INNOVATION WYRKSHOP

# MAKERSPACE EQUIPMENT GUIDE 2021

INNOVATION WYRKSHOP

# Recommended makerspace equipment guide

Makerspaces and the maker cultures surrounding them are and always will be wonderfully diverse – influenced by the administrative politics and policy, funding, equipment, and the communities they engage. They can vary in a huge number of ways from classrooms, garages, and sheds to entire buildings, and consequently may cater to a wide audience from young makers through experienced engineers and scientists.

So how can we write a one-size-fits-all guide to setting up a makerspace? The simple answer is that we can't. But what we can do is write something of a "choose-your-own-adventure" guide that allows you to make an informed decision about the types of technology, space, storage, and supplies that you might need at each juncture of your makerspace planning journey. At any point, you can also view the full spreadsheet.

Each section of this document details a particular category of equipment or specialization commonly found in makerspaces. In each section, you'll find a description, our notes and reminders on safety, any additional considerations you might need to think about, and finally a detailed list of hardware, software, and materials. The cost estimates provided are estimates from popular vendors at the time of writing. The quantities for each item are suggestions based on an approximate number of makers that we expect would be best suited for that particular type of facility. In each case, equipment has been further subdivided and color-coded by the quantities recommended at each makerspace tier:

| | | |
|---|---|---|
| | Tier 1m | Mobile makerspace lab |
| | Tier 1 | Introductory makerspace |
| | Tier 2 | Rapid prototyping, entrepreneurial facility |
| | Tier 3 | Advanced manufacturing & research facility |

Ultimately, this supplemental appendix is intended to serve as a comprehensive list of (and rationale for) equipment commonly found in many different types of makerspaces. We've selected hardware and software that are well reviewed and well supported by the makerspace community, and in almost every case, technology that we strongly endorse and have owned and operated for a number of years.

We hope you find it useful.

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# 3D Printing

Every kind of 3D printer builds parts based on the same main principle: a digital model is turned into a physical three-dimensional object by adding or fusing material layer by layer through a process called "additive manufacturing." 3D printing is fast, customizable, easy to learn, and allows ordinary people to easily manufacture complex objects from the comfort of homes, garages, and of course, makerspaces. And unlike traditional manufacturing where machines might cost hundreds of thousands of dollars and are accessible only to a select few, 3D printers in makerspaces can range from inexpensive desktop models to top-of-the-line industrial machines capable of printing in materials such as metal, PEI, and carbon fiber. And they're available to everyone.

So what are people making with 3D printers? Quite a wide diversity of different projects, it turns out. Want to prototype a toy or model? You can 3D print it. Broke critical parts of your vintage washing machine? 3D print those replacement parts. Want to prototype innovative new parts for your motorcycle? You can! From prototypes, toys and games, educational teaching models, scientific research, functional automotive parts, jewelry, bioengineered devices, houses, and even food – it's all possible with 3D printing.

## Safety considerations

When operated correctly, desktop 3D printers are typically very safe. The main concerns a user might have would be **burn risks** or **cutting risks**. A 3D printer's heat block and nozzle (right) often reach temperatures greater than 200°C. These parts generally move slowly enough that attentive users should not be concerned.

Removing parts requires use of tools such as sharpened metal spatulas and sometimes wire cutters. As with any sharp tools, these may cause injury and lacerations if handled incorrectly.

Most common 3D printed thermoplastics (PLA, PET, TPU, PVA) do not off-gas considerably, and thus using these materials carries minimal-to-no risk of toxic fumes. Since desktop 3D printing is a relatively new innovation, scientific studies advise makers to err on the side of caution and situate 3D printers in areas with sufficient ventilation or a large enough space to minimize risks of inhaling microplastics or harmful gases, such

as potentially carcinogenic styrene. For this reason, we don't advise printing with ABS plastic unless in a properly ventilated area. Some SLA ("stereolithography") 3D printers use lasers to selectively cure liquid photopolymer resin, which is toxic and must be UV cured before handling or disposal of any excess resin. We recommend that users wear powder-free nitrile gloves whenever operating SLA machines or handling 'green' parts that have not yet been UV cured. Cured parts are safe to handle.

Finally, industrial 3D printers come in a huge variety of makes and models, most of which require specific handling procedures. Often these machines require wearing powder-free nitrile gloves, heat resistant gloves, or in many cases, they require a ventilation system connected and potentially filtered to the outside of the building. In the most advanced cases, such as with SLS nylon or DMLS metal powder 3D printers, they require that a connected ventilation and filtration system is set up, and that users wear a personal PAPR (Power Air-Purifying Respirator) when handling materials or operating the machine.

## Additional considerations

- You typically need at least 2 x 2 x 2 feet of dedicated space on a table or workbench. Tables should be relatively stable, and capable of absorbing vibrations as the printers move back and forth.
- Certain 3D printers may require direct connect to a computer to operate the printer. None of the desktop 3D printers on our list requires a direct connection, and can be operated simply by loading files on to USB. Most if not all of the larger industrial machines do require a direct connection.
- While computers might not be required to 3D print, makers will still need to access one in order to create or download 3D models to print.
- A 3D printer requires a grounded outlet. Most desktop 3D printers pull relatively little power, and can operate under a standard 120V outlet.
- 3D printing itself is not a particularly fast process, despite being considered 'rapid prototyping.' Speed is almost entirely dependent on the size of the part to be printed as well as the settings a maker selects in the software. As such, estimates on volume of plastic used or time of a particular print can be very situation-specific.
- Parts printed on a 3D printer often require some post-processing to cleanup breakaway support material, dissolve PVA support material, and even general sanding to improve the final quality.
- Some advanced desktop printers, such as the Ultimakers on this list, are capable of printing with multiple materials at once. This allows printing in multiple colors, materials, and even dissolvable support material.
- It takes approximately 60 minutes to learn to use any of the 3D printers on our list. Designing 3D models in either CAD or 3D modeling software requires separate courses, each of which typically takes 60 to 90 minutes.
- In addition to creating original 3D models, designs can also be freely downloaded from 3D model repositories such as Thingiverse, GrabCAD, TurboSquid, Sketchfab, CGtrader, Prusa, MyMiniFactory, NIH 3D Print Exchange, and Yeggi.

## Incidental hardware and software

Slicers – the programs that convert a 3D model into X, Y, and Z instructions for the 3D printer – are often free and easy to operate. We see little justification for using any of the paid slicers when such excellent free options are available. Ultimaker Cura and PrusaSlicer are free and open-source slicers that support most makes and models of desktop 3D printer. Others, such as GrabCAD or PreForm, are proprietary but included as part of the purchase price for Stratasys and Formlabs machines, respectively. Another free alternative is Slic3r.

## 3D printing equipment & tools

| | | | | | Totals: | Tier 1m | Tier 1 | Tier 2 | Tier 3 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $ 2,213.87 | $ 12,372.51 | $ 124,677.14 | $ 252,999.20 |
| | Quantity | | | | | | | | |
| **Desktop FDM** | | T1 | T2 | T3 | Cost ea. | **$ 2,064.64** | **$ 12,223.28** | **$ 21,681.92** | **$ 43,830.56** |
| Prusa Mini | 4 | 2 | 2 | 0 | $399.00 | $ 1,596.00 | $ 798.00 | $ 798.00 | $ - |
| Original Prusa i3 MK3 kit (3D printer) | 0 | 2 | 2 | 4 | $749.00 | $ - | $ 1,498.00 | $ 1,498.00 | $ 2,996.00 |
| Ultimaker S3 | 0 | 2 | 4 | 6 | $4,495.00 | $ - | $ 8,990.00 | $ 17,980.00 | $ 26,970.00 |
| Ultimaker S5 | 0 | 0 | 0 | 2 | $5,995.00 | $ - | $ - | $ - | $ 11,990.00 |
| 3mm filament | 0 | 4 | 6 | 8 | $72.16 | $ - | $ 288.64 | $ 432.96 | $ 577.28 |
| 1.75 mm filament | 4 | 4 | 6 | 8 | $72.16 | $ 288.64 | $ 288.64 | $ 432.96 | $ 577.28 |
| Filament storage | 2 | 4 | 6 | 8 | $90.00 | $ 180.00 | $ 360.00 | $ 540.00 | $ 720.00 |
| **Desktop SLA** | | | | | | **$ -** | **$ -** | **$ 6,808.73** | **$ 12,992.73** |
| Form 3 3D Printer | 0 | 0 | 1 | 3 | $3,092.00 | $ - | $ - | $ 3,092.00 | $ 9,276.00 |
| Form Wash | 0 | 0 | 1 | 1 | $499.00 | $ - | $ - | $ 499.00 | $ 499.00 |
| Form Cure | 0 | 0 | 1 | 1 | $699.00 | $ - | $ - | $ 699.00 | $ 699.00 |
| Formlabs Pro Service Plan Welcome Packet | 0 | 0 | 1 | 1 | $499.00 | $ - | $ - | $ 499.00 | $ 499.00 |
| Black Resin Cartridge (GPBK04) | 0 | 0 | 2 | 2 | $149.00 | $ - | $ - | $ 298.00 | $ 298.00 |
| Clear Resin Cartridge (GPCL04) | 0 | 0 | 2 | 2 | $149.00 | $ - | $ - | $ 298.00 | $ 298.00 |
| Grey Resin Cartridge (GPGR04) | 0 | 0 | 2 | 2 | $149.00 | $ - | $ - | $ 298.00 | $ 298.00 |
| Durable Resin Cartridge | 0 | 0 | 1 | 1 | $175.00 | $ - | $ - | $ 175.00 | $ 175.00 |
| White Resin Cartridge (GPWH04) | 0 | 0 | 2 | 2 | $149.00 | $ - | $ - | $ 298.00 | $ 298.00 |
| Tough Resin Cartridge | 0 | 0 | 1 | 1 | $175.00 | $ - | $ - | $ 175.00 | $ 175.00 |
| SLA shipping | 0 | 0 | 1 | 1 | $477.73 | $ - | $ - | $ 477.73 | $ 477.73 |
| **Industrial 3D Printing** | | | | | | **$ -** | **$ -** | **$ 95,883.35** | **$ 195,849.37** |
| Stratasys J55 | 0 | 0 | 0 | 1 | $96,926.02 | $ - | $ - | $ - | $ 96,926.02 |
| Waterjet system (for J55) | 0 | 0 | 0 | 1 | $3,040.00 | $ - | $ - | $ - | $ 3,040.00 |
| Stratasys F380CF | 0 | 0 | 1 | 1 | $72,909.35 | $ - | $ - | $ 72,909.35 | $ 72,909.35 |
| SCA cleaning station | 0 | 0 | 1 | 1 | $3,325.00 | $ - | $ - | $ 3,325.00 | $ 3,325.00 |
| P400 concentrate (SCA bath) | 0 | 0 | 1 | 1 | $149.00 | $ - | $ - | $ 149.00 | $ 149.00 |
| Service contracts | 0 | 0 | 1 | 1 | $0.00 | $ - | $ - | $ - | $ - |
| Installation & training | 0 | 0 | 1 | 1 | $2,000.00 | $ - | $ - | $ 2,000.00 | $ 2,000.00 |
| Consumables credit | 0 | 0 | 1 | 1 | $15,000.00 | $ - | $ - | $ 15,000.00 | $ 15,000.00 |
| Shipping (estimate) | 0 | 0 | 1 | 1 | $2,500.00 | $ - | $ - | $ 2,500.00 | $ 2,500.00 |
| **3D printing accessory supplies, tools** | | | | | | **$ 149.23** | **$ 149.23** | **$ 303.14** | **$ 326.54** |
| Putty scraper spatula | 1 | 1 | 2 | 2 | $10.99 | $ 10.99 | $ 10.99 | $ 21.98 | $ 21.98 |
| X-ACTO knife kits | 2 | 2 | 4 | 4 | $11.99 | $ 23.98 | $ 23.98 | $ 47.96 | $ 47.96 |
| Precision tweezer kits (10 pieces) | 5 | 5 | 10 | 10 | $13.99 | $ 69.95 | $ 69.95 | $ 139.90 | $ 139.90 |
| Tweezer kits (4 pieces) | 5 | 5 | 10 | 10 | $6.99 | $ 34.95 | $ 34.95 | $ 69.90 | $ 69.90 |
| Wire cutters (filament) | 2 | 2 | 5 | 10 | $4.68 | $ 9.36 | $ 9.36 | $ 23.40 | $ 46.80 |

# 3D Scanning

3D scanning involves converting real-life objects into digital 3D models. The technology has had a significant impact on various fields, from dentistry, paleontology, art history, CGI in the film industry, and museum collections – to name only a few. And as with many types of technology available in makerspaces, 3D scanning is becoming more and more accessible on a commercial and hobbyist level.

3D scanning objects ("capturing data") can be done a number of ways, and often the best type of 3D scanning is contingent on your budget and what types of objects your community might want to scan. But ultimately, 3D scanning can be broken down into three major categories:

- **Structured-light scanners** (SLS) use infrared or "structured light" to scan an object. Cameras flash bright strobe lights and patterns on to an object to detect distortions in light and pattern projected onto the object's surface. From this, the machine can determine accurate dimensions and texture (color).
- **Photogrammetry** uses hundreds of overlapping photos taken by an ordinary camera to figure out distance, depth, and differences between images. From this data, powerful software can create a 3D object. The quality is usually dependent on the photos and camera used.
- **LiDAR** bounces laser light off an object to gauge distance and depth in order to form a 3D scan. It's usually the quickest of the three, but often doesn't capture data on texture. Think of LiDAR like bat or whale sonar. Count the timing between hundreds of laser 'pings' bouncing off an object and returning back to the machine, and soon enough you have an accurate and very dense point cloud.

