Chapter Nine

The Case for Open Hardware in Libraries

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Over the last couple of years, a slow transformation has taken place within libraries. It's happening in small ways in many places, but the drive toward understanding the library as a center for creation of things—as opposed to a center for preservation and consumption of information—seems to have struck a chord. There are a number of ways this has happened and is happening, from the media centers that you can find in many libraries where patrons are creating audio and video content, to the movement of the moment, makerspaces in libraries.[1] From the media center to the makerspace, patrons are creating their own texts, music, video, and now objects via 3-D printers and CNC (computer numerical control) routers at libraries. The modern library is not for consumption only (not that it ever has been), but for creation and distribution of works.

But this move toward making is interesting in several ways. The rise of media creation came, at least partially, from the rise of libraries using the tools involved in their own operations, much in the same way that public computers were rolled out to patrons in libraries after they had already become commonplace in the backroom operations of libraries. Libraries tend to "dogfood" their new technology—using it internally, or "eating your own dog food"—before rolling it out to the public, often without realizing that they are even in the process of doing so. Scanners were used in interlibrary loan and reserves long before they were provided to the public, and other technologies were well understood in the processes and procedures of the library before they had a public face.

Contrary to this model, the rise of the makerspace in the library seems to be driven by the desire to give the technology to the public, and not by a recognized need for the various technologies to improve the processes and procedures of the library itself. In this chapter I outline a rationale for just this idea: That moving into the next ten years of library operations, it will become increasingly important for libraries to embrace the variety of maker technologies in order to extend their services and assessment of services. I believe that having a makerspace/creation space is ultimately going to be more important for the library than it will for the patrons.

Finer minds than mine have argued that we are heading toward a technological era that will give rise to the post-mass-manufacturing production of goods. Increasingly inexpensive general-purpose computing hardware platforms such as the Raspberry Pi and Arduino provide the base for customizable hardware creation. Features such as 3-D printing, laser cutting, and CNC routers allow for the creation of physical objects, enclosures, and containers. When you combine these with the increasingly rich open-source/libre software collections driven by sites such as GitHub, you have the recipe for bespoke hardware, something that was out of reach for everyone except the very rich until now.

You've always had hardware hackers building away, famously, in their garages. Indeed, this very instinct gave rise to the personal computer revolution as we know it through people such as Steve Wozniak, Bill Gates, and the early homebrew computer clubs. But never has hardware been as easy to build from a recipe. It is very possible these days, if you have the infrastructure in place or a makerspace to visit, for you to read about a piece of hardware and build it yourself simply by following instructions: print this, download this program, copy to your board via USB, slide tab A into slot B, and you have your very own RFID reader, or gate counter, or video capture box. Libraries are currently beholden to vendors for a great deal of hardware, but this hardware is now within the realm of being something we could build ourselves.

But why should libraries bother? Moving to building our own hardware takes the same shift in understanding and economics that moving to open source software has taken in many libraries. Libraries can choose to place their cash into staff instead of into support contracts. Doing so gives libraries flexibility that they don't have with vendor-driven hardware, because it gives libraries the ability (again, just like with software) to make changes that benefit a particular situation and need. It also provides the ability to improve the hardware and software at the library's own pace—anyone who has dealt with any vendor has run into a situation where

the speed with which you want change doesn't match the speed with which the vendor can make it change.

While these are sufficient reasons to pursue our own hardware, they aren't necessarily the most important. I believe that there are emergent reasons related to the increasingly digital nature of our work.

It isn't a secret that library services everywhere are moving increasingly digital. Even with the difficulties and challenges of e-books and other electronic content issues (licensing, DRM, etc.) taken into account. In many cases, digital means distant, and we are removing a lot of the need for patrons to come physically to our locations. My place of work is an academic library, and I assure you that most students do their research remotely, accessing library-provided databases from the comfort of their dorm or apartment. We attempt to catch as many students as possible during their required English classes to provide some library instruction/information literacy classes, and offer a bevy of other instructional opportunities to students, faculty, and staff.

The trend for most libraries, long term, is fewer in-person interactions and lower circulation of physical objects, at least as compared to the previous couple of decades. Meanwhile, we see a rise in digital delivery of content. Library circulation numbers are often buoyed by DVD checkouts, while Netflix and other streaming-video choices grow as a way of consuming video, preparing to bring circulation numbers down.

And yet when ACRL publishes summary statistics about libraries' performance, digital delivery of content is still listed in the "supplementary" section. Libraries are still measured against one another by physical collection size and circulation numbers, things that are increasingly unimportant in the actual delivery of our product to our patrons. How should we react to this?

I maintain that libraries would be far better off with new measurements of usage. The rise of custom hardware is potentially one answer for how we gain these measurements.

