placed on developing content that would not vary across institutions, such as how to load filament on a Stratasys F123 Series FDM 3D printer or how to program a Shapeoko CNC router. We recognize that learning paths can vary drastically among makers; accordingly, the MAP was developed with multiple learning styles in mind, with quizzes, learning outcomes, and content for workshop modules driven by makerspace literature reviews [3], [4]. Instructional material is presented through reading and writing, visual, auditory, and interactive formats. Content is linked directly to digital badges to offer incentives and motivation [5]–[7]. Integrated into the system is an equipment reservation platform built to automatically gate equipment access only to trained users who have completed the necessary coursework.

With no incidental hardware, RFID chips, or swipe cards required, the Maker Access Pass program can serve as a resource for training, credentialing, equipment access, and member management while still providing the flexibility for each space to choose its own machines, and enforce its own protocols and policies that best serve each unique community.

The Case for a Standardized Training System

Innovation often depends on the free movement of people and ideas, and is often driven by diverse creative communities comprised of makers with different backgrounds, ideas, and experiences. When makers from different cultures, gender identities, socioeconomic backgrounds, and life experiences get in the same room, they can provide new, collaborative, wonderfully 'outside-the-box' ways of tackling complex problems.

With this in mind, there is much to be gained by developing shared training and credentials that carry over between makerspaces and that minimize the number of barriers to access. Five key assertions support the case for a standardized training and credentialing system:

1. Machine operation is inherently consistent, allowing for a unified training process.

While it's important to adhere to institution-specific safety standards, machine operation remains a constant. A Prusa i3 MK3S desktop 3D printer boots up, loads filament, levels its bed, and creates printed parts the same way no matter where the machine is housed. It stands to reason that a maker trained on how to safely and responsibly use an Ultimaker S5 desktop 3D printer, a Stratasys J750 industrial polyjet printer, a Cricut Maker cutting machine, or a Glowforge laser cutter should be able to access those same machines in other makerspaces. They should be able to do so with minimal barriers to access, and without having to retake the same machine trainings again at each makerspace they visit. A standardized training and credentialing 'passport' can act as a *lingua franca* for makers, educators, and administrative staff across participating makerspaces. Badges can be issued from any makerspace, designed and shared between makerspaces, and recognized as valid by all participating spaces according to agreed-upon standards. It is possible to develop a shared training program and learning repository that provides the skills necessary to operate hardware and software.

2. A shared learning repository can aid administrators and allow new makerspaces to grow more effectively.

Competencies that champion and integrate values of safety, stewardship, accessibility, and sustainability into the training culture are common pillars across many makerspace training programs. Still, there is considerable redundancies with course development, where administrators, students, staff, and volunteers are expected to develop unique, in-house curriculum on top of other duties.

During their first few years, fledgling makerspaces often require a significant amount of time and effort to design and develop their own library of programming. This ultimately means less time spent hosting workshops, engaging visitors, and building the robust maker community that lies at the heart of a successful makerspace. Providing a shared training program repository would allow these makerspaces to get up and running more quickly, onboard new staff and students with relative ease, and allow them to invest more time on other integral parts of successful operation and community engagement.

3. Maker training and certification should be portable.

When makerspaces share a common language, they open up the door for increased collaboration with fewer barriers, and at a larger interdisciplinary scale. Finkelstein et al. (2013) argue for digital badges as a catalyst for interdisciplinary collaboration, noting that digital badges have the capacity to recognize prior learning and carry over between institutions [8]. Furthermore, a centralized training program would serve to break down institutional boundaries for makers by providing a platform for verification, portability, creation, and collection of digital badges that can be shared by all participating institutions. As such, a standardized digital program gives makers, educators, and makerspace administrators the ability to view practical skills, requisite competencies, and the associated metadata of a maker in one online portal.

4. Training should collaboratively evolve and should be available to students of all ages and abilities.

A collaborative training program makes it easier to define, document, update, and teach both hard and soft technical skills by staying tuned in to the national maker movement. What's more, a shared standardized system ensures that all makers, from Boston to Botswana to Belgium, have the same learning opportunities. Education and pedagogy can be tied to current maker literacies and updated in real-time.

Finally, an evolving system also makes it possible to maintain records, publish new curriculum, establish and distribute standardized guidelines, and regulate the integrity of a shared badge training system across institutions rapidly [9], [10].

5. Shared metadata can steer growth and expansion.

A shared system would enhance makerspace administrators' decision-making and provide insight into worthwhile investments or strategic goals. Data collected by such systems is limited only by imagination, and can provide stakeholders information on a host of factors including training needs, equipment use (or lack thereof), community interest and demand, maker demographics, and maker activity. Within the MAP, these are accessible through the embedded badge metadata, machine reservation platform, and periodic surveys. Administrators would be able to analyze trends and needs across institutions based on when and where makers are being trained, the types and frequencies of machines that are used, the types of projects makers are creating, and the skill-sets that are in highest demand [7], [11]. The automation of data collection would be a boon to administrators, and the types of data collected could change according to need.

