Procedural Literacy:
Problem Solving with Programming, Systems, & Play

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Some 30 years ago, the first wave of personal computers spawned a surge of interest in programming education, especially in getting children to program. At the Xerox Palo Alto Research (PARC) group, Alan Kay and Adele Goldberg proposed an environment in which anyone could program simulations (Kay & Goldberg 1977).[1] Using their object-oriented Smalltalk language, Kay and Goldberg argued that computers could be used expressively by anyone, including children. In 1980, Seymour Papert first outlined a program for teaching children to program with Logo (Papert 1980), a language he co-developed in the 1960s at MIT. By the early 1980s, programming began to gain recognition not only as a kind of professional training but also as a kind of literacy in its own right. This new trend became known as *procedural literacy* (Sheil 1980). Such efforts to teach programming to the uninitiated, and especially the very young, have continued since (for example, Perlin et al 2003).

Learning to become computationally expressive is more important than ever. But I want to suggest that there is a use for computer literacy that extends far beyond the ability to program computers. Computer processing comprises only one register of procedurality. More generally, I want to suggest that *procedural literacy* entails the ability to reconfigure basic concepts and rules to understand and solve problems, not just on the computer, but in general.

A Look Back Through Classical Education and Programming: A Perspective

Before we can think about how students might become literate programmers, it is useful to think about how they might become literate writers in general in the 21st century. Shortly after World War II, Dorothy Sayers, friend of J.R.R. Tolkien and C.S. Lewis, gave a talk at Oxford on what she called "The Lost Tools of Learning" (Sayers 1947). In the presentation, Sayers argued that we have failed to teach children what is most important. Instead of simply bombarding students with subject-specific content, Sayers suggests we first teach them *how to learn*. She points to the medieval method of education, comprised of three parts known as the trivium: Grammar, Dialectic, and Rhetoric. Aristotle first outlined this approach, mostly in works that were lost until the 5th and 6th centuries, when they were rendered into Latin for broader popular use. Sayers was a medievalist and Christian apologist, and thus she points explicitly to the emedieval exercise of the trivium, which focused on the Latin language and authors instead of the Greeks.

In recent years, the use of the trivium has become popular in some private schools, primarily private parochial schools that appreciate its medieval connection with the church. Such schools often call their approaches "classical," in honor of the classical origins of the trivium and the fact that most major early Christian thinkers, like Augustine, were taught in this fashion. Of course, our modern day context is very different than classical antiquity or the Middle Ages. Approaches like the one Sayers suggests or that some modern Christian schools have implemented would be more properly called *neoclassical*: they attempt to integrate the classical trivium with modern-day subject knowledge.

Among the more popular recent attempts to codify a neoclassical education is that of Jessie Wise and Susan Wise Bauer, who coauthored a book on neoclassical education, *The Well-Trained Mind.* On first blush, Wise and Bauer's neoclassical trivium looks almost exactly like the medieval trivium; they even call their three stages Grammar, Logic, and Rhetoric. But in this neoclassical model, the stages are roughly mapped to educational level: grammar in the elementary grades; logic in the middle-school grades, and rhetoric in the high-school grades. In the

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case of writing, in the grammar stage, the child learns the conventions of writing, such as parts of speech, copying, and composition. In the dialectic stage the child learns to ask questions about the conventions, understanding how logic functions and doing more original writing. In the rhetoric stage, the student learns how to form written arguments convincingly and clearly.

Taking for granted that programming literacy is increasingly necessary for the educated adult, it is logical that computer programming education might take very much the same form as written education. A methodology like the trivium engenders a progression toward organized thinking to express, persuade, and advance the human condition; it's time to consider procedural expression as a part of this process.

A reference will help illustrate this position further. One of the subjects encouraged in classical education is the study of Latin. Here is an excerpt of the justification for Latin from *The Well-Trained Mind.*

> Latin trains the mind to think in an orderly fashion. Latin ... is the most systematic language around. The discipline of assembling the endings and arranging syntax ... According to sets of rules is the mental equivalent of a daily two-mile jog. And because Latin demands precision, the Latin-trained mind becomes accustomed to paying attention to detail. (Wise and Bauer 1999:200)

One could easily replace the word *Latin* in the above with the name of a modern computer programming language, say *Java* or *Smalltalk* or C. In many ways, programming offers even stronger evidence for the benefits of systems training than Latin. After all, natural languages are subject to human interpretation.

...PROCEDURAL LITERACY ENTAILS THE ABILITY TO RECONFIGURE BASIC CONCEPTS AND RULES TO UNDERSTAND AND SOLVE PROBLEMS, NOT JUST ON THE COMPUTER, BUT IN GENERAL.

Recasting writing in this way suggests that the trivium can provide a framework for learning expression in general. It can offer an effective way to learn programming, but also a much more effective way to learn disciplined thinking. We can perhaps imagine a course in procedural literacy qua programming that follows this regimen to teach programming, both in itself and as a framework for other pursuits. Think of the curriculum as a multipart, multiyear project that follows the path of the trivium. First the student learns the principles and rules of programming, memorizes the structures, and writes some simple applications. Next the student learns why the code functions in the way it does, understands the historical conditions and impact of digital computing, and writes programs that tackle real world problems or expressions. Finally the student learns how to author software that contributes to the broader human experience.