## Safety considerations

There are few if any safety considerations with 3D scanners. Those who are sensitive to or dislike bright flashing strobe lights may want to steer clear of structured-light scanning (SLS). LiDAR uses lasers, and with any type of laser projection, you shouldn't look directly at it. Listen to your mother and wear good hiking boots to avoid blisters if you decide to capture data outside in nature. Beyond that, 3D scanners are among the safest equipment to be found in a makerspace.

## Additional considerations

- Photogrammetry is often the lowest-resolution of the bunch, but is the best suited for field work or research where you don't have access to plugs, batteries, laptops, or power units necessary for some SLS or LiDAR scanners. All you need is your trusty DSLR camera to get started.
- Photogrammetry is conveniently dimensionless, meaning you can scan very tiny things under a microscope, or entire castles and landscapes by taking systematic photos via drone.
- Structured-light scanners (SLS) excel at capturing dimensioned models with color data quickly but are limited in what they can scan. Dark, fuzzy, homogenous objects or objects that otherwise soak up light and pattern (and thus make it unreadable by the machine) aren't easily scanned unless you change the object by painting it or otherwise making it easier to detect.
- LiDAR scanners are the best suited for capturing raw point clouds quickly. 3D scan a football field in a matter of seconds with a click of a button, but don't expect any color texture data to accompany your scan.
- In this guide, we recommend photogrammetric and SLS equipment, but don't touch on LiDAR equipment, as it's usually more expensive and makerspace users don't often have a need for the scope of work that LiDAR is best equipped to do. Instead, LiDAR is more frequently used in advanced academic and research applications. For recommendations on the best LiDAR equipment out there, we recommend reaching out to either the Shell 3D Visualization Center or the Digital Collections Office at the University of Wyoming. Both groups can provide excellent recommendations on any of the three types of 3D scanners, and which one may be best suited for your community needs.
- Photogrammetry will require additional software. Agisoft Metashape is considered one of the industry standards. We detail these costs under "Software" later in this guide. The two Artec structured-light scanners are accompanied by proprietary software provided as part of the cost of the equipment.

## 3D scanning equipment

| | | | | | Totals: | Tier 1m | Tier 1 | Tier 2 | Tier 3 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $ 489.00 | $ 489.00 | $ 30,778.00 | $ 55,573.00 |
| | Quantity | | | | | | | | |
| 3D Scanners | | T1 | T2 | T3 | Cost ea. | $ 489.00 | $ 489.00 | $ 30,778.00 | $ 55,573.00 |
| DSLR camera | 1 | 1 | 2 | 2 | $489.00 | $ 489.00 | $ 489.00 | $ 978.00 | $ 978.00 |
| Artec Space Spider | 0 | 0 | 0 | 1 | $24,795.00 | $ - | $ - | $ - | $ 24,795.00 |
| Artec Leo | 0 | 0 | 1 | 1 | $29,800.00 | $ - | $ - | $ 29,800.00 | $ 29,800.00 |

# Computers, Displays, & Software

Computers are used almost universally across all the technology offered in a makerspace, and are critical as a means to access information as well as provide the necessary digital tools for makers to create, innovate, design, and collaborate.

Before something can be 3D printed, it must first be made into a digital 3D model that is then sliced into layers using a variety of ‘slicing’ software. Robots, CNCs, and laser cutters must first be programmed before a maker can start a project. Patterns, designs, and materials can be mapped out before sewn or crafted. And beyond this, access to the internet provides project ideas, collaborative help, instructional videos and training modules, and critical resource information. Sharing and documenting projects is critical to the basic idea of making. Innovation typically happens at the intersection of diverse backgrounds, ideas, and experiences – something that is only accelerated by access to an internet community of makers.

## Safety considerations

There are few, if any, physical risks to using computers, laptops, and a variety of software programs, save for proper posture and taking regular screen breaks.

Instead, be cognizant of some of the more intangible risks associated with computers and networks. Consider purchasing reboot to restore software that clears and resets laptops between users. Ensure that students are not disclosing names, addresses, phone numbers, email, city, school, and other personal information online. Likewise, ensure that personal user accounts signed in to different websites are likewise logged out between users.

## Additional considerations

- Work with your local IT groups to make sure that any laptops, hardware, and software purchased meet encryption and security standards for your organization before purchasing.
- For the most part, any operating system (Windows, MacOS) is fine, though we recommend avoiding Linux for the simple sake of appealing to and providing access to the widest audience. Whenever possible, consult with your organization and purchase machines that align with existing hardware and software. Some software, such as high-end computer-aided design (CAD) software like SolidWorks and some Epilog laser cutting software, can only be installed on PCs. Ensuring that hardware and software align with existing technology allows IT groups to more effectively update and maintain the equipment.

- With the exception of some of the larger 3D modeling and 3D scanning programs (Autodesk, Blender, Metashape), most of the software listed does not require powerful laptops with larger processors. Most mid-tier laptops work perfectly well.
- Consider screen size when purchasing laptops. Visualizing 3D models and design work is easier on larger screens.
- Computers and laptops are absolutely necessary for the majority of fabrication, manufacturing, and design tools, from 3D printers and laser cutters to CNC machines and even sewing machines.
- Check to make sure that any computers purchased have access to WiFi as well as HDMI or display ports.
- Display TVs of various sizes are critical to host instructional workshops, to demonstrate ideas, or to display upcoming content, workshops, special events, and so on. In the Innovation Wyrkshop (Tier 3) in Laramie, we have four display TVs run on Raspberry Pis that are wall mounted throughout the space and rotate through exciting upcoming events, new part-time and volunteer positions, regular workshops, and information about available technology. We also have one large 65" TV an associated AV cart that we wheel around the makerspace to display lectures and workshops. We recommend a TV display over projectors, as projectors require dim to dark spaces to be most effective, whereas makerspaces are often (and should be) well-lit and lively.

## Computers, displays, and software

There is a very wide selection of software available to makers for free across a variety of operating systems. Among them: Gimp or Photopea instead of Photoshop for editing and manipulating images and photos. Inkscape for creating and manipulating vector images. Blender and ZBrushCoreMini instead of ZBrush or Autodesk Mudbox or Autodesk Maya for creating 3D models. Onshape for CAD modeling instead of Autodesk Fusion 360 or SolidWorks. 3D printing slicers, mentioned in the 3D printing section of this guide, are almost always free. All of these software options are excellent places to start, and fully sufficient for all Tier 1 (and perhaps even some Tier 2) spaces.

With that said, with the exception of 3D printing slicers, free software is often not what the professionals use. If you have the funds, consider purchasing the more expensive industry standard professional engineering and image-creation softwares, which are usually more powerful, easier to use, and are excellent for those wishing to show off skills as they start professional careers. Most of these professional software companies—including Adobe Creative Cloud and SolidWorks—offer educational discounts. Better still, some such as Autodesk offer entirely free educational licenses for those with educational credentials, such as a school email or student or educator ID.

| | | | | | Totals: | Tier 1m | Tier 1 | Tier 2 | Tier 3 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $ 13,940.00 | $ 16,748.40 | $ 27,754.32 | $ 38,262.40 |
| | Quantity | | | | | | | | |
| Computers & tablets | | T1 | T2 | T3 | Cost ea. | $ 13,017.47 | $ 15,770.55 | $ 23,371.49 | $ 32,453.97 |
| HP Workstation Z2 G4 | 0 | 1 | 2 | 3 | $1,286.77 | $ - | $ 1,286.77 | $ 2,573.54 | $ 3,860.31 |
| HP Workstation Z2 G4* | 0 | 1 | 1 | 2 | $1,286.77 | $ - | $ 1,286.77 | $ 1,286.77 | $ 2,573.54 |
| Acer EK220Q Abi monitor | 0 | 2 | 3 | 5 | $83.78 | $ - | $ 167.56 | $ 251.34 | $ 418.90 |
| HP ZBook Power G7 Mobile Workstation | 10 | 10 | 15 | 20 | $1,238.89 | $ 12,388.90 | $ 12,388.90 | $ 18,583.35 | $ 24,777.80 |
| Charging security cart (medium) | 1 | 1 | 1 | 0 | $323.00 | $ 323.00 | $ 323.00 | $ 323.00 | $ - |
| Charging security cart (large) | 0 | 0 | 0 | 1 | $428.00 | $ - | $ - | $ - | $ 428.00 |
| Computer mouse pad | 10 | 12 | 18 | 25 | $5.99 | $ 59.90 | $ 71.88 | $ 107.82 | $ 149.75 |
| Computer mouse (30 pack) | 1 | 1 | 1 | 1 | $179.19 | $ 179.19 | $ 179.19 | $ 179.19 | $ 179.19 |
| USB thumb drives | 1 | 1 | 1 | 1 | $52.99 | $ 52.99 | $ 52.99 | $ 52.99 | $ 52.99 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| USB to SD card reader | 1 | 1 | 1 | 1 | $13.49 | $ 13.49 | $ 13.49 | $ 13.49 | $ 13.49 |
| **NGDLE (initial setup costs)**** | | | | | | **$ -** | **$ -** | **$ -** | **$ -** |
| Canvas LMS initial fees | 0 | 0 | 0 | 0 | $9,000.00 | $ - | $ - | $ - | $ - |
| DesignPLUS implementation | 0 | 0 | 0 | 0 | $3,000.00 | $ - | $ - | $ - | $ - |
| **Software** | | | | | | **$ 179.00** | **$ 179.00** | **$ 2,083.00** | **$ 3,508.60** |
| Adobe Creative Cloud | 0 | 0 | 5 | 11 | $237.60 | $ - | $ - | $ 1,188.00 | $ 2,613.60 |
| Autodesk Fusion360 | 10 | 10 | 15 | 20 | $0.00 | $ - | $ - | $ - | $ - |
| Autodesk Maya | 10 | 10 | 15 | 20 | $0.00 | $ - | $ - | $ - | $ - |
| Autodesk Mudbox | 10 | 10 | 15 | 20 | $0.00 | $ - | $ - | $ - | $ - |
| Autodesk Meshmixer | 10 | 10 | 15 | 20 | $0.00 | $ - | $ - | $ - | $ - |
| Ultimaker Cura | 10 | 10 | 15 | 20 | $0.00 | $ - | $ - | $ - | $ - |
| Arduino | 10 | 10 | 15 | 20 | $0.00 | $ - | $ - | $ - | $ - |
| Blender | 10 | 10 | 15 | 20 | $0.00 | $ - | $ - | $ - | $ - |
| Agisoft Metashape | 1 | 1 | 5 | 5 | $179.00 | $ 179.00 | $ 179.00 | $ 895.00 | $ 895.00 |
| Inkscape | 10 | 10 | 15 | 20 | $0.00 | $ - | $ - | $ - | $ - |
| Gimp | 10 | 10 | 15 | 20 | $0.00 | $ - | $ - | $ - | $ - |
| PrusaSlicer | 10 | 10 | 15 | 20 | $0.00 | $ - | $ - | $ - | $ - |
| ZBrush Core Mini | 10 | 10 | 15 | 20 | $0.00 | $ - | $ - | $ - | $ - |
| Cricut Design Space | 10 | 10 | 15 | 20 | $0.00 | $ - | $ - | $ - | $ - |
| **TVs** | | | | | | **$ 556.00** | **$ 556.00** | **$ 2,028.99** | **$ 2,028.99** |
| Samsung Smart TV (65") | 0 | 0 | 1 | 1 | $744.00 | $ - | $ - | $ 744.00 | $ 744.00 |
| TCL Roku Smart TV (32") | 4 | 4 | 4 | 4 | $139.00 | $ 556.00 | $ 556.00 | $ 556.00 | $ 556.00 |
| Ergotron UHD AV Cart | 0 | 0 | 1 | 1 | $728.99 | $ - | $ - | $ 728.99 | $ 728.99 |
| **Wiring, connectivity** | | | | | | **$ 187.53** | **$ 242.85** | **$ 270.84** | **$ 270.84** |
| HDMI | 3 | 3 | 3 | 3 | $20.08 | $ 60.24 | $ 60.24 | $ 60.24 | $ 60.24 |
| Ethernet | 2 | 2 | 2 | 2 | $21.99 | $ 43.98 | $ 43.98 | $ 43.98 | $ 43.98 |
| Display port cables | 1 | 2 | 2 | 2 | $55.32 | $ 55.32 | $ 110.64 | $ 110.64 | $ 110.64 |
| Ethernet switch | 1 | 1 | 2 | 2 | $27.99 | $ 27.99 | $ 27.99 | $ 55.98 | $ 55.98 |
| Wireless router*** | 0 | 1 | 1 | 1 | $0.00 | $ - | $ - | $ - | $ - |
| Wireless hotspot | 1 | 0 | 0 | 0 | $0.00 | $ - | $ - | $ - | $ - |

*Two sets of desktop PCs, some to support industrial machinery (line 1), some for staff (line 2)
** NGDLE ("Next Generation Digital Learning Environment." A step up from a traditional LMS. Currently, implementation costs for the “Maker Access Pass” NGDLE are covered by the University of Wyoming Innovation Wyrkshop. Included here for future use.
*** Wireless router and hotspots are covered as part of internet plans (see: Operations).

# Crafting, Arts, & Sewing

No makerspace would be complete without the huge variety in supplies to sew, cut, paint, glue, and craft. K-12 makerspaces take advantage of these types of easy-to-use machinery and scrap material workshops to engage young minds and ignite an interest in STEAM.

Sewing machines and sergers need no introduction, but it bears a quick mention that cutting machines (often referred to as vinyl cutters) are a relatively new technology born from the machine pen and ink plotters of the 60's and 70's and have become increasingly popular in makerspaces. These computer-controlled machines might look a bit like a desktop printers. Like a printer controls a nozzle, the computer controls the forward, back, and side-to-side movement of a sharp blade over the surface of the material. This blade is used to cut out shapes and letters from sheets of thin self-adhesive plastic (vinyl), cork, paper, balsa wood, cardboard, canvas, fabrics, foam, and even leather.