HARDWARE

One of the advantages of the meteoric uptake of mobile phones is that the cost of the sensors they use (microphones, cameras, accelerometers, GPS, light sensors, compasses, and much more) has been driven down to nothing. This has allowed the manufacturers of other devices to incorporate sensors where just five to

seven years ago it would have been far too expensive. That, combined with the momentum of Moore's law, means that we now have the ability to manufacture—or more important, make for ourselves—electronics that can report things about the world in new ways.

Hardware projects such as Node (www.variabletech.com) and Twine (http://supermechanical.com/) show us that it's possible to build inexpensive sensor-driven hardware that is networked and capable of communicating with other systems—exactly the right sort of thing to have around if you are looking to find new things to measure in your library. Imagine the very near future, when it will be possible to measure not only how many people come into your library, but what books your patrons are looking at on the shelves and not checking out. Imagine knowing every time someone went into an aisle and moved a book. How rich a dataset could a library create about browsing habits, patron choices, and selection behaviors, and what could that do to our space planning, our acquisitions, and our programming planning if we had that kind of information?

While the growth of projects and products using open hardware is explosive, the actual hardware being used has standardized pretty heavily around just a couple of platforms. The two largest platforms for hardware at this point are Arduino and Raspberry Pi, with a long tail of other hardware for specialized uses available. If you understand these two, there really is very little limit to the sorts of things you can build. Combine these hardware building blocks with a 3-D printer, and you've got a completely packaged hardware solution, complete with case and mounting solution.

Arduino is the name of a type of open hardware, a particular type of board that has a wide variety of instantiations (Uno, Mega, Lilypad, Mini, Duemilanove, Esplora, and Due are just a few of the more popular models). It is a microcontroller, an integrated circuit that has a processor and memory, but most important, a series of input and output controllers. It's programmable via a very simple IDE (integrated development environment) that uses C and C++, but includes a software library called Wiring that makes many operations much simpler than writing raw C code.

Arduino has become the most popular style of microcontroller for small-electronics work because of its versatility and low price. While they vary in price greatly, you can find Arduinos for between $15 and $30, and once a program has been developed for an Arduino microprocessor, altering it and replicating it from board to board is very straightforward. This makes the development of a program that solves a specific problem replicable across libraries, in the same way that open-source software allows many libraries to benefit from the efforts of a few. You

don't have to write the program for the Arduino; you just have to know where to get it and how to load it.

So what sort of things can you do with an Arduino? The simplest way to think about it is as an action and reaction machine. Anytime something happens, and then you want something else to happen, the Arduino can do that for you. Someone walks through your door, and you want to count it? Hook an Arduino up to a sensor and tell it to count whenever someone trips that sensor. When someone puts a book in your book return, do you want a robot to wave at them? You could do that as well. Arduinos are used for all sorts of robotic efforts, from Furby-like interactive robots to autonomous flying drones.

We will return to projects that libraries might want to implement using Arduino microprocessors in a bit. Let's take a look at Arduino's relative in open source hardware, Raspberry Pi.

The Raspberry Pi microprocessor is slightly different in design and use than an Arduino. It is also an open platform, but the Raspberry Pi is a full computer, with processor, RAM, and USB ports; an HDMI port for video out; an audio port; and an SD card port that used for the "hard drive" of the device. The Raspberry Pi also has an Ethernet port built in, to make hardwired networking straightforward. It will run a variety of operating systems, but most users settle on some form of Linux.

The Raspberry Pi, even though it is a fully-functional computer, costs $35–50 at retail in the United States. This low cost makes it ideal to implement things that require a bit more logic than simple input/output like an Arduino. Since the Raspberry Pi is just another Linux computer, it can do most of the same things that other Linux-based computers can do, albeit on a smaller scale or with a lower load. It can act as a server for any number of efforts, including as a web server. Many labs are using the Raspberry Pi as a development platform for individuals who are learning to code. Rather than having a single server that everyone shares, a lab can afford to allow each user to have their own personal server based on the Raspberry Pi to test everything from web apps to database management.

As a stand-alone computer, the Raspberry Pi is even suitable for low-power kiosk use. It will run a modern web browser and connect to an HDMI monitor, which means that for many library users, it may easily take care of their computing needs. It works very well as a front-end client for any number of display needs, and is one of the very cheapest options to get computer-driven visual content onto a screen.

Both platforms are popular enough that entire ecosystems of products revolve around them now. There is a thriving business in Arduino expansion boards, called

Shields, that give it additional capabilities. These include data-logging Shields that will write data collected out to SD cards or other memory, Shields that have sensors or LEDs built in that can react to stimuli, or Shields that simply provide additional connectivity options such as Wi-Fi or Bluetooth. If you can imagine something that you'd like to plug into Arduino, someone somewhere probably has it for sale.