Wise and Bauer rely on Latin for a two-fold purpose: on the one hand, Latin is a kind of structured mental exercise. On the other hand, Latin is a natural language that can provide a window into several key components of Western culture, especially the culture of ancient Rome and the medieval church. I would argue that procedural literacy can service the second purpose; it facilitates the process of grammatical learning in general, and it helps create adults who are able to express themselves through technology, which will not cease its infiltration of our world experience.

But programming is only one way to understand procedural literacy. Now I would like to consider conceptions of literacy that can contribute to a broader understanding of procedurality.

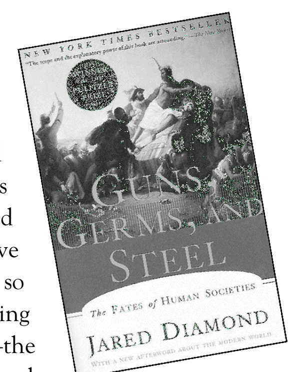
Procedural History: A Different Approach

Interrelatedness of Knowledge

In addition to binding the stages of the trivium to the modern notion of academic grade levels, Wise and Bauer mark two important revisions to the classical trivium. First, Wise and Bauer stress what they call the "interrelatedness of knowledge." They advocate an approach to learning across disciplines, specifically an iterative four-year pattern of literature, history, and science from the ancients, the middle ages, early modern, and modern times, respectively. Interrelatedness for Wise and Bauer has to do with creating links between knowledge fields, for example history, literature, and the sciences. In their conception, these connections are defined almost entirely by the progression of history, for example the Greek epic, the notion of heroism, and Greek history.

Wise and Bauer hope to break down the barriers between disciplines that often take place in contemporary classrooms, where history, literature, and science are considered separate, segregated subjects. But in so doing, Wise and Bauer risk occluding the combinatory nature of historical progress, effectively creating new silos of largely arbitrary historical periods. What would an approach to history look like that didn't make this gesture?

Accidental Causes of History



Jared Diamond won the Pulitzer Prize for nonfiction for his book on a different approach to understanding history, *Guns, Germs, and Steel* (Diamond 1999). As an evolutionary biologist studying birds in New Guinea, a native friend of Diamond's posed the question, why do white men from the West have so many possessions, while natives like him have so little? Diamond reframed this question, observing that that we know *what* happened in history—the conquest of much of the world by Europeans through the use of horses, pistols, non-native diseases like smallpox, forged swords, shields, and other implements. But we don't understand *why* the history of the world unfolded in such a way that the Europeans possessed such advantages. If guns, germs, and steel are the *proximate causes* of the flow of history as we know it, what are the *ultimate causes*? Why, asks Diamond, didn't the Aztecs sail their ships to Europe and conquer the Spaniards?

Much of human history has assumed that some basic difference in ability or intelligence among human peoples can explain why some have so much and others so little. Diamond argues that the reason doesn't lie in anything inherent to people, but in a few fundamental accidents of geography and natural resources. In areas with especially abundant land, such as Mesopotamia and China, ancient peoples happened upon agricultural innovation. This allowed them to remain in one place longer, rather than wandering from place to place as nomads after they had expended a region's resources. Such locations, as it happened, also offered a variety of more easily domesticated animals like horses and pigs, suitable for food, burden, and work. Sedentary communities of farmers were able to grow larger and eventually, through creating food surpluses, to relieve portions of their population from devoting most of their time to feeding their immediate families. In geographies with large east-west axes, such as Eurasia, similar climates across broad longitudinal distances facilitated easy transfer of crops, animals, agricultural methods, and techniques of animal husbanding, facilitating massive social growth across long distances. Landmasses with north-south axes, such as North and South America, couldn't support the same crops and livestock over commensurate distances, due to rapid climate changes along the latitudes and natural geological obstacles like the impassable Andes and the narrow isthmus of Panama.

Once food storage freed some from the burden of farming, growing societies could devote these populations to other tasks, such as soldiering, shipbuilding, technology, religion, and politics. The latter two classes especially provided the structure necessary to grow clans of people into chiefdoms and later states. Inventors created new crafts, including methods of metallurgy necessary to forge strong steel tools and weapons for war.

As communities grew into towns and cities housing people and domesticated animals in close quarters, disease transferred easily between them. While these scourges decimated local populations, they also bred strong resistances to even the most afflictive of diseases. As these societies took their ships and swords to war, the peoples they met had far inferior weapons, armor, political systems, and immune systems compared to their invaders. In short, Diamond argues that the proximate causes of European conquest via horses, guns, germs, and steel resulted from the accidental ultimate causes of land fertility, geographic distribution, and variety of plants and animals that occupied such regions.