## Safety considerations

The biggest hazards for anyone using fast-moving machinery with blades and needles would be **cutting risks**. As a moving needle on a sewing machine punches in and out of the material, accidents and slips can happen easily. Makers should be attentive, or else risk slipping a finger under the needle while holding the fabric in place. Inattentive users can have injuries that range from simple puncture wounds to pieces of the needles or even thread embedded in fingers. Because cutting machines are computer-controlled, they are relatively safe. As long as makers don't put their hands near the machinery during operation, there are few risks involved. There is also a **burning risk** associated with auxiliary equipment, such as steam or clothes irons

We recommend that makers wear safety glasses while operating sewing machines. As the needle in the sewing machine moves through materials with different thicknesses and strengths, it can weaken. It is not uncommon for needles to break after repeated use. When a sewing machine is in motion, this can throw the small pieces towards the user.

## Additional considerations

- Most of the equipment listed here requires grounded outlets.
- Two sewing machines can typically fit on a 3’ x 6’ table or workbench. There must be enough room to spread out, and to lay projects down.
- Some software, such as niche software used to design patterns, is not included on this list.
- Sewing machines, sergers, and cutting machines often come with a wide range of small tools so adminstrators should factor in tool and consumable material (fabric, thread) storage. Storage is not one-size-fits-all and often site-specific, so we’ve included a discretionary budget here to accommodate those incidental requirements.
- Unlike equipment like 3D printers, where consumable materials may be difficult to get or proprietary, materials and consumables used in the crafting arena differ greatly across makers and personal preference. Thus, we advise purchasing some universal consumables (thread, small fabric scrap to practice, some vinyl) but expect makers to source their own materials for their own projects.

## Crafting & sewing equipment

| | | | | | | Totals: | Tier 1m | Tier 1 | Tier 2 | Tier 3 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | $ 1,932.15 | $ 2,760.97 | $ 3,642.09 | $ 3,642.09 |
| | Quantity | | | | | | | | | |
| **Sewing & Sewing Supplies** | 🚚 | T1 | T2 | T3 | Cost ea. | | $ 863.49 | $ 1,696.55 | $ 1,981.50 | $ 1,981.50 |
| Singer Quantum 9960 Sewing Machines | 1 | 2 | 2 | 2 | $ 599.99 | | $ 599.99 | $ 1,199.98 | $ 1,199.98 | $ 1,199.98 |
| Singer Heavy Duty 4452 Sewing Machine | 0 | 1 | 1 | 1 | $ 199.00 | | $ - | $ 199.00 | $ 199.00 | $ 199.00 |
| Singer ProFinish 14CG754 2-3-4 Thread Serger | 0 | 0 | 1 | 1 | $ 284.95 | | $ - | $ - | $ 284.95 | $ 284.95 |
| Sewing scissors | 1 | 2 | 2 | 2 | $ 16.99 | | $ 16.99 | $ 33.98 | $ 33.98 | $ 33.98 |
| Measuring Tape 5pk | 1 | 1 | 1 | 1 | $ 7.59 | | $ 7.59 | $ 7.59 | $ 7.59 | $ 7.59 |
| Clothes iron | 1 | 1 | 1 | 1 | $ 24.99 | | $ 24.99 | $ 24.99 | $ 24.99 | $ 24.99 |
| Ironing board (small) | 1 | 0 | 0 | 0 | $ 17.10 | | $ 17.10 | $ - | $ - | $ - |
| Ironing board (regular) | 0 | 1 | 1 | 1 | $ 34.18 | | $ - | $ 34.18 | $ 34.18 | $ 34.18 |
| Fabric marker | 1 | 1 | 1 | 1 | $ 11.99 | | $ 11.99 | $ 11.99 | $ 11.99 | $ 11.99 |
| Safety pin* | 1 | 1 | 1 | 1 | $ 12.82 | | $ 12.82 | $ 12.82 | $ 12.82 | $ 12.82 |
| Magnetic pincushion | 2 | 2 | 2 | 2 | $ 13.95 | | $ 27.90 | $ 27.90 | $ 27.90 | $ 27.90 |
| Machine needle combo pack | 1 | 1 | 1 | 1 | $ 16.99 | | $ 16.99 | $ 16.99 | $ 16.99 | $ 16.99 |
| Needle threaders | 1 | 1 | 1 | 1 | $ 6.99 | | $ 6.99 | $ 6.99 | $ 6.99 | $ 6.99 |
| Polyester thread (24 ct). | 1 | 1 | 1 | 1 | $ 23.59 | | $ 23.59 | $ 23.59 | $ 23.59 | $ 23.59 |
| Acrylic ruler | 1 | 1 | 1 | 1 | $ 17.11 | | $ 17.11 | $ 17.11 | $ 17.11 | $ 17.11 |
| Assorted needles | 1 | 1 | 1 | 1 | $ 5.44 | | $ 5.44 | $ 5.44 | $ 5.44 | $ 5.44 |
| Sewing pins | 1 | 1 | 1 | 1 | $ 13.00 | | $ 13.00 | $ 13.00 | $ 13.00 | $ 13.00 |
| Pinking shears | 1 | 1 | 1 | 1 | $ 11.70 | | $ 11.70 | $ 11.70 | $ 11.70 | $ 11.70 |
| Embroidery scissors | 1 | 1 | 1 | 1 | $ 8.00 | | $ 8.00 | $ 8.00 | $ 8.00 | $ 8.00 |
| Cutting mats | 2 | 2 | 2 | 2 | $ 13.00 | | $ 26.00 | $ 26.00 | $ 26.00 | $ 26.00 |
| Rotary cutter | 1 | 1 | 1 | 1 | $ 15.30 | | $ 15.30 | $ 15.30 | $ 15.30 | $ 15.30 |
| **Crafting Supplies** | | | | | | | **$ 1,068.66** | **$ 1,064.42** | **$ 1,660.59** | **$ 1,660.59** |
| Cricut Maker | 1 | 1 | 1 | 1 | $369.00 | | $ 369.00 | $ 369.00 | $ 369.00 | $ 369.00 |
| Hot glue gun & glue | 2 | 2 | 2 | 2 | $12.45 | | $ 24.90 | $ 24.90 | $ 24.90 | $ 24.90 |
| Wagner Furno 300 heat gun | 0 | 0 | 1 | 1 | $22.94 | | $ - | $ - | $ 22.94 | $ 22.94 |
| Paint brushes (wide) | 2 | 2 | 2 | 2 | $11.98 | | $ 23.96 | $ 23.96 | $ 23.96 | $ 23.96 |
| Paint brushes (detail) | 2 | 2 | 2 | 2 | $3.97 | | $ 7.94 | $ 7.94 | $ 7.94 | $ 7.94 |
| Foam brushes | 1 | 1 | 1 | 1 | $7.00 | | $ 7.00 | $ 7.00 | $ 7.00 | $ 7.00 |
| Glue sticks | 1 | 1 | 1 | 1 | $22.89 | | $ 22.89 | $ 22.89 | $ 22.89 | $ 22.89 |

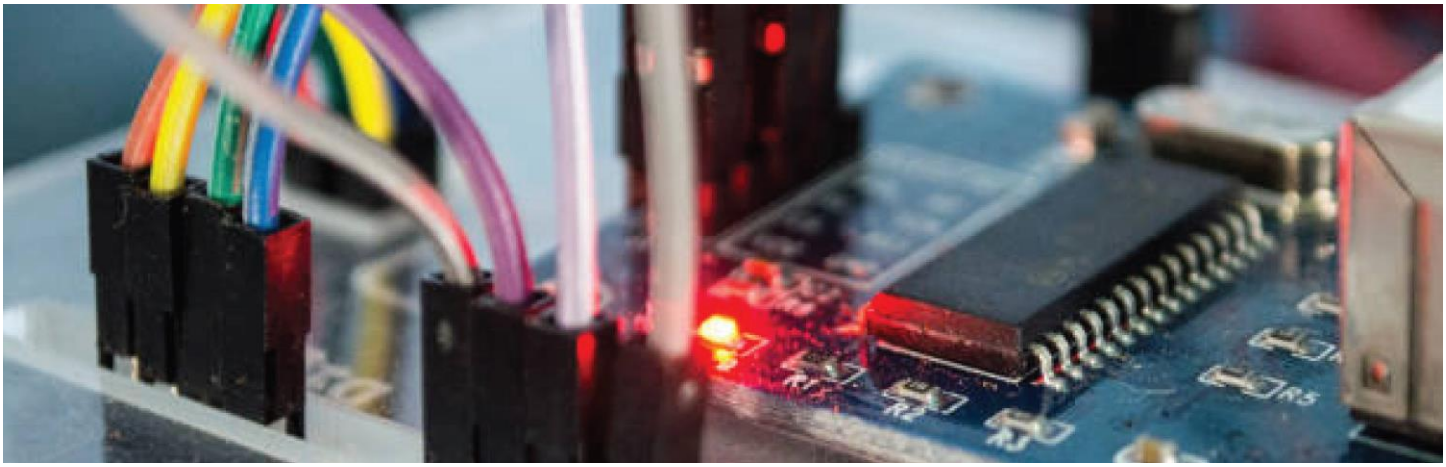
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Duct tape | 1 | 1 | 1 | 1 | $66.50 | $ 66.50 | $ 66.50 | $ 66.50 | $ 66.50 |
| Masking tape | 3 | 2 | 5 | 5 | $15.49 | $ 46.47 | $ 30.98 | $ 77.45 | $ 77.45 |
| Electrical tape | 0 | 1 | 2 | 2 | $11.25 | $ - | $ 11.25 | $ 22.50 | $ 22.50 |
| Epoxy | 0 | 0 | 3 | 3 | $5.17 | $ - | $ - | $ 15.51 | $ 15.51 |
| Discretionary | 1 | 1 | 2 | 2 | $500.00 | $ 500.00 | $ 500.00 | $ 1,000.00 | $ 1,000.00 |

# Electronics

Whether you're an artist needing to develop an LED lightshow, a hacker soldering together your own DIY cellphone, or just an innovator designing a solar-powered battery bank, learning about electronics and the tools commonly found on an electronics bench is integral to maker culture. A robust array of electronic components, integrated circuits, and microcontrollers can allow makers to learn more about the tech used in fields like communication systems, sensors, displays, robotics, instrumentation, voice recognition, computer vision, motors, power systems, and the Internet-of-Things.

Microcontrollers such as Arduino or Raspberry Pi are simple, inexpensive controllers that come in a variety of shapes and sizes and allow makers to easily measure, monitor, and manipulate the physical world. Their primary advantage is that they make physical computing projects quick and easy to build. Whether you're using them to drive flashing LEDs, activate motors, or sense changes in the real world, microcontrollers are well worth including in your makerspace. They're often used in K-12 makerspaces as a means to get younger audiences into the world of advanced electronics and electromechanical systems, which includes robotics.

Amplify those maker projects by harnessing the full power of electricity – maybe with a bit coding too.



## Safety considerations

Most electronics in a makerspace are relatively low-powered and safe. The more common risks you might run into are **burning risks** from the tips of soldering irons, which can reach temperatures between 400° to 800°F or more, as well as risk of **toxic fumes** that may be generated from soldering material. All types of soldering emit fumes during the soldering process, so proper ventilation is key. Desktop carbon filter fans can easily eliminate any small fumes generated from normal soldering. During typical soldering, there is very little health risk (though makers should wash their hands if they've been soldering for long periods of time, or handling lead solder). Lead-free solder requires higher temperatures, can give off more toxic fumes, and is generally harder to work with, and for these reasons we don't recommend it.

## Additional considerations

- Electronics equipment and tools are frequently accompanied by tiny resistors, wires, and small passive components like LEDs and switches. Ensure that you have plenty of small storage available to house and organize these small components or your electronics bench can become disorganized very quickly.
- Our introductory tiers focus more on microcontrollers and the very basics of soldering, whereas the more advanced makerspace tiers have higher-quality and advanced industrial tools and testing equipment to support more complex projects.
- In addition to soldering, also consider solderless breadboards, which are a great way for makers to quickly and nondestructively explore circuits.
- Make sure that you have at least one benchtop smoke absorber for each soldering station to ensure that you're properly ventilating the area.
- For some advanced circuitry testing equipment, access to a computer is recommended. Mid-tier laptops can be used for these projects.
- Improperly-made homemade projects may be dangerous in the space, but don't let this be a deterrent from setting up an electronics. In our case, we witnessed a user bring in a homemade RC car with a custom-made heat sink that quickly overheated and caught fire when turned on. This was a learning experience, and simply prompted us to implement a rule that makers should properly vet these types of advanced projects with staff before use. When utilized properly, an electronics bench should not carry any significant risk of fire or fumes.