Results

The pilot of the Maker Access Pass program was well received by the student, faculty, staff, and community users at the University of Wyoming (UW), a mid-sized land-grant university located in the Mountain West United States. It's widely accepted that data drives makerspace growth by providing administrators direction in decision-making [8], [12], [13], but knowing what data is important to track and having systems in place to consistently collect and collate this data can be a challenge for young makerspaces. The integrated digital badge ecosystem of the Maker Access Pass program collects a wealth of key performance indicator data [14] for participating makerspaces. From 2018 to 2020, the two-year pilot at the flagship Innovation Wyrkshop makerspace on the UW campus provided a wealth of metadata for further development of the program, as well as informed decision-making that was presented to stakeholders and granting organizations. In late 2020, the program was expanded to include 64% (7 out of 11 spaces) of all major Wyoming community and academic makerspaces, effectively forming a grassroots public network of collaborative makerspaces united behind the MAP's common standards and shared operational infrastructure. In Spring 2022, the program added its first out-of-state makerspace in north central Iowa, with interest from other out-of-state groups. By Fall 2022, four new mobile makerspaces will be added to the network.

The pilot MAP program includes more than 90 training workshops for 40 unique hardware and software brands, offered across ten series (safety; 3D printing; 3D scanning; 3D modeling, CAD, and graphic design; woodshop equipment and tools; crafting, art, and fabrication; laser systems; electronics and microcontrollers; extended reality (XR) hardware and software; and developer software and game design). Of these, only orientation and safety courses are unique to a specific makerspace. In most cases, workshops are divided into three tiers: in-depth 100-level courses (practical), shorter 200-level courses (theory), and soon 300-level (application). There are currently an additional 15 courses in development by regional partners, with no upper limit to the number of courses offered.

Courses are proposed, designed, and developed by any interested party with a knowledge or passion for specific subject matter, including students, volunteers, full-time staff, and administrators. Courses are then vetted by a small team who help to import content into templates, edit, and publish. Most popular workshops are offered as both in-person and online, asynchronous workshops.

The University of Wyoming's Innovation Wyrkshop makerspace serves as a case example of the value of such an initiative. Since establishing the MAP program, the Innovation Wyrkshop has observed a meteoric rise in usage (Table 1, Fig. 2). In 2022, the Wyrkshop served an average of 1,528 visitors per month – approximately 12% of the University's total student population.

Since its inception, the MAP has been used to award over 5,211 digital badges, serving over 3,530 attendees who have made over 7,930 individual machine reservations (Fig. 3).

Table 1: Visitors per year (count), from September 2017 to June 2022. The first year of the MAP (blue) saw notable growth in the number of visitors, with steady growth thereafter. A revised version of the MAP released in early 2021 (green) resulted in significant growth. **Notably, data collected does not distinguish between unique individual visitors vs. returning visitors. †2022 values are projected from June 2022 onwards, using average monthly visitors to date.*

	2017	2018	2019	2020	2021	2022†
Visitors per year*	885	4818	6298	4550	11295	18338
Monthly avg	221	402	525	379	941	1528
Monthly growth rate	-	81.5%	30.7%	-27.7%	148.2%	62.4%

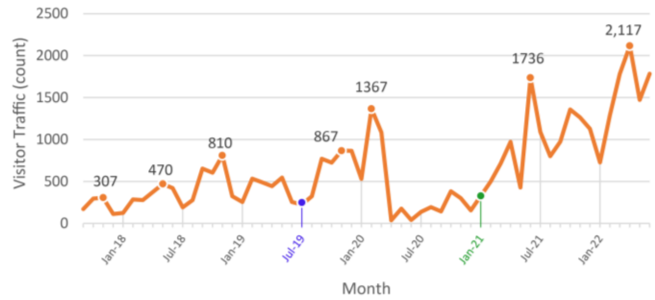

Fig. 2 Count of visitor traffic by month. MAP had a soft launch in October 2018, but was formally published in July 2019 (blue). A revised MAP v2.0 was released in January 2021 (green).

Fig. 3 Laramie Innovation Wyrkshop statistics

Importantly, this maker community is not just made up of engineers and tech-savvy students. Out of all the reported projects (n=5,004) recorded by the MAP program, 40% have had an engineering focus, whereas 27% have had an art focus, 17% involve science, 14% integrate technology, and 2% involve math. In another poll, out of all projects (n=4,745), 33% are self-reported by makers as hobby or personal interest projects, 22% are classroom or educational focused, 18% are research initiatives, and 11% are entrepreneurial endeavors. Today, the Maker Access Pass program has grown to include over 90 distinct short courses ranging from technical literacies, such as operating a Stratasys industrial 3D printer or Epilog laser cutter, to workforce readiness, career exploration, and CTE soft skills, such as leadership and workplace communication.