The same goes for the Raspberry Pi, with everything from breakout boards for simple circuit connections to camera kits that are designed specifically with the Pi in mind, available for purchase from websites such as Adafruit and SparkFun. You can purchase kits that will turn your Raspberry Pi into anonymity proxies and remote Wi-Fi cameras, and more and more connectors and kits are available almost daily. You can, of course, even buy a card that connects the Arduino to the Raspberry Pi, cleverly called the A La Mode (www.makershed.com/AlaMode_for_Raspberry_Pi_p/mkwy1.htm).

These are only the tip of the iceberg for open hardware, as different boards are released constantly. Specialized or improved versions of these boards, such as the BeagleBone board (http://beagleboard.org/), allow for more focused or particular development and use. Arduino boards are getting smaller and cheaper, with some available for under ten dollars and smaller than a quarter.

When you combine these hardware pieces with the ability to custom print cases/containers for them with increasingly inexpensive 3-D printing technology, you have bespoke manufacturing at an individual library level. Use the recipe to plug A into B, and you have a working project; then search Thingiverse for a case/container or design one yourself. Print it out on your 3-D printer, and you've got a solution for a problem that is just as good—and better in many ways—than the custom hardware you're buying from a vendor.

IMPLEMENTATION

How does this fit into a library context? What sorts of problems could this solve? One thing that all libraries should be collecting is basic statistics, such as gate/door count. Showing that your building is busy is a natural and honest statistic to report to the agencies that hold the funding strings for libraries, whether it be the provost at a university or the board of a public library. It is a basic statistic, a foundation against which other statistics such as circulation can be compared and discussed. And while most libraries aren't buying gate/people counters yearly, I bet that between servicing and purchase price, libraries spend hundreds of dollars

per year—and in some cases, thousands—on just this single piece of reasonably simple hardware.

All it will take is one library or librarian writing the code for a gate counter (and not even writing, just adapting existing code) and releasing it freely online, and the cost for implementing a system could plummet to just the cost of the basic hardware and a few minutes of time. As very rough math, a gate counter from a typical library vendor costs $300 and up, to as much as thousands for one with wireless capabilities. For well under $100 worth of hardware, a library could build a gate counter that is more fully featured—and certainly better understood and repairable—than the existing options.

Not only that, but once the cost of hardware hits a certain point (as it has with sensors), it becomes trivial to measure things that almost no one measures currently. Once the cost of the hardware for one of these gate counters drops to $50, it is suddenly very tempting to sprinkle them liberally throughout a library. How would you change your usage policies if you could look at minute-to-minute occupancy numbers for your study rooms? Using counters around the library would give you a much more robust understanding of room usage and traffic patterns, and would give you data to better the experience of your patrons.

The exciting thing about this isn't the data that you can measure. As William Gibson once said, "The street finds its own uses for things."[2] Once this type of inexpensive hardware is in the world, the sorts of things that it might be used to gather about are innumerable. And gate counters are only the first step of sensors that could be used. Want to see if occupancy actually correlates with noise levels, or is there really some other reason you get noise complaints only on certain nights? Build something that will give you the data to figure it out. Build the things that measure the future.

Libraries use lots of other obvious bits of hardware that could be replaced with open hardware alternatives. Temperature and humidity sensors are another common hardware bit that libraries use, that are priced far higher than the component parts, and that could be built and replaced several times over and still save the library money over the traditional vendor. Moreover, the devices could be precisely customized. For instance, with a Raspberry Pi and a few sensors, you could have a device that e-mails you if it senses water on the ground. With a web connection, you could easily have a sensor that alerts you via Twitter when your server room is getting too hot, or that posts to Facebook when your study rooms have available spaces for the day. Much of this sort of automated interaction with the world can be offloaded to inexpensive hardware that we build ourselves.

These inexpensive boards and sensors are now on the way to enabling the quantification of just about every aspect of one's personal life. From steps taken to bites eaten, what you do every day can now be measured, recorded, analyzed, and shared in order to help you change your habits. I think this same effort—which has long been the realm of high-end retailers due to the costs involved—is now available to anyone who wants it. And I think that libraries *should* want it, very much. As we move forward into the increasingly digital future, measuring how people are using our physical spaces—and thus what we can do to ensure that they are being used effectively—will be important for us to be able to communicate to stakeholders.