## Electronics equipment

| | | | | | | Totals: | Tier 1m | Tier 1 | Tier 2 | Tier 3 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | $ 1,932.15 | $ 2,760.97 | $ 3,642.09 | $ 3,642.09 |
| | | Quantity | | | | | | | | |
| **Soldering** | | **T1** | **T2** | **T3** | **Cost ea.** | | **$ 393.93** | **$ 401.33** | **$ 4,888.69** | **$ 5,298.02** |
| Soldering Station | 0 | 0 | 1 | 2 | $230.00 | | $ - | $ - | $ 230.00 | $ 460.00 |
| Solder tip 0.25x13.4mm | 0 | 0 | 1 | 2 | $11.00 | | $ - | $ - | $ 11.00 | $ 22.00 |
| Solder tip 5.0x7.5mm | 0 | 0 | 1 | 2 | $11.00 | | $ - | $ - | $ 11.00 | $ 22.00 |
| Solder tip 0.4x8.9mm | 0 | 0 | 2 | 2 | $11.00 | | $ - | $ - | $ 22.00 | $ 22.00 |
| Solder tip 2.5x6.4mm | 0 | 0 | 1 | 2 | $11.00 | | $ - | $ - | $ 11.00 | $ 22.00 |
| Reword Station | 0 | 0 | 1 | 2 | $49.99 | | $ - | $ - | $ 49.99 | $ 99.98 |
| Soldering Station | 1 | 1 | 0 | 0 | $104.95 | | $ 104.95 | $ 104.95 | $ - | $ - |
| Soldering tips | 1 | 1 | 0 | 0 | $29.00 | | $ 29.00 | $ 29.00 | $ - | $ - |
| Voltera PCB Printer | 0 | 0 | 1 | 1 | $4,199.98 | | $ - | $ - | $ 4,199.98 | $ 4,199.98 |
| Bench top smoke absorber | 1 | 1 | 1 | 2 | $43.00 | | $ 43.00 | $ 43.00 | $ 43.00 | $ 86.00 |
| Wire Strippers/Cutters | 1 | 1 | 2 | 2 | $30.00 | | $ 30.00 | $ 30.00 | $ 60.00 | $ 60.00 |
| Wire strippers small AWG | 1 | 1 | 1 | 2 | $13.39 | | $ 13.39 | $ 13.39 | $ 13.39 | $ 26.78 |
| Third Hand soldering Tool | 1 | 1 | 1 | 2 | $39.95 | | $ 39.95 | $ 39.95 | $ 39.95 | $ 79.90 |
| Desoldering Wick | 1 | 1 | 2 | 2 | $9.00 | | $ 9.00 | $ 9.00 | $ 18.00 | $ 18.00 |
| Lead Free Tip Tinner | 1 | 2 | 3 | 3 | $7.40 | | $ 7.40 | $ 14.80 | $ 22.20 | $ 22.20 |
| Flux Pen | 1 | 1 | 2 | 2 | $9.03 | | $ 9.03 | $ 9.03 | $ 18.06 | $ 18.06 |
| Flux Pen Refill | 1 | 1 | 1 | 1 | $8.95 | | $ 8.95 | $ 8.95 | $ 8.95 | $ 8.95 |
| Solder | 2 | 2 | 3 | 3 | $26.00 | | $ 52.00 | $ 52.00 | $ 78.00 | $ 78.00 |
| Soldering Mat with ESD wristband | 1 | 1 | 1 | 1 | $18.39 | | $ 18.39 | $ 18.39 | $ 18.39 | $ 18.39 |
| Micro Cutter | 1 | 1 | 2 | 2 | $4.91 | | $ 4.91 | $ 4.91 | $ 9.82 | $ 9.82 |
| Desoldering Pump | 1 | 1 | 1 | 1 | $9.98 | | $ 9.98 | $ 9.98 | $ 9.98 | $ 9.98 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Tweezer Kit | 1 | 1 | 1 | 1 | $13.98 | $ 13.98 | $ 13.98 | $ 13.98 | $ 13.98 |
| **Basic Electronics Bench** | | | | | | **$ 256.78** | **$ 356.73** | **$ 950.95** | **$ 950.95** |
| Kit of Passive electronic components | 1 | 1 | 1 | 1 | $89.95 | $ 89.95 | $ 89.95 | $ 89.95 | $ 89.95 |
| Kit of IC's | 0 | 1 | 1 | 1 | $99.95 | $ - | $ 99.95 | $ 99.95 | $ 99.95 |
| Jumper wire kits | 1 | 1 | 2 | 2 | $12.95 | $ 12.95 | $ 12.95 | $ 25.90 | $ 25.90 |
| Wire kit | 2 | 2 | 3 | 3 | $16.00 | $ 32.00 | $ 32.00 | $ 48.00 | $ 48.00 |
| USB Microscope | 1 | 1 | 1 | 1 | $20.00 | $ 20.00 | $ 20.00 | $ 20.00 | $ 20.00 |
| Microscope | 0 | 0 | 1 | 1 | $509.99 | $ - | $ - | $ 509.99 | $ 509.99 |
| Electronic screwdriver kit | 1 | 1 | 1 | 1 | $15.00 | $ 15.00 | $ 15.00 | $ 15.00 | $ 15.00 |
| Breadboards | 16 | 16 | 24 | 24 | $3.95 | $ 63.20 | $ 63.20 | $ 94.80 | $ 94.80 |
| Perf board | 1 | 1 | 2 | 2 | $12.00 | $ 12.00 | $ 12.00 | $ 24.00 | $ 24.00 |
| Electrical Wire 22 AWG | 1 | 1 | 2 | 2 | $11.68 | $ 11.68 | $ 11.68 | $ 23.36 | $ 23.36 |
| **Testing equipment** | | | | | | **$ -** | **$ 70.00** | **$ 8,816.35** | **$ 14,916.35** |
| USB Oscope, Logic Analyzer, Power Supply | 1 | 1 | 1 | 2 | $399.00 | $ 399.00 | $ 399.00 | $ 399.00 | $ 798.00 |
| Basic power supply | 0 | 1 | 0 | 0 | $70.00 | $ - | $ 70.00 | $ - | $ - |
| Triple output power supply | 0 | 0 | 1 | 1 | $1,409.00 | $ - | $ - | $ 1,409.00 | $ 1,409.00 |
| Tektronix MDO34 oscilloscope | 0 | 0 | 1 | 0 | $5,150.00 | $ - | $ - | $ 5,150.00 | $ - |
| Add'l tektronix equipment configuration cost | 0 | 0 | 1 | 0 | $950.00 | $ - | $ - | $ 950.00 | $ - |
| Tektronix MSO44 oscilloscope | 0 | 0 | 0 | 1 | $7,550.00 | $ - | $ - | $ - | $ 7,550.00 |
| Add'l tektronix equipment configuration cost | 0 | 0 | 0 | 1 | $1,250.00 | $ - | $ - | $ - | $ 1,250.00 |
| Multimeter 6.5 Digit | 0 | 0 | 1 | 0 | $1,190.00 | $ - | $ - | $ 1,190.00 | $ - |
| Multimeter 7.5 Digit | 0 | 0 | 0 | 1 | $4,590.00 | $ - | $ - | $ - | $ 4,590.00 |
| BNC Test Lead Set | 0 | 0 | 1 | 1 | $13.99 | $ - | $ - | $ 13.99 | $ 13.99 |
| Banana Cable Lead Set | 0 | 0 | 3 | 3 | $12.79 | $ - | $ - | $ 38.37 | $ 38.37 |
| Test Lead Banana to Gator | 0 | 0 | 1 | 1 | $64.99 | $ - | $ - | $ 64.99 | $ 64.99 |
| **Microcontrollers / FPGA** | | | | | | **$ 724.95** | **$ 843.90** | **$ 1,426.25** | **$ 1,644.15** |
| Arduino Student kit | 4 | 4 | 8 | 8 | $59.00 | $ 236.00 | $ 236.00 | $ 472.00 | $ 472.00 |
| Raspberri Pi 4 Kit | 1 | 2 | 3 | 5 | $98.95 | $ 98.95 | $ 197.90 | $ 296.85 | $ 494.75 |
| Micro:bit board bundles | 4 | 4 | 5 | 5 | $17.50 | $ 70.00 | $ 70.00 | $ 87.50 | $ 87.50 |
| Clue Python Board | 4 | 4 | 5 | 5 | $40.00 | $ 160.00 | $ 160.00 | $ 200.00 | $ 200.00 |
| Microcontroller accessory kits | 2 | 2 | 3 | 3 | $37.00 | $ 74.00 | $ 74.00 | $ 111.00 | $ 111.00 |
| Premium Jumper Wire Kits | 6 | 6 | 9 | 9 | $11.00 | $ 66.00 | $ 66.00 | $ 99.00 | $ 99.00 |
| Raspberry Pi Pico RP2040 | 4 | 8 | 12 | 16 | $5.00 | $ 20.00 | $ 40.00 | $ 60.00 | $ 80.00 |
| FPGA | 0 | 0 | 2 | 2 | $49.95 | $ - | $ - | $ 99.90 | $ 99.90 |

# General Supplies

Equip your makerspace with a wide variety of tools for fastening, cutting, hammering, measuring, or building up/breaking apart and you'll be able to accommodate a wide diversity of projects. Our general supplies list is straightforward, and details the miscellaneous equipment, office supplies, brainstorming supplies, cleaning supplies, and safety supplies necessary for any space to thrive.

## Safety considerations


Almost everything in a makerspace is relatively safe to use when used responsibly, and as long as makers are aware of some universal safety requirements before they get started. Each makerspace is different, and may follow different administrative policies and protocols, but we've found that there are some universal safety rules that most makerspaces should consider:

- Safety cards that include PPE requirements, reminders, and hazards should be posted prominently near all relevant machinery.
- Safety glasses should be worn in designated areas, particularly those where there may be flying debris.
- Hair should be secured in designated areas, such as woodshops and around power tools.
- Loose and dangling clothing (jewelry, hoodie cords, necklaces, watches, bracelets) should NOT be worn in designated areas, such as woodshops and around power tools.
- Closed-toed shoes should be worn in designated areas, such as woodshops.

## Additional considerations

- Additional PPE and cleaning supplies should be clearly marked and easily accessible to all visitors.
- A label maker can be your best friend for keeping a space organized.
- All power tools should be accessible only after training and (in the case of younger makers) with supervision. Power tools should only be operated by makers with the strength to control the tool.
- There might be fears of makers walking off with or stealing tools, but over four years, we've not had one instance of theft. Provide makers with the tools, autonomy, and confidence to create safely, and they'll take some ownership over the space and help to ensure it's maintained well.

- Keep all tools, from screwdrivers and hammers to power tools clearly visible, accessible, and on display. If tools are squirreled away in cabinets or hard to access, makers won't know that they're available for use. Wall mounted pegboards are one very effective way to ensure that tools are easily accounted for while still ensuring that they remain visible.
- Not everything is a hammer. Ensure that makers are using tools properly.
- A common area with sofas and coffee table is a recurring theme across larger makerspaces. These 'brainstorming areas' encourage collaboration, foster relationships, and help to build up and strengthen the beating heart of any makerspace: its maker community.

## General supplies and miscellaneous equipment

| | | | | | | Totals: | Tier 1m | Tier 1 | Tier 2 | Tier 3 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | $ 5,176.57 | $ 5,066.17 | $ 8,995.64 | $ 9,286.10 |
| | Quantity | | | | | | | | | |
| **Misc tools & equipment** | 🚚 | **T1** | **T2** | **T3** | **Cost ea.** | | $ 139.37 | $ 139.37 | $ 254.02 | $ 360.80 |
| Neiko digital calipers | 1 | 1 | 2 | 2 | $20.87 | | $ 20.87 | $ 20.87 | $ 41.74 | $ 41.74 |
| Stanley 25' tape measure | 1 | 1 | 2 | 4 | $17.00 | | $ 17.00 | $ 17.00 | $ 34.00 | $ 68.00 |
| Yardstick | 1 | 1 | 2 | 3 | $2.79 | | $ 2.79 | $ 2.79 | $ 5.58 | $ 8.37 |
| Rulers | 2 | 2 | 1 | 1 | $5.99 | | $ 11.98 | $ 11.98 | $ 5.99 | $ 5.99 |
| Protractor and compass set | 1 | 1 | 2 | 2 | $9.99 | | $ 9.99 | $ 9.99 | $ 19.98 | $ 19.98 |
| Wire cutter/stripper | 1 | 1 | 1 | 1 | $6.75 | | $ 6.75 | $ 6.75 | $ 6.75 | $ 6.75 |
| Ifixit Professional toolkits | 1 | 1 | 2 | 3 | $69.99 | | $ 69.99 | $ 69.99 | $ 139.98 | $ 209.97 |
| **Office supplies** | | | | | | | **$ 1,757.48** | **$ 1,770.90** | **$ 2,290.38** | **$ 2,290.38** |
| HP Color LaserJet Pro M454dn | 0 | 0 | 1 | 1 | $429.00 | | $ - | $ - | $ 429.00 | $ 429.00 |
| 8.5x11 paper | 0 | 0 | 1 | 1 | $28.88 | | $ - | $ - | $ 28.88 | $ 28.88 |
| Extension cord | 5 | 5 | 10 | 10 | $16.82 | | $ 84.10 | $ 84.10 | $ 168.20 | $ 168.20 |
| Tripp Lite 6 Outlet Surge Protector | 5 | 5 | 5 | 5 | $11.50 | | $ 57.50 | $ 57.50 | $ 57.50 | $ 57.50 |
| Westcott Scissors (2 pack) | 5 | 5 | 2 | 2 | $7.88 | | $ 39.40 | $ 39.40 | $ 15.76 | $ 15.76 |
| Pencils | 4 | 4 | 2 | 2 | $11.60 | | $ 46.40 | $ 46.40 | $ 23.20 | $ 23.20 |
| Mechanical pencils | 20 | 20 | 20 | 20 | $6.72 | | $ 134.40 | $ 134.40 | $ 134.40 | $ 134.40 |
| Pens | 2 | 2 | 5 | 5 | $5.79 | | $ 11.58 | $ 11.58 | $ 28.95 | $ 28.95 |
| Sharpies | 2 | 2 | 2 | 2 | $6.40 | | $ 12.80 | $ 12.80 | $ 12.80 | $ 12.80 |
| DYMO LabelManager 160 | 1 | 1 | 1 | 1 | $22.79 | | $ 22.79 | $ 22.79 | $ 22.79 | $ 22.79 |
| Stapler | 2 | 2 | 3 | 3 | $8.02 | | $ 16.04 | $ 16.04 | $ 24.06 | $ 24.06 |
| Staples | 1 | 1 | 1 | 1 | $11.74 | | $ 11.74 | $ 11.74 | $ 11.74 | $ 11.74 |
| Zip ties | 2 | 2 | 3 | 3 | $8.90 | | $ 17.80 | $ 17.80 | $ 26.70 | $ 26.70 |
| String | 1 | 1 | 1 | 1 | $6.59 | | $ 6.59 | $ 6.59 | $ 6.59 | $ 6.59 |
| Twine | 2 | 2 | 1 | 1 | $5.30 | | $ 10.60 | $ 10.60 | $ 5.30 | $ 5.30 |
| AA and AAA batteries, assorted | 2 | 2 | 2 | 2 | $21.98 | | $ 43.96 | $ 43.96 | $ 43.96 | $ 43.96 |
| Desk organizers | 0 | 2 | 2 | 2 | $6.71 | | $ - | $ 13.42 | $ 13.42 | $ 13.42 |
| Paper Clips | 4 | 4 | 2 | 2 | $7.46 | | $ 29.84 | $ 29.84 | $ 14.92 | $ 14.92 |
| Sticky notes | 4 | 4 | 4 | 4 | $19.87 | | $ 79.48 | $ 79.48 | $ 79.48 | $ 79.48 |
| Binder clips | 4 | 4 | 2 | 2 | $13.99 | | $ 55.96 | $ 55.96 | $ 27.98 | $ 27.98 |
| Sterilite 6 qt storage bins | 2 | 2 | 3 | 3 | $38.25 | | $ 76.50 | $ 76.50 | $ 114.75 | $ 114.75 |
| Discretionary | 1 | 1 | 1 | 1 | $1,000.00 | | $ 1,000.00 | $ 1,000.00 | $ 1,000.00 | $ 1,000.00 |
| **Education & brainstorming** | | | | | | | **$ 157.54** | **$ 297.53** | **$ 1,244.29** | **$ 1,244.29** |