Using automated data collected by the MAP system, or entered periodically by administrators, the MAP can provide valuable insights and record important trends across the entire network. Data is recorded at the makerspace level (visitor traffic through time, workshop attendance through time, workshop popularity, etc.) (Fig. 4), at the equipment level (machine usage and popularity, primary userbase, purpose of usage, hours logged, etc.) (Fig. 5), and at the user level (self-identity, confidence and self-efficacy, reason for use, interests, badges earned, favorite machines, demographics).

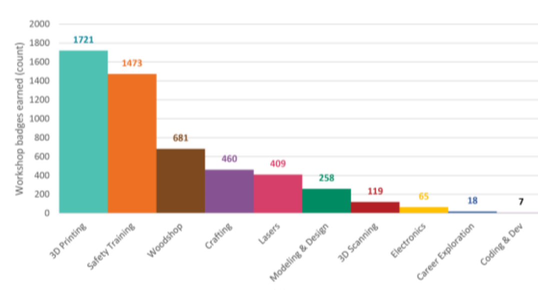

Fig. 4 Workshop badges earned in Laramie, WY by category

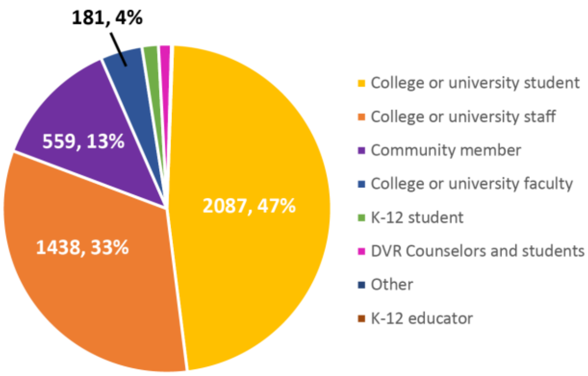

Fig. 5 Self-reported maker identity by category

Data-driven decision-making: seasonal trends.

If we track 3D printer workshops with at least one attendee through time, we can observe a general increase in number of 3D printing courses attended that correspond to the beginning of the academic semester (Fig. 6) and subsequently decrease in the number of workshops attended as the semester progresses. Notably, we expected but did not observe an uptick in usage around national holidays. We actively analyze this type of data to determine when and how often to offer 3D printing classes.

Data-driven decision-making: equipment availability.

Likewise, we can drill down to explore a specific machine's use during the makerspace's open hours (Fig. 7). We are able to assess how frequently laser cutters are reserved from 10:00 AM when doors typically open to 9:00 PM when they close. This data highlights a spike in usage immediately when doors open and, as might be predicted, a jump in usage during lunch and another one at the end of the day once most campus classes have ended. We can use this data to schedule workshops around predicted machine reservation times. In addition, with consistent high demand throughout the day, this data can provide justification to stakeholders if we need to purchase additional laser cutters.

Overall, data collected by the MAP is broad in scope, and can be assessed almost in real-time at a highly granular level. It paints a picture of distinct, diverse makers – primarily

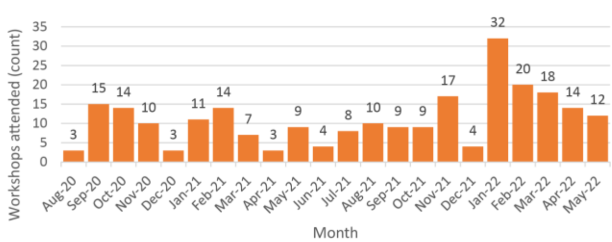

Fig. 6 3D printing workshops by month

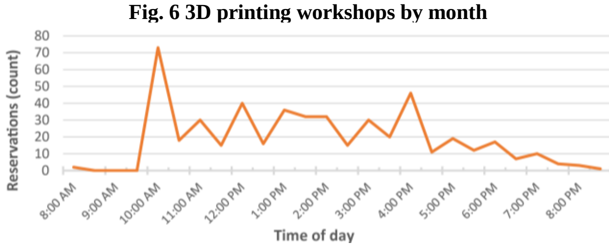

Fig. 7 Laser cutter reservations by time of day

students, staff, and community members – who bring their unique academic, professional, and personal perspectives, goals, and interests into the makerspace.

Challenges, Lessons Learned, and Critical Considerations

A successful shared training program requires a framework that is underpinned by best practices and supported by a body of makerspace and credentialing literature. It should consider factors such as design and accessibility, delivery methods, and pedagogy. It also needs to account for training validity and badge authenticity, as well as factors that may limit maker motivation, create roadblocks, or prohibit ease of adoption by other institutions. The system must also consider how best to implement shared policy, guidelines, and processes that align well with the practices of each participating institution. We have identified five priorities for consideration below.

