



The Library

Bret Victor / February 8, 2019

You enter the library from the top.

The building is cylindrical, six stories tall. Each level is a ring, wider than the one above it, such that from any point, you can see everything beneath you. From the top, you see everything.

You look down and see all the systems of the world.

Well, not exactly — one can't actually *see* a system directly. What you see are representations, visible living models, each one bigger than you are. Every place you look is devoted to a particular domain of knowledge — thermodynamics here, biochemistry there, constitutional law over there — and every domain beckons to you with a large living model of its core system, inviting you to learn it.

You hold in your hands a map of the library, and this is also a map of knowledge. A dynamic dot indicates “you are here”. You are oriented within the knowable, a bounded space with shape and contours, everything within reach. Every connection between domains of knowledge will become a line on this map.

The message of this library is: *the world is knowable*. And knowable not as *stories* but as *systems*. The material here is not made of myths, proverbs, hearsay, soundbites, the sort of stuff print-based libraries traffic in. You look down and see models, to be constructed, analyzed, verified, compared, critiqued, abstracted and instantiated.

The other message of this library: *knowledge is constructed*. Nothing here will tell you what's true. The material in this library will present evidence — or guide you in obtaining evidence from experiment — and then guide you in constructing models that support that evidence. To construct good models, you will need good tools, and the library will guide you in constructing these as well. These will often be mathematical tools, but in the medium in which this library exists, mathematical tools are just as real as tools for drawing or carpentry.

The tools that you've constructed throughout previous visits are in your toolkit, which is kept for you in a lockbox near the entrance. You retrieve your kit and descend into the library.

The Section

You proceed towards the section on electricity, where you and a few friends have been working on an activity for the last couple months. Unlike the print medium, which is inherently oriented toward private study, the characteristics of this medium make people prefer to study together — the material is large-scale, visible, sharable, discussable. It also takes up a lot of floor space, and it can feel awkward to use so much room for a single person.

As you walk to the electricity section, you pass by other sections that have become familiar. You've never studied the human immune system, but in a conversation the other day, you were surprised to find that you had a pretty good understanding of it. Immunology is one of the sections you pass by frequently, and because all of the models are out and visible, you can't help but play with them occasionally and overhear people working on related activities. You've worked in enough places around the library that you've been peripherally exposed to most everything.

You reach the section where your friends are waiting, toying with some of the models lying around. Like most sections, it is structured as a large central open area surrounded by shelves of activities. (In a print-based library, this would resemble a “reading room” surrounded by shelves of “books”.) When on the shelf, most activities are represented by a handheld dynamic model of the core system that the activity is about. This is usually one of the final models you construct when doing the activity, and playing with it off the shelf is like “peeking at the last page of the book”. Most activities on the shelf also have a map of the space they expand into — this is their “table of contents”.

Since everyone's arrived, you go to the shelf with the activity you've been working on, pick up the map, and bring it over to an available part of the central area. You activate the map, and the area transforms into the space depicted. Some of this transformation happens robotically, and some via projected instructions which your group carries out by hand. You've been working on this activity for a while, so you're pretty familiar with where things go, and you get the space set up in a minute or two.

In this section, another group is currently working on a different activity. The configuration of your activity today has automatically adapted to their presence — some things have shifted to stay out of their way, while a few shared resources overlap with theirs. There are often multiple groups sharing a section, and good activities are designed not just for their participants, but also for peripheral learning by adjacent groups.

The Activity

You and your friends have been working on an activity (really, kind of a series of activities) titled *Constructing Computation*. You were initially surprised that the author anchored it in the electricity section (activities are “anchored” in one particular section of the library, even though they often require you to move you around to other sections over the course of study), but the reason became clear when you found yourself constructing an electron.