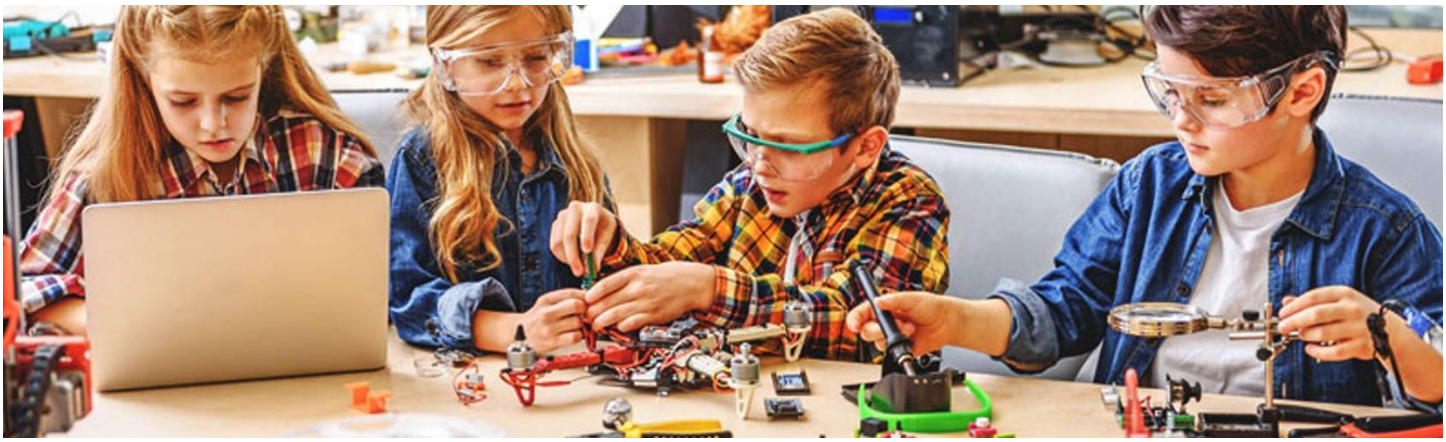
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| White board (96x48") | 0 | 0 | 1 | 1 | $653.84 | $ - | $ - | $ 653.84 | $ 653.84 |
| White Board (48x36") | 1 | 2 | 4 | 4 | $139.99 | $ 139.99 | $ 279.98 | $ 559.96 | $ 559.96 |
| Block erasers | 1 | 1 | 1 | 1 | $4.61 | $ 4.61 | $ 4.61 | $ 4.61 | $ 4.61 |
| Dry erase markers | 1 | 1 | 2 | 2 | $12.94 | $ 12.94 | $ 12.94 | $ 25.88 | $ 25.88 |
| **Shelving, tables, & seating** | | | | | | **$ 1,000.00** | **$ 639.96** | **$ 2,973.61** | **$ 3,101.32** |
| Metal peg board (48 x 32) | 0 | 0 | 1 | 2 | $127.71 | $ - | $ - | $ 127.71 | $ 255.42 |
| Peg board hooks (assorted, slotted) | 0 | 0 | 1 | 1 | $34.99 | $ - | $ - | $ 34.99 | $ 34.99 |
| Peg board hooks (assorted, pegs) | 0 | 0 | 1 | 1 | $30.99 | $ - | $ - | $ 30.99 | $ 30.99 |
| OMAR 2 section shelving unit | 0 | 1 | 2 | 2 | $139.96 | $ - | $ 139.96 | $ 279.92 | $ 279.92 |
| Common area sofas & tables | 0 | 0 | 1 | 1 | $2,000.00 | $ - | $ - | $ 2,000.00 | $ 2,000.00 |
| Discretionary | 2 | 1 | 1 | 1 | $500.00 | $ 1,000.00 | $ 500.00 | $ 500.00 | $ 500.00 |
| **Cleaning** | | | | | | **$ 1,343.13** | **$ 1,370.12** | **$ 731.54** | **$ 731.54** |
| Broom & dust pan | 0 | 1 | 1 | 1 | $26.99 | $ - | $ 26.99 | $ 26.99 | $ 26.99 |
| Paper towels | 2 | 2 | 4 | 4 | $24.50 | $ 49.00 | $ 49.00 | $ 98.00 | $ 98.00 |
| Hand broom | 1 | 1 | 1 | 1 | $16.44 | $ 16.44 | $ 16.44 | $ 16.44 | $ 16.44 |
| All-purpose cleaner | 6 | 6 | 3 | 3 | $3.19 | $ 19.14 | $ 19.14 | $ 9.57 | $ 9.57 |
| Disinfectant mist spray | 2 | 2 | 1 | 1 | $39.89 | $ 79.78 | $ 79.78 | $ 39.89 | $ 39.89 |
| Disinfectant wipes | 2 | 2 | 1 | 1 | $53.50 | $ 107.00 | $ 107.00 | $ 53.50 | $ 53.50 |
| Isopropyl alcohol | 0 | 0 | 2 | 2 | $75.75 | $ - | $ - | $ 151.50 | $ 151.50 |
| Hand vacuum | 1 | 1 | 1 | 1 | $52.18 | $ 52.18 | $ 52.18 | $ 52.18 | $ 52.18 |
| Lens wipes | 1 | 1 | 1 | 1 | $19.59 | $ 19.59 | $ 19.59 | $ 19.59 | $ 19.59 |
| Push broom | 0 | 0 | 1 | 1 | $13.88 | $ - | $ - | $ 13.88 | $ 13.88 |
| Discretionary | 4 | 4 | 1 | 1 | $250.00 | $ 1,000.00 | $ 1,000.00 | $ 250.00 | $ 250.00 |
| **Safety** | | | | | | **$ 779.05** | **$ 848.29** | **$ 1,501.80** | **$ 1,557.77** |
| First aid kit (small, wall) | 1 | 1 | 2 | 2 | $20.93 | $ 20.93 | $ 20.93 | $ 41.86 | $ 41.86 |
| First aid kit (large, wall) | 0 | 0 | 1 | 1 | $112.98 | $ - | $ - | $ 112.98 | $ 112.98 |
| First aid kit signage | 1 | 1 | 3 | 3 | $8.80 | $ 8.80 | $ 8.80 | $ 26.40 | $ 26.40 |
| Safety glasses (12 pack) | 2 | 2 | 3 | 3 | $16.07 | $ 32.14 | $ 32.14 | $ 48.21 | $ 48.21 |
| Glasses storage | 1 | 1 | 1 | 1 | $79.92 | $ 79.92 | $ 79.92 | $ 79.92 | $ 79.92 |
| Splash goggles | 2 | 2 | 5 | 5 | $4.85 | $ 9.70 | $ 9.70 | $ 24.25 | $ 24.25 |
| Work gloves (small) | 0 | 1 | 2 | 2 | $10.98 | $ - | $ 10.98 | $ 21.96 | $ 21.96 |
| Work gloves (medium) | 0 | 1 | 2 | 2 | $16.99 | $ - | $ 16.99 | $ 33.98 | $ 33.98 |
| Work gloves (large) | 0 | 1 | 4 | 4 | $16.99 | $ - | $ 16.99 | $ 67.96 | $ 67.96 |
| Disposable gloves | 10 | 10 | 10 | 10 | $10.16 | $ 101.60 | $ 101.60 | $ 101.60 | $ 101.60 |
| Disposable dust masks (20 pack) | 0 | 2 | 5 | 5 | $12.14 | $ - | $ 24.28 | $ 60.70 | $ 60.70 |
| ClearArmor Hearing Protection Ear Muffs | 0 | 0 | 4 | 4 | $14.95 | $ - | $ - | $ 59.80 | $ 59.80 |
| Ear plugs | 0 | 0 | 1 | 1 | $86.28 | $ - | $ - | $ 86.28 | $ 86.28 |
| Aprons | 0 | 0 | 5 | 5 | $39.99 | $ - | $ - | $ 199.95 | $ 199.95 |
| Face shield | 0 | 0 | 0 | 2 | $24.00 | $ - | $ - | $ - | $ 48.00 |
| Wash clothes | 1 | 1 | 1 | 1 | $17.99 | $ 17.99 | $ 17.99 | $ 17.99 | $ 17.99 |
| Spray bottles | 1 | 1 | 1 | 2 | $7.97 | $ 7.97 | $ 7.97 | $ 7.97 | $ 15.94 |
| Elbow-length rubber gloves | 0 | 0 | 1 | 1 | $9.99 | $ - | $ - | $ 9.99 | $ 9.99 |
| Discretionary | 1 | 1 | 1 | 1 | $500.00 | $ 500.00 | $ 500.00 | $ 500.00 | $ 500.00 |

# K-12 Outreach

Studies have shown that the drive to explore, interact, and observe begins in early childhood. When young children enter school, they may already have substantial knowledge of the natural world, can think both concretely and abstractly, use a range of scientific reasoning processes, and are eager, curious, and ready to learn.

Providing access to high-quality STEAM tools, activities, and programming can strengthen these innate abilities. Introductory makerspaces have all the necessary creative tools and programming that have proven to be critical to setting children on a path to long-term academic and professional success.

Tier 1 makerspaces provide access to the most common types of emergent technology, but also focus on an important aspect of K-12 engagement: exploratory, experiential STEAM learning tools that range from LEGO robotics to snap circuitry.



## Additional considerations

- The tools and educational toys listed below were selected because of their reputation, versatility, or because of our experience (or the experience of one of our makerspace partners) with the respective tool or a toy's impact on younger audiences.
- We recommend an admittedly expensive Maker Cart here at the suggestion of the Natrona County Library's Creation Station makerspace. Maker Carts are pricey, but can provide Tier 1 spaces with a portable, easy-to-organize variety of tools for youth to explore and learn. Natrona County Library strongly endorsed these types of TeacherGeek carts, citing high levels of engagement and creative exploration with junior makers.
- We recommend a series of more advanced K-12 engagement kits (LEGO robotics, Sphero robotics, Makey Makey circuitry) aimed at 8th to 12th grade makers for our Tier 2 and Tier 3 spaces. Even though these spaces are aimed primarily at entrepreneurial or advanced desktop manufacturing, there is still significant value in providing exploratory tools and kits for younger audiences.

## K-12 engagement kits, tools, and educational toys

| | | | | | Totals: | Tier 1m | Tier 1 | Tier 2 | Tier 3 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $ 6,682.67 | $ 16,712.17 | $ 3,548.75 | $ 3,548.75 |
| | Quantity | | | | | | | | |
| **K-12 Engagement** | | **T1** | **T2** | **T3** | **Cost ea.** | **$ 6,682.67** | **$ 16,712.17** | **$ 3,548.75** | **$ 3,548.75** |
| Sphero Mini Education 16-pack | 1 | 0 | 0 | 0 | $1,075.00 | $ 1,075.00 | $ - | $ - | $ - |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Sphero BOLT | 0 | 10 | 5 | 5 | $149.00 | $ - | $ 1,490.00 | $ 745.00 | $ 745.00 |
| Lego Classic Box (large) | 2 | 2 | 1 | 1 | $149.00 | $ 298.00 | $ 298.00 | $ 149.00 | $ 149.00 |
| Lego Mindstorms | 0 | 5 | 2 | 2 | $464.90 | $ - | $ 2,324.50 | $ 929.80 | $ 929.80 |
| Ozotbot (Evo) | 5 | 5 | 5 | 5 | $99.99 | $ 499.95 | $ 499.95 | $ 499.95 | $ 499.95 |
| Cubelets Creative Constructors Pack | 1 | 1 | 0 | 0 | $1,490.00 | $ 1,490.00 | $ 1,490.00 | $ - | $ - |
| littleBits STEAM+ Student Set | 5 | 5 | 0 | 0 | $299.95 | $ 1,499.75 | $ 1,499.75 | $ - | $ - |
| Makey Makey Classic | 12 | 12 | 5 | 5 | $45.00 | $ 540.00 | $ 540.00 | $ 225.00 | $ 225.00 |
| Brackitz, Mini STEAM Center | 1 | 1 | 0 | 0 | $99.99 | $ 99.99 | $ 99.99 | $ - | $ - |
| Code & Go Robot Mouse | 1 | 1 | 0 | 0 | $59.99 | $ 59.99 | $ 59.99 | $ - | $ - |
| Code-a-Pillar | 1 | 1 | 0 | 0 | $119.99 | $ 119.99 | $ 119.99 | $ - | $ - |
| TeacherGeek STEAM Maker Cart 2.0 | 0 | 1 | 0 | 0 | $6,790.00 | $ - | $ 6,790.00 | $ - | $ - |
| Books | 1 | 1 | 1 | 1 | $500.00 | $ 500.00 | $ 500.00 | $ 500.00 | $ 500.00 |
| Discretionary | 1 | 2 | 1 | 1 | $500.00 | $ 500.00 | $ 1,000.00 | $ 500.00 | $ 500.00 |

# Laser Cutters and Engravers

More than almost any other machine, even 3D printers, laser cutters are often the most popular tool in a makerspace, and laser cutting in makerspaces is as accessible as it's ever been. Unlike 3D printing (which builds parts layer-by-layer), laser cutters create designs and patterns by cutting into material. This "subtractive manufacturing" tech pinpoints a powerful focused laser beam on a material to melt, burn, or vaporize the material away.