1. Acknowledge and respect each makerspace's unique design, pedagogy, and delivery.

Makerspaces and the cultures surrounding them are and always will be diverse – influenced by politics and policy, funding, equipment, and by the communities they engage. Therefore, efforts to standardize content are most easily confined to machine training and operation. The MAP design team found it too difficult and too intrusive to try to standardize safety protocol, and thus focused on the core competencies necessary for safe and consistent hardware and software operation. Assigning makerspaces a rank according to a series of criteria, similar in scope to Wilczynski's classification system [15], is a compelling possibility to create uniform safety training. More dangerous makerspaces or spaces with more technically complex equipment would be assigned a "level 5" safety training rank, and less dangerous or complex makerspaces assigned subsequently lower ranks. In such a way, safety training could be compartmentalized and standardized without overreach.

2. Assign value and validation to a shared currency.

Evidence suggests that undervalued, redundant, low-impact, or difficult-to-adopt badge systems routinely fail to meet their long-term goals [9]. For workshops and badges to remain relevant, they must be widely recognized. Credentials as a 'shared currency' are only as valuable as the organizations that recognize them, meaning that validity of the badges and associated competencies rely on cooperation from all participating institutions to succeed. It has been challenging to convince a small minority of locations of the value of the MAP program, and likewise can be difficult to ensure that basic teaching guidelines and minimum standards are being met at these makerspaces. Thus, not all locations are well-suited for the MAP.

3. Design with makers' motivation in mind.

The success of a standardized training program relies on how engaged and motivated makers are to pursue new workshops and earn new badges [9], [16]. Badges should not only serve as progress markers, waypoints, or a token reward system, but should also be viewed as symbols of accomplishment. They should include sufficient metadata to highlight meaningful evidence of skills earned, with robust metrics to instill confidence and trust to advisors and employers that the makers have been trained correctly [11]. Thus, the reasons for makers to participate should not be simply to collect badges, though that's certainly a proven motivator [17] (Fig. 8). Instead, badges should look to augment intrinsic drivers with some extrinsic motivators, such as a desire to demonstrate evidence of skills, learning, and growth [7], [9].

A commitment to appeal to the most makers possible should influence the design and delivery of all content. Standard operating guides (Appendix A1), safety cards, and teaching handouts (Appendix A2) should be written, updated, and revised periodically using feedback from makers, new equipment best practices, and with direction from curriculum and instructional designers. Quizzes, learning outcomes, and content for workshop modules can be driven by makerspace literature reviews, machine manuals, online guides, and online video instruction [3], [4].

Courses should be developed by anyone from student staff to administrators, with guidance and oversight from experts across the network. Studies suggest that empowering students and providing a fair amount of autonomy allows them to "learn by doing" [18]–[22]. This self-reliant, open-ended approach has been shown to instill an increased sense of confidence, ownership and accountability [19], [23], [24]. We have seen this firsthand: the majority of MAP courses have been designed by student staff whose diligence and passion for sharing content and teaching what they love clearly demonstrates to us that they take great pride in their work.

4. Consider consortia

In some cases, badges may be interpreted differently even though the badge metadata outlines core competencies and criteria. What happens if there are differences of opinion about what a training module should include? Who arbitrates these disputes? What if workshop content designed by volunteers, students, or staff is objectively incorrect?

Currently, publishing new courses is bottlenecked by the small five-person MAP design team. We contend that a Makerspace Curriculum Review Board (MCRB) should be established to help expedite course development, and to develop the framework upon which basic training is unified [25]. A democratic system would support ongoing assessment and evolution of workshop content, and would also serve as a forum to resolve disputes and to improve the standardized training program. The MCRB could involve instructors, educators, knowledge experts, instructional designers, student staff, volunteers, and makerspace administrators. It would be the MCRB's responsibility to recognize credentials and help align machine training content with local, regional, institutional, national, and international makerspace standards.

5. Plan for evolving literacies.

Finally, training and credentialing programs should factor in the natural evolution of any training program through time. How should a standardized training program deal with versioning of an evolving framework? Should there be badge expiration dates? At what point will curriculum have changed enough to require makers be retrained?

Fig. 8 MAP badges are often printed off and proudly displayed on laptops, windows, and walls by Laramie makers. Most badge programs allow participants to share badges on social media and on resumes and CVs too.

Conclusions

The reasonable success of this expansion, the substantial uptick in usage, and the lessons learned throughout the pilot demonstrate the value of the Maker Access Pass program as an effective tool for makerspace management. As a key resource, the MAP can augment and accelerate the establishment of new makerspaces and larger-scale makerspace training networks.