This type of hardware creation can also enhance other aspects of library processes. With a small computer like the Raspberry Pi and a Microsoft Kinect (the Kinect is just a fancy pair of webcams with some sensors embedded), you could set up a small system that "watches" a set of shelves and records everything about patron browsing on those shelves. For instance, you could have such a system watch your "New Books" area and record the most popular genres that are looked at and picked up, but maybe not necessarily circulated. How many people visit that particular shelf per day? How long do they browse? What catches their eye? Systems such as this are being used in retail now, in drugstores and department stores, in order to better arrange products to catch the eye of the consumer. Libraries should be using the same types of technologies to boost their services and content, and we could do so for much lower cost with open hardware and software.

We are firmly living in the world of big data at this point. I think that George Dyson had it right when he said, "Big data is what happened when the cost of storing information became less than the cost of making the decision to throw it away."[3] Most librarians should be familiar with the phrase, and some have started talking about how we use our own big data (see, for instance, Carl Grant's blog post on moving from being reactive to proactive with data usage.[4] We are starting to have the data on hand about our virtual usage via cloud services that allow us to do really interesting things with data, as Grant points out. My suggestion vis à vis open hardware is that we need to be thinking about how we can get that same level of data from our physical spaces.

HARDWARE CAN BE FUN

We often talk in terms of outcomes and assessment of services, but rarely is the goal just to have fun—something that gets overlooked or maybe just underappreciated

when talking about library services. Giving our patrons happiness, providing them with services that delight as well as inform, should be a thing that we aim for in libraries. Reading is informative, yes, and important and powerful, and libraries have been appropriately revered for their role in assisting with it. But it is also at times overwhelmingly fun and joyous. How can we make our physical spaces reflect this fun?

One possibility is to work to delight your patrons by building hardware that adds play and fun to the environment. With open hardware, it is easy to add interactivity to spaces through a huge variety of inputs and outputs. Furniture that reacts to noise levels, or digital art that reacts to sensors placed around the room, objects that react to you when you put them in the right or wrong order; just making the physical space aware of the people in it has some amazing power to direct the way that people feel about it. Using the amazing creative tools that some libraries now have at their fingertips can fundamentally change the way that people interact with our spaces, and to do so by measuring existing behaviors and then iterating to alter those behaviors is a future for libraries that I'd like to see.

I want to see libraries that understand their physical spaces as closely as they understand their collections. I want to see ambient sensors that measure the way those collections actually get used in the spaces, by the patrons. And most of all, I want to see how all this can come together to create more effective and efficient libraries.

CONCLUSION

Moore's law tells us that electronics are never again going to be as expensive or as slow as they are right at the moment you read this, no matter when you read this. The march into the future is relentless for electronics, and while it may slow sometime, I'm betting it won't in any of our lifetimes. This constant improvement and cost cutting is unique among consumer goods, where most goods get worse in quality but cheaper, or more expensive and better. To get cheaper and better all at the same time is a hard thing for humans to plan for; for this reason, it's a situation that we almost never see.

Open source software had its tipping point when the Internet emerged and suddenly reduced the cost of communication to nearly zero. Open hardware is going to have its moment as the cost of the silicon itself drives to near-but-never-exactly zero. As price decreases, the literal cost of failure does as well, providing the ability to experiment without incurring a serious budgetary setback. Just a few

years ago, if you wanted to have a piece of custom hardware, it would have cost you tens of thousands of dollars just to start the process of production. Now you can design, build, and even house your electronics project for less than the cost of a tank of gas in many cases. As the price continues to drop (as it assuredly will), implementation and use of these technologies becomes more and more tempting, until at some point in the future it will be trivial to produce working hardware models of things that help you day to day.

Libraries need to be considering this transition from "hardware is difficult and expensive" to "hardware is cheap and trivial." Libraries are rarely the early movers in technology. Looking back over the last couple of decades, we were late to the party on open source, late to the party on mobile, and, I would say as I write this, we are late to the party on social technologies. The measurement and quantification of everything that happens is coming, and unless we are very careful, it will be a space that is overwhelmed by private companies and locked off for open experimentation. Building our own hardware, working to make the things that measure our future, is as important as all the technological innovations that I listed above. Let's not be late to this party.

NOTES

1. I am using *makerspace* as a catchall term for "creation spaces," which in some libraries are called fablabs or tinkerspaces.
2. William Gibson, "Burning Chrome," *Omni*, July 1982, 72–77.
3. Tim O'Reilly, "George Dyson's Definition of 'Big Data,'" Google+ post, May 6, 2013, https://plus.google.com/+TimOReilly/posts/Ej72QmgdJTf
4. Carl Grant, "The Approaching Divide in the Provision of Library Services," *Thoughts from Carl Grant* (blog), August 21, 2013, http://thoughts.care-affiliates.com/2013/08/the-approaching-divide-in-provision-of.html.