Laser cutters allow makers to very accurately cut complex shapes from flat materials including paper, wood, acrylic, leather, cardboard, fabric and can, in some cases, even engrave metal and glass. Makers can cut or carve, etch logos, drill, and assemble complicated assemblies of 2D cutouts to build 3D structures. Oftentimes, laser cutters are affordable and easy to use, and are very frequently used by schools, hobbyists, small businesses, makerspaces and universities. It's an affordable tech that serves as a gateway to monetizable crafts for both first-timers and experienced makers alike, and can be considered a staple of most makerspaces.


## Safety considerations

It's possible to accidentally set small fires or create toxic gases with a laser cutter. Should you be afraid to include laser cutters as part of your makerspace? No, certainly not. Laser cutters, when used correctly, can be exceptional tools, and among the most heavily used in a makerspace. Should you instruct makers to be cautious and always double-check the materials being used? Yes, always.

The primary hazard while using a laser cutter is a **fire risk**. For this reason, we require that makers stay with their project from start to finish. <u>At no point should the laser be allowed to run unattended.</u> Even small fires can cause costly damage to the equipment. $H_2O$ spray bottles and hand towels should be stored next to each laser cutter, and are used to douse small fires by wetting the cloth thoroughly and smothering the flame. A $CO_2$ fire extinguisher should always be located nearby and accessible in case of large, sustained fires. A $CO_2$ extinguisher can be used to quench fires without causing more damage to the laser cutter. Worth noting: small, fleeting flames happen frequently with laser

cutters, and are no cause for concern. Longer, sustained flames lasting 10 seconds or more are cause for concern.

Besides fire risks, laser cutters present a second equally dangerous hazard: **toxic fumes**. As the laser heats up and vaporizes material, gases are released. While most recommended materials do not release hazardous gases, some can still cause irritation or noxious odors. Others still, even wood, can cause a room to get smoky very quickly if there is no exhaust system present. For this reason, a robust air filtration system, either built into the unit itself or hooked up to the unit, is mandatory. For this same reason, if a user does not know the composition of the material they wish to cut, it must not be cut or engraved using a laser cutter.

There is luckily little risk of damaging your eyes from observing the laser while the machine is running. Laser cutters are usually fully enclosed systems that prevent laser operation unless the safety interlocked lid is fully closed. Most lasers typically contain a carbon dioxide ($CO_2$) laser that produces an invisible laser beam. If the lid is opened during operation, the majority of lasers turn off immediately. Most laser cutters also have protective UV glass designed to allow users to observe the project safely.

### Forbidden materials

Some materials, such as vinyl and PVC, will release chlorine gas when cut with a laser. Chlorine is both incredibly toxic as well corrosive. It can and will seriously injure the maker, as well as damage the laser. Below we've listed out materials that makers should never use with a laser cutter, and materials that makers should be aware may behave unpredictably when cut or engraved, and thus should be used responsibly.

**DANGER**

**NEVER cut these materials:**

| Material | | Danger! | Cause/Consequence |
|---|---|---|---|
| PVC (Poly Vinyl Chloride, and also vinyl, pleather, or artificial leather). |  | Emits chlorine gas when cut! | Besides the health risks, it will ruin the optics, cause the metal of the machine to corrode, and ruin the motion control system. |
| Thick ( >1mm ) Polycarbonate/Lexan |  | Cuts very poorly, discolors, catches fire | Polycarbonate is often found as flat, sheet material. The window of the laser cutter is made of Polycarbonate because polycarbonate strongly absorbs infrared radiation! This is the frequency of light the laser cutter uses to cut materials, so it is very ineffective at cutting polycarbonate. Polycarbonate is a poor choice for laser cutting. |
| ABS |  | Melts | ABS does not cut well in a laser cutter. It tends to melt rather than vaporize, and has a higher chance of catching on fire and leaving behind melted gooey deposits on the vector cutting grid. It also does not engrave well (again, tends to melt). |
| HDPE/milk bottle plastic |  | Catches fire and melts | It melts. It gets gooey. Don't use it. |
| PolyStyrene Foam |  | Catches fire | It catches fire, it melts, and only thin pieces cut. This is the #1 material that causes laser fires!!! |
| PolyPropylene Foam |  | Catches fire | Like PolyStyrene, it melts, catches fire, and the melted drops continue to burn and turn into rock-hard drips and pebbles. |
| Fiberglass |  | Emits fumes | It's a mix of two materials that can't be cut. Glass (etch, no cut) and epoxy resin (fumes) |
| Coated Carbon Fiber |  | Emits noxious fumes | A mix of two materials. Thin carbon fiber mat can be cut, with some fraying - but not when coated. |

| Safe to cut, but pay attention to warnings | | | |
|---|---|---|---|
| **Material** | **Max thickness** | **Notes** | **Warnings!** |
| Natural woods | 1/4" | Avoid oily or resinous woods | Be very careful about cutting oily woods, or very resinous woods as they also may catch fire. |
| Plywood or composite woods | 1/4" | These contain glue, and may not cut as well as solid wood. | |
| MDF or engineered woods | 1/4" | These are okay to use but may experience a higher amount of charring when cut. | |
| Paper, card stock | Thin | Cuts very well on the laser cutter, and also very quickly. | |
| Cardboard, carton | Thicker | Cuts well but may catch fire. | Watch for fire risk |
| Cork | 1/4" | Cuts nicely, but the quality of the cut depends on the thickness and quality of the cork. Engineered cork has a lot of glue in it, and may not cut as well. | Avoid thicker cork. |
| Acrylic, lucite, plexiglas, PMMA | 1/2" | Cuts extremely well leaving a beautifully polished edge. | |
| Thin polycarbonate sheeting | <1mm | Very thin polycarbonate can be cut, but tends to discolor badly. Extremely thin sheets (0.5mm and less) may cut with yellowed/discolored edges. Polycarbonate absorbs IR strongly, and is a poor material to use in the laser cutter. | Watch for smoking or burning |
| Delrin (POM) | Thin | Delrin comes in a number of shore strengths (hardness) and the harder Delrin tends to work better. Great for gears! | |
| Kapton tape (Polyimide) | 1/16" | Works well, in thin sheets and strips like tape. | |
| Mylar | 1/16” | Works well if it's thin. Thick mylar has a tendency to warp, bubble, and curl. | Gold coated mylar will not work. |
| Solid styrene | 1/16" | Smokes a lot when cut. | Keep it thin. |
| Depron foam | 1/4" | Used a lot for hobby, RC aircraft, architectural models, and toys. 1/4" cuts nicely, with a smooth edge. | Must be constantly monitored. |
| Gator foam | - | Foam core gets burned and eaten away compared to the top and bottom hard paper shell. | Not a fantastic thing to cut, but it can be cut if watched. |
| Cloth, felt, hemp, cotton | - | They all cut well. | No plastic coated or impregnated cloth! |
| Leather, suede | 1/8” | Leather is very hard to cut, but can be if it's thinner than a belt (1/8"). | Real leather only! **NEVER** 'pleather' or other imitation leathers! |
| Magnetic sheet | - | Cuts beautifully | |
| NON-CHLORINE-containing rubber | - | Fine for cutting. | Beware chlorine-containing rubber! |
| Teflon (PTFE) | - | Cuts OK in thin sheets | |
| Carbon fiber mats/weave that has NOT had epoxy applied | - | Can be cut, very slowly. | You must **NEVER** cut carbon fiber that has been coated! |
| Coroplast (corrugated plastic) | 1/4" | Difficult because of the vertical strips. Three passes at 80% power, 7% speed, and it will be slightly connected still at the bottom from the vertical strips. | |

## Additional considerations

- You'll need a good exhaust system to operate the laser cutters. This is mandatory.
- Some laser cutters may require 240v outlets to pull the necessary power to run the machine. We've accounted for rough estimates of any power conversion costs (as well as any costs to install a proper ventilation system) in the Startup section of this guide.
- A computer, either linked over WiFi or connected via Ethernet port, is usually required to send the files from any type of design software (Adobe Illustrator, Inkscape) to the laser cutting software and ultimately to the machine.
- Some machines, particularly larger laser cutters with more powerful lasers, may not be well suited for a K-12 environment. As the wattage of a laser cutter increases, so too does its power and consequently the risk of fire.
- There are two primary types of laser cutters:
    - $CO_2$ lasers, such as the Glowforge and Full Spectrum Pro Series listed below, which offer more precise or sharper cuts, and are often higher powered, but cannot easily engrave reflective objects such as glass or metal, and
    - Fiber lasers, which are usually lower power but can cut faster, offer lower operating costs, and can engrave metal and glass. Fiber lasers are typically less common and more expensive in terms of initial investment.
    - Hybrid CO2/Fiber lasers (such as the Epilog Fusion Pro) that offer both options as part of the same machine, but often at a much higher initial investment.
- Unlike 3D printers, where consumable materials may be difficult to get or proprietary and thus provided by the makerspace, materials and consumables used by laser cutters differ greatly across makers and personal preference. Thus, we advise purchasing some universal consumables for practice or demonstrations (some cardboard, some wood) but expect makers to source their own materials for their own projects.

## Laser cutting equipment & tools

| | | | | | Totals: | Tier 1m | Tier 1 | Tier 2 | Tier 3 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $ 5,490.00 | $ 5,990.00 | $ 15,910.00 | $ 71,920.00 |
| | Quantity | | | | | | | | |
| **Laser cutters/engravers** | 🚚 | **T1** | **T2** | **T3** | **Cost ea.** | **$ 4,990.00** | **$ 4,990.00** | **$ 14,910.00** | **$ 70,920.00** |
| Glowforge Plus | 1 | 1 | 1 | 0 | $3,995.00 | $ 3,995.00 | $ 3,995.00 | $ 3,995.00 | $ - |
| Glowforge Air Filter | 1 | 1 | 1 | 0 | $995.00 | $ 995.00 | $ 995.00 | $ 995.00 | $ - |
| Full Spectrum Pro Series 36x24 $CO_2$ Laser | 0 | 0 | 1 | 1 | $9,920.00 | $ - | $ - | $ 9,920.00 | $ 9,920.00 |
| Epilog Fusion Pro | 0 | 0 | 0 | 1 | $61,000.00 | $ - | $ - | $ - | $ 61,000.00 |
| **Laser cutter accessory supplies, tools** | | | | | | **$ 500.00** | **$ 1,000.00** | **$ 1,000.00** | **$ 1,000.00** |
| Discretionary | 1 | 2 | 2 | 2 | $500.00 | $ 500.00 | $ 1,000.00 | $ 1,000.00 | $ 1,000.00 |

# Operating Costs

Running a makerspace may seem a bit daunting at first, but that's what we hope this guide is for. We have plenty of experience setting up makerspaces, hosting outreach events, and building a robust and popular library of programming -- so there's no need to reinvent the wheel. While no two makerspaces are alike, there are some universal truths shared across all makerspaces that bear a quick mention below. Whether it's best practices to organize and operate a makerspace, promote safe equipment use, build community, foster maker responsibility and ownership, or simply to provide a safe space to play and innovate, we want to cover it briefly here.

## Training

- Before they should be given access to the tools, all makers will require some type of training to work with the equipment, hardware, or software that interests them. This is done, of course, to ensure their safety, but also to ensure that tools do not break, and that the space remains safe for everyone.
- Makerspace administrators and teachers are the ones who must outline and present the expectations for safe, responsible tool use by all participating makers. Usually this means a huge time investment to develop and host new workshops and training programs.
- Instead, we've factored in costs here for new makerspaces to take advantage of our standardized statewide training program. The Maker Access Pass is currently operational in 9 out of 10 makerspaces across Wyoming and can be adopted without need for special hardware. No swipe cards, login kiosks, or RFID chips needed. If your facility has an internet connection, it can host the Maker Access Pass.

## Hours, supervision, and staffing

- How accessible your makerspace is depends on the availability of expert staff and volunteers who have been trained to use the equipment. It can be beneficial to have a few supervisory part-time or full-time staff around who know how to operate all of the equipment in the space, in order to ensure makers have the appropriate support to run hardware or software.
- There are three primary makerspace management models supported by the literature. The suggestions below were sourced from a large repository of papers and presentations from two major makerspace journals and accompanying conferences: the International Symposium on Academic Makerspaces (ISAM) and American Society for Engineering Education (ASEE). As part of this guide, we've highlighted what we believe to be the best staffing model for each tier. You may disagree, and at the

end of the day, these are merely suggestions. Any combination of volunteer, part-time student, and full-time professional staff may suit your facility's needs as you decide.

## Consumables, outreach materials, and annual fees

- As part of this guide, we advise allocating funds each year to purchase typical consumable materials (3d printing filament, wood), providing materials for outreach activities free of charge, as well as rainy-day funds in the rare chance that equipment malfunctions or breaks down.
- Equipment suggested as part of this guide has been selected due to their excellent reputation, excellent performance observed over a period of four years, popularity in industry, as well as exemplary customer support. Accordingly, machine obsolescence is only predicted to occur around five years, and only for smaller desktop and benchtop hardware and software. Industrial equipment included on these lists is expected to remain relevant for at least 10 years.
- Our makerspaces charge at-cost for materials (e.g. $0.50 per hour to 3D print on the desktop machines) in order to recoup costs.
- NGDLE ("Next Generation Digital Learning Environment") funds to support the Maker Access Pass are highlighted here as part of recurring costs. The Maker Access Pass is comprised of an LMS instance, browser-based booking software, and associated LMS accessibility and compliance software. At present, LMS costs and LMS accessibility and compliance SaaS costs are paid for by the University of Wyoming and not factored in to operation and recurring costs.