There is a compelling case to be made for a standardized hardware and software training program shared across makerspaces. In Wyoming and northern Iowa, over 3,500 makers have been trained according to a standardized set of core competencies agreed upon by a democratic consortium of makerspaces and creative centers. Importantly, these shared standards do not impede on the policy, politics, and protocols of individual spaces.

Finally, we wish to advocate for the establishment of a greater collaborative Makerspace Curriculum Review Board (MCRB). Such a democratic consortium could aid in creating and sharing out common curriculum, developing operational best practices, and building out a scalable training and credentialing system that could be adopted by makerspaces across the country.

A standardized system provides a major opportunity to bridge divides, grow memberships, unite diverse communities, and forge collaborative partnerships across a nationwide network. With a shared training 'passport' such as the Maker Access Pass, that's a possibility.

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Resources

1. https://www.makeraccesspass.com/
2. bit.ly/Wyrkshop_KPI
3. https://www.wyrkshop.org/
4. https://www.pappajohncenter.com/education/community/innovation-workspace-initiative/

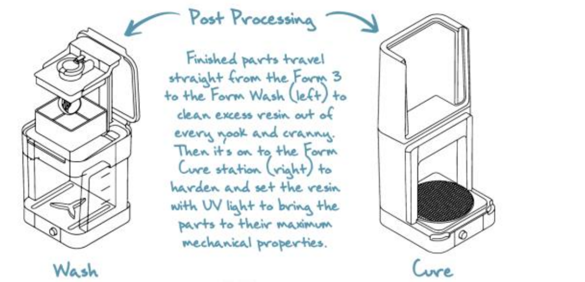
Appendix A1: A student-facing operating guide