The spatial medium encourages authors to take a pretty broad view of their subject, and *Constructing Computation* is a typical example. In this activity, you:

- construct a model of a quantum-mechanical electron
- use your electron along with a model crystal lattice to model electron behavior in solids
- use these physics to construct a model semiconductor
- use your semiconductors to construct a model transistor
- use your transistor to model logic gates
- use your gates to model computational units, and then a CPU,
- design a programming language, construct a compiler for it, and use your CPU to run your program

You don't really do these things in sequence, or rather, it's a “spiral curriculum” kind of sequence, which is reflected almost literally as a spiral you walk around the space, visiting each of the layers of abstraction in turn. Because each of these layers has its own place, as you're working in one layer you see your actions represented in each of the other layers. Your program adds two numbers and you watch the electron wavefunctions dance.

Instead of a strict dependency-ordered sequence, the author has you constructing (learning) everything gradually in parallel. That means you build your first AND gate from “scaffolding” transistor models that were given to you (and thus that you don't fully understand). But eventually you will construct your own transistors, and then reconstruct your AND gate from your own transistors, and so on, until all of the scaffolding has been replaced by your own constructions.

The same goes for tools. You construct these models using tools, so you need to construct your tools. Sometimes you can use scaffolding tools for a while, but you eventually have to build your own. Because you've done other activities in this library, your toolkit already has a lot of what you need, but this activity is adding a few new ones. In this library, all tools, including mathematical tools, are learned/constructed in the course of modeling real systems.

The Tools

Today's iteration of your electron model is built on the concept of a vector potential, so you need a vector potential tool. In your toolkit, you already have a line integral tool that you constructed last year. It looks kind of like a pair of short pencils connected with a string. The pencils are glammed up with glitter glue — you were really into glitter for a brief period last year. Your friends tease you a bit when you do line integrals, but you're still fond of it.

You've already built a few higher-level tools based on line integrals, so you're familiar with how it goes. Working with your electrons, you perform the line integral, and nearby you use a couple other mathematical tools to set up the rest of the calculations. Now you're ready to build the physical form in which your abstraction will live. Your vector potential tool will look a bit like a compass with a couple of attachments, and you decide to laser cut the pieces this time. You screw the pieces together, imbue the object with the calculations spread out on the table, and now you've got your new tool. For old time's sake, you add a dash of glitter glue across the top.

A vector potential is something you do. Before long, it will live inside your hands, and you will perform vector potentials like a pianist performs arpeggios. But a vector potential is also something you see. The potential field of your electron fills the space around you — you simultaneously live inside *it*. This is typical of representations in this medium — you work with small models in your hands, while observing effects in large models all around you. You are both inside and outside the systems you construct.

How could it be otherwise? These are *systems*. They are far too complex to be seen, let alone discussed, using anything smaller than a full space; they are far too complex to be analyzed and manipulated using anything less than the full dexterity of a human hand.

The Authors

Today you are learning about electrons. But you're not just learning about electrons, because you have to construct the electron model yourself, so you're also learning the modeling tools (or “mathematics”). But you're not just learning the mathematical tools, because you have to construct the tools yourself, so you're also learning the meta-tools (or “programming languages”) with which activities are authored in the first place.

That is, by working through an activity, you learn everything you would need to *author* that activity.

And you are an author yourself, of a sort, in the same way that everyone around here is — you make little projects here and there to explore topics that you're curious about. These are mostly just for fun, but a few months ago you got interested in music synthesis, and after making a bunch of little sound models, you tied them together into a passably-coherent activity and put it in the community section of the library for others to try out.

The librarians have pretty high standards for what they'll place in the main library, but they're usually fine with just about anything in the community section as long as it's not obscene. Many of the main-library activities started out as community-section projects; the authors just kept working on them until they were good enough to publish.

Today in the library, there are several full-time authors working on their projects, scattered among the learners. It can be hard to tell them apart, since in this library, learning is constructing anyway. Oftentimes learners themselves can't tell when they've inadvertently started authoring — they divert from an activity in order to chase a question they're curious about, and a few months later, their diversion has become a full-fledged activity of its own.

It's suspected that many of the published activities started off as diversions from some other activity, just as many books have started off as responses to other books.