## Operation and recurring costs

| | | | | | | Totals: | Tier 1m | Tier 1 | Tier 2 | Tier 3 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | $ 21,433.68 | $ 42,289.90 | $ 81,055.90 | $ 116,516.50 |
| | | Quantity | | | | | | | | |
| **Staffing** | | **T1** | **T2** | **T3** | **Cost ea.** | | **$ -** | **$ 25,000.00** | **$ 58,533.00** | **$ 83,533.00** |
| Students (part-time, 10 hours each week) | 0 | 5 | 3 | 8 | $5,000.00 | | $0.00 | $25,000.00 | $15,000.00 | $40,000.00 |
| Full-time staff (pay grade 19) | 0 | 0 | 1 | 1 | $43,533.00 | | $0.00 | $0.00 | $43,533.00 | $43,533.00 |
| **Recurring annual costs*** | | | | | | | **$ 21,328.70** | **$ 17,000.00** | **$ 22,188.00** | **$ 32,613.60** |
| Consumables and materials | 1 | 1 | 2 | 3 | $5,000.00 | | $ 5,000.00 | $ 5,000.00 | $ 10,000.00 | $ 15,000.00 |
| Outreach budget | 2 | 2 | 1 | 1 | $5,000.00 | | $ 10,000.00 | $ 10,000.00 | $ 5,000.00 | $ 5,000.00 |
| Technology budget, equipment repairs | 1 | 1 | 3 | 5 | $2,000.00 | | $ 2,000.00 | $ 2,000.00 | $ 6,000.00 | $ 10,000.00 |
| Renewing software | 0 | 0 | 5 | 11 | $237.60 | | $ - | $ - | $ 1,188.00 | $ 2,613.60 |
| Fuel | 1 | 0 | 0 | 0 | $4,328.70 | | $ 4,328.70 | $ - | $ - | $ - |
| **NGDLE (recurring annual costs)** | | | | | | | **$ 104.98** | **$ 289.90** | **$ 334.90** | **$ 369.90** |
| Canvas LMS fees/user ** | 50 | 150 | 300 | 500 | $13.00 | | $ 650.00 | $ 1,950.00 | $ 3,900.00 | $ 6,500.00 |
| LibCal (number of calendars)*** | 1 | 5 | 5 | 5 | $39.98 | | $ 39.98 | $ 199.90 | $ 199.90 | $ 199.90 |
| LibCal (equipment)**** | 13 | 18 | 27 | 34 | $5.00 | | $ 65.00 | $ 90.00 | $ 135.00 | $ 170.00 |
| DesignPLUS (3 year)***** | 0 | 0 | 0 | 0 | $31,096.00 | | $ - | $ - | $ - | $ - |

* Recurring costs assumes utilities are covered by the institution in which the makerspace is housed. For those facilities where utilities are *not* covered, see: *Startup*.

**Quantity indicates approximate number of users, at $13.00 per user. Educational cost of the Canvas LMS used by the Maker Access Pass. Canvas is currently funded and provided to the Maker Access Pass makerspaces for free by UW. Costs listed here (but not included in totals) in the event Canvas costs are no longer supported by the University.

***The workshop and space booking software used by the Maker Access Pass. Roughly $39.98 per booking calendar. Each space or zone of a makerspace (larger spaces have more ‘zones’) must be factored in.

**** The equipment booking software used by the Maker Access Pass. Roughly $5.00 per individual piece of equipment able to be reserved.

***** Accessibility and compliance SaaS package for Canvas. Currently funded for three years (through June 2023) by the University of Wyoming. If no longer supported by UW, approximate annual cost $11,000 to be split across all participating MAP spaces (with ten current makerspaces, roughly $1000 per space).

# Startup Costs

It's quite common for makerspaces to capitalize on existing space on campuses or within creative communities, so if that describes your situation, you can disregard this section. If you're interested in setting up a brand new space, or building a mobile makerspace, read on.

In the event that existing space is unavailable, we've provided additional estimated costs and considerations for a brick-and-mortar facility. This list factors in estimates for a commercial lease, utilities, internet, and includes renovations needed to build proper exhaust systems or accommodate industrial machines requiring 240v outlets, as well as the necessary workbenches and stools for makers to work effectively. Accompanying this, we've included estimates on annual recurring costs for renting space as well as covering costs for utilities and internet.

### Additional considerations

- In all likelihood, Tier 1m makerspaces (i.e. mobile makerspaces) will require proper retrofitting to accommodate custom workbenches, stowable seating, and increased power requirements to run a small fleet of 3D printers, sewing machines, laptops, electronics equipment, and TVs. We're not experts here – we've never built a mobile makerspace. But we have read a number of guides and recommendations from other makerspaces as well as tiny home owners, and used those to provide the estimates below. We recommend mobile makerspaces for Wyoming communities as part of this guide because of their value as STEAM tools for remote or distance learning communities.
- Here we recommend retrofitting a retired school bus. Buses are typically kept in operation for a minimum of 12 years, after which they retire. According to the Federal Transit Administration, buses are expected to last about 12-15 years and somewhere 250,000 miles under normal conditions before being retired. Wyoming school buses may be able to be purchased after only 120,000 miles.
- A commercial driver's license is required before you can purchase and operate a bus.
- Mobile makerspaces are frequently leased to schools or community groups on a 6-month or semesterly basis. Accordingly, they aren't required to be driven daily, with the exception of summer events where they might travel to farmer's markets and special summer fairs to promote maker resources across the state. Accordingly, we have not factored in maintenance costs for the bus, as it will not be driven daily or even weekly.

## Startup costs

| | | Quantity | | | | Totals: | Tier 1m | Tier 1 | Tier 2 | Tier 3 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | $ 21,433.68 | $ 42,289.90 | $ 81,055.90 | $ 116,516.50 |
| **One-time startup costs** | | **T1** | **T2** | **T3** | **Cost ea.** | | $ 21,949.90 | $ 22,349.75 | $ 31,174.75 | $ 54,349.50 |
| Stools | 10 | 0 | 0 | 0 | $64.99 | | $ 649.90 | $ - | $ - | $ - |
| Stools (included with workstations below) | 0 | 30 | 30 | 60 | $0.00 | | $ - | $ - | $ - | $ - |
| Workstations/benches | 0 | 5 | 5 | 10 | $4,359.95 | | $ - | $ 21,799.75 | $ 21,799.75 | $ 43,599.50 |
| Small workbench | 2 | 2 | 0 | 0 | $275.00 | | $ 550.00 | $ 550.00 | $ - | $ - |
| Workbenches (DIY) | 5 | 0 | 0 | 0 | $200.00 | | $ 1,000.00 | $ - | $ - | $ - |
| Bus (vehicle) | 1 | 0 | 0 | 0 | $12,000.00 | | $ 12,000.00 | $ - | $ - | $ - |
| Bus retrofit | 1 | 0 | 0 | 0 | $5,000.00 | | $ 5,000.00 | $ - | $ - | $ - |
| Exhaust system | 0 | 0 | 1 | 1 | $8,000.00 | | $ - | $ - | $ 8,000.00 | $ 8,000.00 |
| Power conversion | 2 | 0 | 1 | 2 | $1,375.00 | | $ 2,750.00 | $ - | $ 1,375.00 | $ 2,750.00 |
| **Recurring annual costs, new facility** | | | | | | | **$ 940.00** | **$ 12,959.88** | **$ 30,959.88** | **$ 42,959.88** |
| Lease, commercial space* | 0 | 1000 | 2500 | 3500 | $9.00 | | $ - | $ 9,000.00 | $ 22,500.00 | $ 31,500.00 |
| Utilities* | 0 | 1000 | 2500 | 3500 | $3.00 | | $ - | $ 3,000.00 | $ 7,500.00 | $ 10,500.00 |
| Verizon FIOS internet** | 0 | 1 | 1 | 1 | $959.88 | | $ - | $ 959.88 | $ 959.88 | $ 959.88 |
| Mobile hotspot | 1 | 0 | 0 | 0 | $400.00 | | $ 400.00 | $ - | $ - | $ - |
| Verizon plan for mobile hotspot | 1 | 0 | 0 | 0 | $540.00 | | $ 540.00 | $ - | $ - | $ - |

*quantity here indicates sq. ft, and uses Wyoming averages ($9.00, $3.00) for commercial space and utilities respectively.

**Verizon telecommunications selected simply because of its effective coverage around Wyoming. Other carriers may be preferred.

# Woodworking

The introduction of affordable high-quality tools and access to an unprecedented treasure trove of information has drastically changed the woodworking landscape. Once occupied by only a few very skilled professionals, now woodworkers come in all shapes and sizes. Today, anyone with an internet connection and a basic set of tools can try their hand at the marvels of nail- and glue-free joinery techniques from East Asia, popular styles of rustic woodworking from the heartland of the United States, and the ergonomic and sleek modern look of current-day Scandinavian design.

Makerspaces are often places that provide access to technology and equipment that most people don't have the space or money to house at home, such as 3D printers or laser cutters. The tools that you might often find in a well-stocked woodshop (saws, sanders, drill presses, lathes, CNC routers, and power tools) fit perfectly into this same approach. Many home woodshops might have to vie for space with water heaters, cars, bikes, and household storage. RAs in college dorms might frown on students hiding table saws in their dorm room. Newcomers or those just dipping a toe into the woodworking water might not have the resources or knowledge to select the best tools for their projects.

Enter the makerspace woodshop, where communities are provided ready and easy access to a wide variety of woodshop equipment. And where there's a woodshop, there is almost invariably a small community of like-minded furniture makers, crafters, woodturners, woodcarvers, pyrographists, and expert enthusiasts to learn from and with whom to collaborate. It should come as no surprise that woodshops are among the most popular and sought-after areas in a makerspace.

## Safety considerations

With sharp, spinning saw blades and flying debris, woodshops can be among the most dangerous places in a makerspace. Don't let this deter you from setting up a woodshop in your space. When overseen and operated with the proper levels of safety, woodshops compete with 3D printers and laser cutters for the top spot of 'most frequently utilized spot in the makerspace.' In four years (knock on wood), we've not had any incidents in our makerspaces. Why? We ensure that makers go through the necessary training to teach them how to work in a woodshop safely.

The primary hazards while working in the woodshop come from **cutting risks**. Splinters, flying debris, and sharp tools can cause scratches and cuts. In a woodshop more than any other location, we advise following some general rules:

- Safety cards that include PPE requirements, reminders, and hazards should be posted prominently near all relevant machinery.
- A first aid kit should be readily available and a signage about the kit should be posted near the entrance.
- Safety glasses should be worn at all times.
- Hair should be secured at all times.
- Loose and dangling clothing (jewelry, hoodie cords, necklaces, watches, bracelets) should NEVER be worn in a woodshop.
- Closed-toed shoes should be worn in a woodshop.
- Respirators or N95 masks are recommended for anything that creates fine particulate or sawdust.
- When working with power tools, wear hearing protection.
- Work gloves may seem well suited for a woodshop, but there is an ever-present risk of gloves drawing hands into moving machinery. Gloves are best used to handle rough lumber, but should NEVER be worn when operating any machine or tool with rotating parts.
- Tools many only be used by those trained how to operate them safely and responsibly.
- Table saws and rotating saws can be among the most dangerous pieces of equipment in a makerspace. When wood is used improperly with certain tools, it can cause the wood to bind to the blade and cause kickback. This can turn the wood into a flying projectile capable of reaching speeds that can punch through cement. Or people.

With these hazards in mind, it's always a good idea to consult with woodworkers to position all woodshop equipment in a way that greatly minimizes the likelihood of these accidents happening. Woodshops that are operated safely and responsibly are among the best resources a makerspace can offer to its community.

## Additional considerations

- Makerspace woodshops exist to help build confidence not only to use woodshop tools, but also equip makers with critical skills that carry on beyond the walls of the makerspace. Learning how to use woodshop tools gives makers the skills and competencies to do other household projects, like mounting a TV or building and hanging cabinets. Learning the foundation to master woodshop tools can open countless doors. Furthermore, learning to use most woodshop tools is relatively fast and simple to do.
- You'll need a good ventilation system to run a woodshop, or you risk getting sawdust everywhere. Consider also investing in a shop vac and accompanying cyclone dust collector to separate out large chips. It's always good practice to require all woodworkers to fully tidy and vacuum their areas when finished working.
- Some advanced woodshop tools, such as lathes and planers may require 240v outlets to pull the necessary power to operate. We've accounted for rough estimates of any power conversion costs (as well as any costs to install a proper ventilation system) in the Startup section of this guide.
- A computer, either linked over WiFi or connected directly to the machine, is usually required to operate CNC routers and CNC mills. Keeping that machine free of sawdust is a task in itself.
- Some machines, particularly larger industrial machinery, may not be well suited for a K-12 environment. We don't advise allowing users under 13 to operate lathes, planers, and table saws.
- Unlike 3D printers, where consumable materials may be difficult to get or proprietary and thus provided by the makerspace, woodshop materials and consumables differ greatly across makers and personal preference. Thus, we advise purchasing some universal consumables for practice or demonstrations (nails, screws, fasteners, some scrap wood) but expect makers to source their own materials for their own projects.