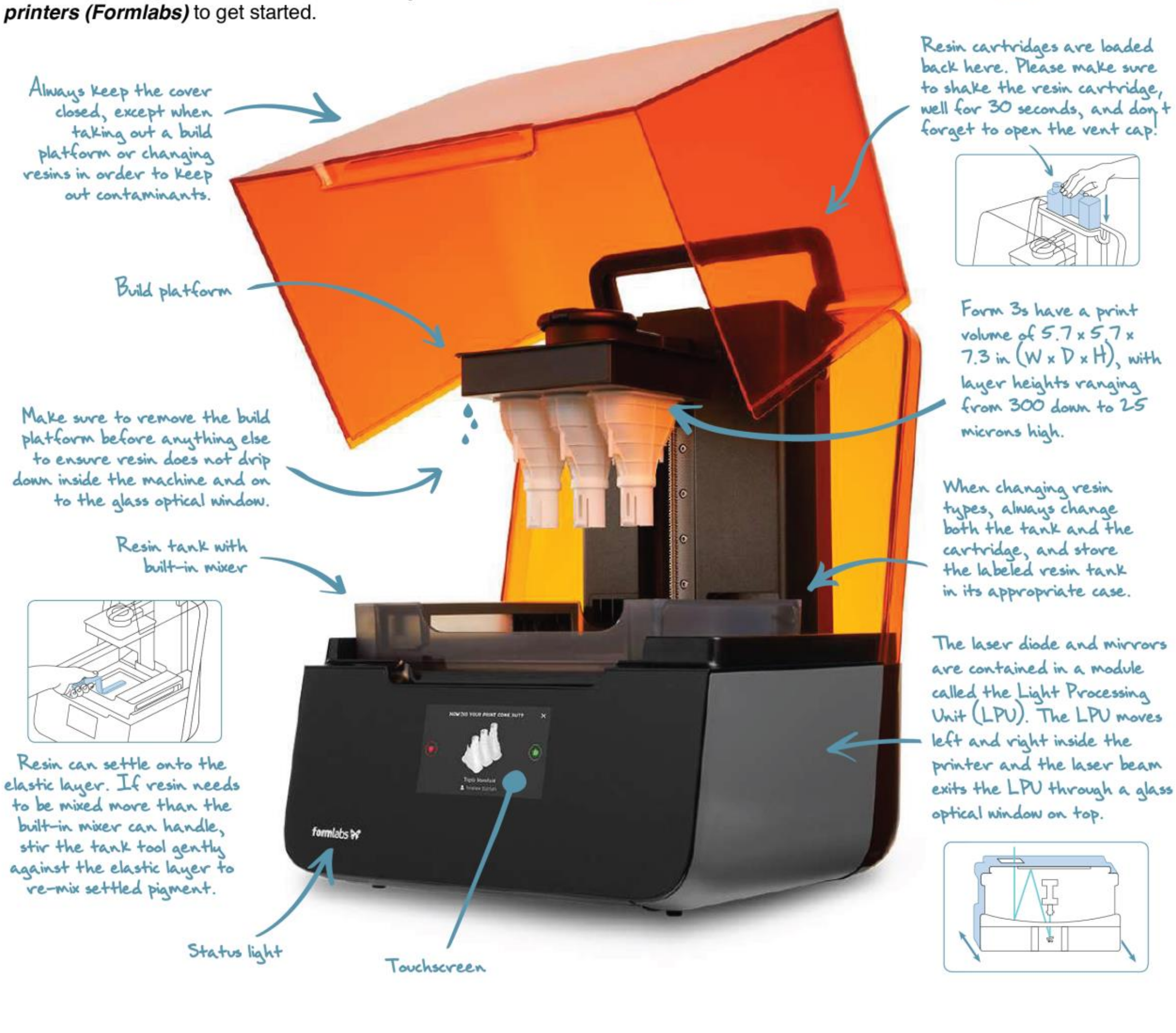
FORMLABS FORM 3

SLA 3D PRINTER OPERATION GUIDE

Form 3 resin printers from Formlabs are exceptionally hardy stereolithography (SLA) 3D printers, and considered some of the industry's best and brightest for desktop SLA printing. Capable of printing down to 25 micron layer heights, Form 3 printers are known for their exacting detail, biocompatibility, and even their castability on a scale that FDM 3D printers can't typically offer.

Begin printing today on either of our two Formlabs Form 3 stereolithography printers! Simply attend ***SAF102*** in the EERB SIC and pass ***SLA101: Introductory resin 3D printers (Formlabs)*** to get started.





Startup Checklist

- ☐ The build platform is clean and clear
- ☐ I've sealed and put away any undesired resin tanks currently loaded in the machine.
- ☐ I've closed the vent cap and put away any undesired resin cartridges currently loaded in the machine.
- ☐ I've chosen the resin I want to use; the cartridge has been shook for at least 30 seconds, the resin tank has been sufficiently mixed, and the cartridge vent cap is now open.
- ☐ I've inspected the resin cartridge bite valve to ensure resin will flow.
- ☐ I've filled out a reservation online for the time desired, as well as the info card next to the SLA 3D printer I want to use.

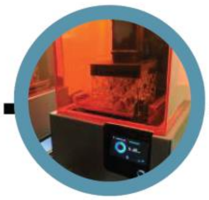
Step 1: Open PreForm and select your preferred printer as well as the material you've loaded in to the machine and the desired layer thickness of your printed part. If necessary, add a printer via its IP address.

Step 2: Parts usually print best at a 30 - 40° angle to minimize the cross-sectional area and adhesion to the tank bottom. Adjust the orientation of the model by opening the Orientation panel. Whenever possible, simply click "Auto-Orient."

Step 3: • Add supports to the model by opening the Supports panel. PreForm allows you to generate custom supports, but their default values are set to ensure successful prints for most geometries. Whenever possible, simply click "Auto-Generate."

Step 4: Inspect the printability status to see if your part is likely to fail, and why. If necessary, make adjustments. If the printability is acceptable, click the Printer icon to open the print dialog.

Step 5: Check your print settings one last time, and upload the job. On the printer itself, hit Upload Job and follow the instructions.



Step 6: Stay near your printer and make sure to check it periodically for the first 20 minutes. If the first layers don't print well, there's a chance the entire print could fail.

Step 7: Use Form Wash to rinse the remaining liquid resin from printed parts' surfaces. Simply unclip and mount the entire build platform in the Wash station. We typically wash a print for 20 minutes. Allow the print to dry for least 30 minutes so the isopropyl alcohol (IPA) fully evaporates after washing.

Step 8: We prefer to remove supports between the Wash and Cure steps, but you may not. Remove your part from the build platform carefully, and use the Form Cure to expose printed parts to light and heat to stabilize the parts for performance. We typically cure parts for 60 minutes at 60°C.

Quick FAQs:

Q: Why SLA printers?
A: SLA printers, while a bit slower and messier, offer much higher resolution and more dimensionally accurate prints than their FDM counterparts. They can also print in an array of unique materials, such as ceramics, castable resins and waxes, extreme temperatures, and even biocompatible materials used in medicine and dentistry.

Q: How much does SLA printing cost?
A: It costs roughly $0.50 per gram to use our resin, which our cost calculator will convert from ml (volume) to grams for you. You're welcome to bring your own resin tanks and resin cartridges purchased directly from Formlabs if you wish, as long as you pre-approve them ahead of time. If you bring your own materials, you may use our machines at no charge. Please make sure to take your materials home with you!

Q: What happens if my print fails?
A: If it's a fault of our printers and you notify us within 14 days of the print finishing, we'll happily let you print it again at no charge. If the print fails as a result of an error in your model or settings, unfortunately you'll still need to pay for the part. It pays to check with us before printing!

Q: Can you print this project for me?
A: Unfortunately not. It's makerspace policy that we don't operate machines for other makers, but we'll happily teach you how to use the equipment.

Shutdown Checklist

- ☐ I've cleaned up the build platform and placed it back in the Form 3.
- ☐ I've cleaned the surrounding area of resin or IPA that might have spilled.
- ☐ I've thoroughly cleaned and put away all tools, including spatulas, tank tools, and clippers.
- ☐ The Form 3 cover is closed, the resin tank and resin cartridge are secured, and the vent clip is sealed again.
- ☐ If there were issues with my printed part, I've talked to a staff about next steps.
- ☐ I've worked with a staff member to pay for my print in a timely manner.

Updated January 2020

Appendix A2: Samples pages from an instructor-facing teaching guide

LAS110: Introduction to Epilog Fusion Laser Cutters

KEY ITEMS

- **Course link:** LAS110
- **Passcode:** LAS110_f2j3jf

OBJECTIVES

Learn the basics of using an Epilog Fusion Pro laser cutter. At the end of the course users will have firm knowledge on the following:

- Basic laser system operations
- Key differences between fiber and CO_2 lasers
- Epilog Dashboard and Epilog Job Manager software
- Material hazards and dangers
- Effects of material density on laser cutting and engraving
- Basic laser safety

COMPETENCIES

- ❑ Knowledge of CO_2 and fiber laser systems.
- ❑ Basic knowledge of vector software (Inkscape, Adobe Illustrator, etc.)
- ❑ Knowledge of basic physical processes with regards to the EM spectrum.
- ❑ Knowledge for safe operation of an Epilog Fusion series laser.

VOCABULARY & KEY TERMS

Speed – The rate at which the laser head travels. This will be a percentage of maximum travel speed.

Power -- The amount of photons or energy particles released by the laser. This will be a percentage of maximum laser wattage.

Dithering – The way that raster images are engraved. Basically a collection of dots that shades an image with higher concentrations being darker than lower concentrations.

Dots per inch (DPI) – The maximum number of laser dots per inch of material when dithering. Doubling this value from 300 DPI to 600 DPI creates four times as many dots per inch (two times the dots in the X-direction and two times the dots in the Y-direction).

Focus – The distance between the laser head and the material being engraved/cut.

BACKGROUND

Epilog lasers are considered an industry standard for laser cutters and engravers. The Fusion series laser cutters and engravers are both excellent and accurate machines. Equipped with a CO_2 sealed laser tube and a ytterbium fiber laser, their versatility is rarely matched. From laser cut art to usable machine parts Epilog laser systems can provide accurate and professional looking products for the everyday user.

MATERIALS & PREPARATION

- ❑ Epilog Fusion Series laser
- ❑ Computer with Epilog Dashboard installed
- ❑ Small piece of scrap material (wood preferred)

To prepare for this workshop, it's handy to have some physical examples to display when discussing the following topics:

- Focusing the laser (acrylic sheet)
- Speed and power variation chart
- Non-uniform engraving depths
- Miscellaneous projects to show capacity of the machines.

BEFORE YOU START

Ask the class about their own experience with lasers, the makerspace, and review general safety information. Ensure all class members are

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wearing eye protection as well as following the basic PPE guidelines before entering the work area. Ensure that a makerspace member also has the required OSHA fire safety badge. The fire safety badge is important for operating the laser safely in case of any mishaps during the class.

WORKSHOP OUTLINE

Turning on the laser

The laser has a very specific procedure to turn it on. Follow these steps with the students.

1. Before anything else, turn on the ventilation system for the laser cutter.
2. Ensure that the ventilation hose is connected and unobstructed. In the Laramie Innovation Wyrkshop, this means turning the red stopper lever to be parallel to the ventilation tubing attached to the Epilog.
3. Plug in the Ethernet cords to the machine and computer.
4. Turn the key and importantly, **wait for the homing sequence to finish before placing any material.** Ensure the metal cutting or engraving trays are pushed back as far as they will go. If these are too far forward, they may get caught under the lip on the Fusion's front door. This can cause issues with the machine, and will make a loud clicking from the motors when it happens.

Laser safety features and manual controls

The laser has a few important safety features to highlight:

1. The emergency stop button is located next to the power key on the machine. This should be pressed when issues arise with the machine crunching into the plate, when a fire occurs, or in the case of another unforeseeable emergency.
2. The laser door has two interlocks. These interlocks act as safety features that turn off the laser beam in the event that the door is open. Before starting to engrave or cut, always ensure that these interlocks are fully closed. If the interlocks are open, the laser head will still follow its predefined path, but will not cut. This is a common reason for many ruined projects, so be sure to mention it to students.