## Woodworking equipment & tools

| | | | | | | Totals: | Tier 1m | Tier 1 | Tier 2 | Tier 3 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | $ 1,872.14 | $ 3,196.08 | $ 13,364.11 | $ 27,451.67 |
| | | Quantity | | | | | | | | |
| **Manual hand tools** | | T1 | T2 | T3 | Cost ea. | | $ 460.16 | $ 520.11 | $ 763.99 | $ 1,014.17 |
| Eastwing claw hammer | 1 | 1 | 1 | 2 | $20.97 | | $ 20.97 | $ 20.97 | $ 20.97 | $ 41.94 |
| Mallet | 1 | 1 | 1 | 1 | $6.53 | | $ 6.53 | $ 6.53 | $ 6.53 | $ 6.53 |
| Lutz 15-in-1 Ratchet Screwdriver | 2 | 2 | 2 | 4 | $15.49 | | $ 30.98 | $ 30.98 | $ 30.98 | $ 61.96 |
| Large wrench and socket sets | 1 | 1 | 1 | 1 | $225.99 | | $ 225.99 | $ 225.99 | $ 225.99 | $ 225.99 |
| Adjustable wrench set (3 piece) | 1 | 1 | 1 | 1 | $19.09 | | $ 19.09 | $ 19.09 | $ 19.09 | $ 19.09 |
| Folding hex key sets | 1 | 1 | 1 | 2 | $11.95 | | $ 11.95 | $ 11.95 | $ 11.95 | $ 23.90 |
| Channellock 8-Inch slip joint pliers | 1 | 1 | 1 | 2 | $8.99 | | $ 8.99 | $ 8.99 | $ 8.99 | $ 17.98 |
| Stanley 5" needle nose pliers | 2 | 2 | 2 | 4 | $4.51 | | $ 9.02 | $ 9.02 | $ 9.02 | $ 18.04 |
| Stanley mini pliers set (5 piece) | 1 | 1 | 1 | 2 | $19.92 | | $ 19.92 | $ 19.92 | $ 19.92 | $ 39.84 |
| Irwin vise grip locking pliers | 1 | 1 | 1 | 2 | $8.65 | | $ 8.65 | $ 8.65 | $ 8.65 | $ 17.30 |
| Stanley box cutter utility knife | 2 | 2 | 2 | 4 | $4.19 | | $ 8.38 | $ 8.38 | $ 8.38 | $ 16.76 |
| Stanley hand saw | 1 | 1 | 1 | 1 | $10.52 | | $ 10.52 | $ 10.52 | $ 10.52 | $ 10.52 |
| Tekton 2-in-1 high-tension hacksaw | 1 | 1 | 1 | 1 | $11.46 | | $ 11.46 | $ 11.46 | $ 11.46 | $ 11.46 |
| Claus utility scissors | 2 | 2 | 2 | 4 | $6.20 | | $ 12.40 | $ 12.40 | $ 12.40 | $ 24.80 |
| Irwin combination square | 1 | 2 | 4 | 4 | $12.99 | | $ 12.99 | $ 25.98 | $ 51.96 | $ 51.96 |
| Irwin c-clamp (6") | 2 | 4 | 4 | 4 | $12.99 | | $ 25.98 | $ 51.96 | $ 51.96 | $ 51.96 |
| Stanley staple gun | 1 | 1 | 1 | 1 | $16.34 | | $ 16.34 | $ 16.34 | $ 16.34 | $ 16.34 |
| Vaughan 15" pry bar | 0 | 1 | 1 | 1 | $11.99 | | $ - | $ 11.99 | $ 11.99 | $ 11.99 |
| Swanson speed square | 0 | 1 | 2 | 2 | $8.99 | | $ - | $ 8.99 | $ 17.98 | $ 17.98 |
| Irwin c-clamp (8") | 0 | 0 | 2 | 4 | $25.46 | | $ - | $ - | $ 50.92 | $ 101.84 |
| Woodworker's vise | 0 | 0 | 1 | 1 | $21.99 | | $ - | $ - | $ 21.99 | $ 21.99 |
| Dewalt 36" Bar clamps | 0 | 0 | 4 | 6 | $34.00 | | $ - | $ - | $ 136.00 | $ 204.00 |
| **Handheld power tools** | | | | | | | **$ 839.56** | **$ 839.56** | **$ 1,121.46** | **$ 1,431.94** |
| Dewalt 5-tool combo kit | 1 | 1 | 1 | 1 | $349.00 | | $ 349.00 | $ 349.00 | $ 349.00 | $ 349.00 |
| Spare batteries, Dewalt | 1 | 1 | 1 | 1 | $99.00 | | $ 99.00 | $ 99.00 | $ 99.00 | $ 99.00 |
| Wireless Dremel 7300 kit | 1 | 1 | 1 | 1 | $24.97 | | $ 24.97 | $ 24.97 | $ 24.97 | $ 24.97 |
| Dremel 4300-9/64 High Performance Rotary Tool Kit | 1 | 1 | 1 | 1 | $160.00 | | $ 160.00 | $ 160.00 | $ 160.00 | $ 160.00 |
| Dewalt cordless compact drill driver kit and drill bits | 1 | 1 | 2 | 2 | $122.10 | | $ 122.10 | $ 122.10 | $ 244.20 | $ 244.20 |
| Drill bit kits | 1 | 1 | 1 | 1 | $50.00 | | $ 50.00 | $ 50.00 | $ 50.00 | $ 50.00 |
| Black & Decker lithium ion driver | 1 | 1 | 1 | 2 | $34.49 | | $ 34.49 | $ 34.49 | $ 34.49 | $ 68.98 |
| DEWALT 1.25 HP compact router | 0 | 0 | 1 | 1 | $128.00 | | $ - | $ - | $ 128.00 | $ 128.00 |
| Ryobi Universal Router Table-A25RT03 | 0 | 0 | 0 | 1 | $110.99 | | $ - | $ - | $ - | $ 110.99 |
| Black & Decker 5A jig saw and blades | 0 | 0 | 1 | 1 | $31.80 | | $ - | $ - | $ 31.80 | $ 31.80 |
| Dewalt Finish Nailer | 0 | 0 | 0 | 1 | $165.00 | | $ - | $ - | $ - | $ 165.00 |
| **Benchtop and table saws** | | | | | | | **$ -** | **$ -** | **$ 2,769.00** | **$ 2,769.00** |
| SawStop table saw | 0 | 0 | 1 | 1 | $1,900.00 | | $ - | $ - | $ 1,900.00 | $ 1,900.00 |
| DEWALT 12" Slide Comput miter saw | 0 | 0 | 1 | 1 | $360.00 | | $ - | $ - | $ 360.00 | $ 360.00 |
| DEWALT 1.3A 20" variable-speed scroll saw | 0 | 0 | 1 | 1 | $489.00 | | $ - | $ - | $ 489.00 | $ 489.00 |
| Scroll saw blade set | 0 | 0 | 1 | 1 | $20.00 | | $ - | $ - | $ 20.00 | $ 20.00 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Benchtop sanders** | | | | | | **$ -** | **$ -** | **$ 461.74** | **$ 461.74** |
| WEN belt & spindle sander | 0 | 0 | 1 | 1 | $168.74 | $ - | $ - | $ 168.74 | $ 168.74 |
| Variable Speed Random Orbit Sander, 5" | 0 | 0 | 1 | 1 | $70.00 | $ - | $ - | $ 70.00 | $ 70.00 |
| Bench Sander (Belt and Disk) | 0 | 0 | 1 | 1 | $223.00 | $ - | $ - | $ 223.00 | $ 223.00 |
| **Drill presses** | | | | | | **$ -** | **$ -** | **$ 995.00** | **$ 995.00** |
| Floor Drill Press | 0 | 0 | 1 | 1 | $995.00 | $ - | $ - | $ 995.00 | $ 995.00 |
| **CNC machines** | | | | | | **$ -** | **$ -** | **$ 1,699.00** | **$ 13,008.70** |
| Shapeoko XXL | 0 | 0 | 1 | 1 | $1,699.00 | $ - | $ - | $ 1,699.00 | $ 1,699.00 |
| Tormach PCNC 440 (desktop CNC) | 0 | 0 | 0 | 1 | $11,309.70 | $ - | $ - | $ - | $ 11,309.70 |
| **Planers** | | | | | | **$ -** | **$ -** | **$ 1,995.00** | **$ 1,995.00** |
| Baleigh Industrial Planer IP-156 | 0 | 0 | 1 | 1 | $1,995.00 | $ - | $ - | $ 1,995.00 | $ 1,995.00 |
| **Lathes** | | | | | | **$ -** | **$ -** | **$ -** | **$ 2,193.22** |
| Wood Lathe - 18" x 47" | 0 | 0 | 0 | 1 | $2,095.00 | $ - | $ - | $ - | $ 2,095.00 |
| Lathe chisel set | 0 | 0 | 0 | 1 | $98.22 | $ - | $ - | $ - | $ 98.22 |
| **Consumables & Misc.** | | | | | | **$ 572.42** | **$ 1,836.41** | **$ 3,558.92** | **$ 3,582.90** |
| Mobile deck panel truck | 0 | 0 | 1 | 1 | $209.00 | $ - | $ - | $ 209.00 | $ 209.00 |
| Shop vac | 0 | 0 | 1 | 1 | $87.62 | $ - | $ - | $87.62 | $87.62 |
| Cyclone dust separator | 0 | 0 | 1 | 1 | $29.98 | $ - | $ - | $29.98 | $29.98 |
| Sandpaper | 0 | 1 | 3 | 3 | $13.99 | $ - | $ 13.99 | $ 41.97 | $ 41.97 |
| Wood glue | 0 | 0 | 3 | 5 | $11.99 | $ - | $ - | $ 35.97 | $ 59.95 |
| Super glue (liquid) | 2 | 2 | 3 | 3 | $20.96 | $ 41.92 | $ 41.92 | $ 62.88 | $ 62.88 |
| Super glue (gel) | 1 | 1 | 3 | 3 | $30.50 | $ 30.50 | $ 30.50 | $ 91.50 | $ 91.50 |
| Nails, screws (assorted | 1 | 1 | 1 | 1 | $500.00 | $ 500.00 | $ 500.00 | $ 500.00 | $ 500.00 |
| Discretionary | 0 | 0.5 | 1 | 1 | $2,500.00 | $ - | $ 1,250.00 | $ 2,500.00 | $ 2,500.00 |

# XR (Extended Reality) Equipment

Virtual reality, augmented reality, and mixed reality – collectively referred to as ‘extended reality” – in a typical classroom have an extraordinary Ms. Frizzle (of Magic School Bus fame) effect. You can go anywhere, and do practically anything. Makers can scale up to the size of galaxies, or scale down to swim alongside microscopic tardigrades. Anyone can travel to the Great Pyramid of Giza and wander through the labyrinth of construction tunnels, rather than simply gaze at static images of pyramids in a book.

While common adoption of XR for classroom use is still a few years away, it’s gaining traction in makerspaces for its wide range of STEAM applications and the means by which it can convey complex topics in meaningful ways. And since gamification in classrooms is on the rise, the use of VR to improve engagement and make learning more enjoyable, realistic, and hands-on is only due to rise in coming years.

## Safety considerations

There are few, if any, physical risks to using XR hardware and software, save for taking regular screen breaks. And perhaps moving furniture to avoid banging shins into unseen tables as makers wander around and explore new worlds.

Hygiene should also be considered, as makers often work up a sweat, which can be gross with shared headsets. Headsets can be wiped down with disinfectant wipes, equipped with easy-to-swap-and-clean foam replacement pads, and even cleaned in special UV chambers in order to kill germs quickly between users.

## Additional considerations

- Typical VR stations need an exploratory area of around 15’ x 15’ for makers to wander safely.
- Increasingly, standalone or untethered VR is coming to market. These typically don’t require base station sensors but have some limitations. Typically they offer fewer games, and also don’t enable makers to walk around a digital space.
- Most VR applications have invisible, digital walls in place that flash up on a maker’s screen if they get too close to out-of-bound areas beyond the 15’ x 15’ space. Don’t count on makers stopping in time, and provide ample space around the area to prevent makers from swinging controllers into other valuable equipment.
- Mandate that makers use the hand straps on VR controllers. Airborne controllers accidentally flung during a virtual tennis serve can be damaging to equipment, and painful to makers in the line of fire.

- You may need to budget additional funds to purchase VR experiences (a term we prefer over ‘games’) to promote VR as a useful tool across the educational STEAM arena.
- Tethered VR, which offers a wider range of experiences, will require a VR-ready computer with a relatively robust graphic card and processor. We have used a backpack computer that allows the maker to explore without getting too tangled up in cords.
- VR treadmills are on the rise, but are not quite affordable or mainstream enough to be included on this list. Kat-VR is one company leading the charge here. Likewise, keep an eye out for haptic sensors, gloves, and headsets that track eye movement and facial expression soon. The world of Ready Player One is fast approaching.
- We intentionally did not factor in smartphones to be used with Google Cardboard units, as smartphones can be difficult to budget for. More and more frequently, young adults have access to their own smartphones, a fact we relied on when building this list.

## XR hardware

Steam is the most popular VR platform. You can get many VR experiences over Steam for free. We don’t budget for additional paid Steam experiences here. For those wishing to create their own XR experiences, Unity is a popular choice, and free to download.

| | | | | | Totals: | Tier 1m | Tier 1 | Tier 2 | Tier 3 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $ 941.75 | $ 941.75 | $ 5,133.90 | $ 5,133.90 |
| | Quantity | | | | | | | | |
| XR | | S | M | L | Cost ea. | $ 941.75 | $ 941.75 | $ 5,133.90 | $ 5,133.90 |
| Google Cardboard | 5 | 5 | 2 | 2 | $8.95 | $ 44.75 | $ 44.75 | $ 17.90 | $ 17.90 |
| Oculus Quest 2 | 3 | 3 | 2 | 2 | $299.00 | $ 897.00 | $ 897.00 | $ 598.00 | $ 598.00 |
| HTC Vive Pro | 0 | 0 | 1 | 1 | $1,199.00 | $ - | $ - | $ 1,199.00 | $ 1,199.00 |
| Vive-ready backpack PC | 0 | 0 | 1 | 1 | $3,319.00 | $ - | $ - | $ 3,319.00 | $ 3,319.00 |