After the safety features, it is important to discuss how to manually operate the machine. To do this, we access the Epilog control panel located on the right side of the machine (Refer to **Figure 1** in "Supplemental Images"). The control panel and joystick have many menus and features that bear a brief review:

1. **Jog menu** – Allows for movement of the machine with the use of the joystick. Values can also be "nudged" for more precision, which is done in increments as low as one thousandth of an inch (0.001").
2. **Pointer button** – Toggles the red dot pointer on and off. If the machine is properly calibrated, the red dot should show up in exactly the centerline of the laser head.
3. **Focus menu** – The menu to control the z-axis of the machine. This is very important when talking about focusing the laser. It can also be precision nudged to increments as small as 0.001".
4. **Job menu** –The menu where jobs are selected, traced, and started.
5. **Trace button** – When a job is highlighted in the job menu and the trace button is clicked, the status indicator above the reset button will change from "idle" to "trace." The laser head will trace a box around the outside of the object to cut or engrave, which shows the boundaries for the job and helps align material.
6. **Reset button** – Useful when a job is paused and a maker wishes to start the job over again.
7. **Start/Stop button** – The button to start and pause the current job. Located next to the joystick.

The final critical safety topic to discuss is what to do in the event of a fire. By their nature, lasers burn things, and fire is inevitable. For that reason, users should NEVER leave the machine unattended while cutting. When a small fire occurs (a fleeting flame, one that can be

[Appendix A2 Sample Text Ends]

SUPPLEMENTAL IMAGES

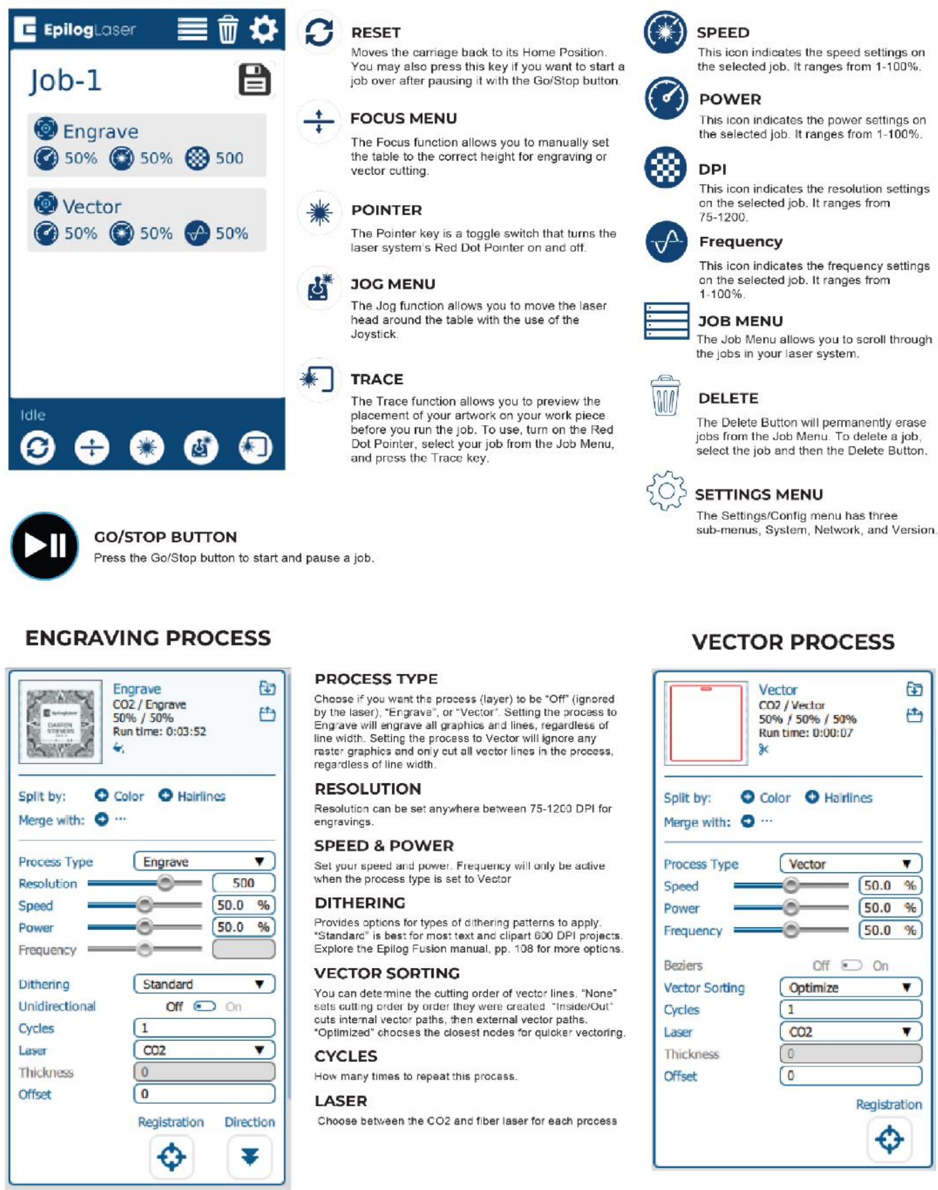

Figure 1: The Epilog Control Panel (top) and Epilog software (bottom)