The concept of history that Diamond endorses is very different from the one we typically learn in school. For one thing, individual achievement is significantly underplayed in Diamond's system; invention and innovation are better understood as the accidental outcome of situations rather than the radical ingenuity of individuals. For Diamond, the "interrelatedness of knowledge" (to use Wise and Bauer's term) turns out to be less relevant to historical moments than to the underlying conditions out of which such moments arose. Those conditions comprise both the actual events that took place and the configuration of geographic and material circumstances that bore them.

DIAMOND'S (CONCEPT OF) HISTORY IS... FUNDAMENTALLY A PROCEDURAL ONE... ASKING THE STUDENT TO CONSIDER THE SYSTEM THAT PRODUCED THOSE EVENTS...

Diamond's history is thus fundamentally a procedural one, a history created out of the configurations of material conditions to produce political, social, and expressive outcomes. These outcomes in turn recombine with their underlying material conditions to produce new historical moments. Such an approach to history goes far beyond the relation between contemporaneous events, asking the student to consider the *system* that produced those events. Comprehending such a history means understanding material conditions, and how such conditions recombine with one another to underwrite the outcomes we normally construe as history itself. Studying history in this fashion cultures procedural thought itself. In this case, learning to challenge the fundamental causes of cultural conditions both affords a potentially richer approach to history and exercises the ability to think about systems as the results of interrelated components.

Procedural Play

Given that computer programs are artifacts of procedural expression, perhaps it is not surprising that some of the best examples of artifacts that enact Diamond's conception of history are videogames. Games like *Civilization* (Firaxis 1991) and *Empire Earth* (Stainless Steel Studios 2001) focus on the progress of history from era to era. As software systems, these games represent history through rules of interaction rather than patterns of writing. In *Civilization*, technological innovation enables military dominance, which the player must exercise to progress through history effectively. In *Empire Earth*, local events are relegated to part of an overarching, forward progress.

Videogames offer a compelling challenge to Wise and Bauer's second revision to the classical trivium, the idea that neoclassical education is "language-focused." In their words, this means that "learning is accomplished through words, written and spoken, rather than through images (pictures, videos, and television)."

On first blush, Wise and Bauer's neoclassical approach would seem to prevent *Civilization* from offering any kind of educational benefit; after all, games seem to be image-focused, not language-focused. However, Wise and Bauer don't account for a kind of language that isn't written like the words on this page. Educational technologist and games-and-learning theorist Kurt Squire showed that *Civilization* mediated students' understanding of world history in a different way, especially the relationship between physical, cultural, and political geography and history (Squire 2004). Not coincidentally, the historical novelty of *Civilization* bears a striking resemblance to that of *Guns, Germs, and Steel.* Such examples suggest that the expression at work in videogames is not fundamentally image-based. The language that underlies programming is that of procedurality, the same logic at work in Diamond's notion of history and in *Civilization*'s representation of history. In this sense, videogames offer a different kind of language-focused learning. Artifacts like *Civilization* suggest that procedural literacy can be cultured not only through authorship, such as learning to program, but also through the consumption or enactment of procedural artifacts themselves. In other words, we can

A scene from Civilization.

Playmobil toys.

become procedurally literate through *play.*

From its early stages, Papert's Mindstorms project used the computer language Logo to allow children to instruct their own robot creations. Starting in the mid-1980s, Papert and his colleagues collaborated with toymaker Lego to combine their configurative toys with the Logo language. Children built structures like elevators and robots with Lego bricks, then connected them to an interface box they could program with Logo. But even without a Logo interface, Legos offer their own lessons in procedurality. Procedurality is central to Legos' "creativity:" individual Legos can be reconfigured in many different ways to create new objects. Even without Papert-style Logo instruction, playing with Legos gives children exposure to procedural literacy. Lego bricks are a bit like the "basic building blocks" Wise and Bauer relegate exclusively to the terrain of language. Legos recombine in multiple multiples to create new, previously unpredictable meaning.

And yet, such an elementary sort of procedurality doesn't necessarily mean a better one. Constructing a Lego object requires the builder to start at the level of the brick, slowly constructing an entire car, plane, or spacecraft from the smallest possible components. Once assembled, Lego structures are always at great risk of dismantling.

…IN OTHER WORDS, WE CAN BECOME PROCEDURALLY LITERATE THROUGH PLAY.

In comparison, consider Playmobil, another type of children's toy. Like Lego, Playmobil are made of molded plastic and sold in themes like airport, pirate, and knight. But unlike Lego, units of Playmobil are larger and more integrated. For example, a "Castaway" Playmobil kit comes with castaway, small island with palm tree, dead tree with torn white flag, torn lean-to, message in a bottle, 3 crabs, 3 fish skeletons, 2 starfish and pile of driftwood. When I began buying Playmobil for my kids, I originally thought there was no way they could offer the same kind of creative play as Lego, since the latter can be recombined in many more ways. But on further reflection, I realized that the high specificity of Playmobil pieces offers procedural play on a much higher level than Lego. We don't see just knights in Playmobil, we see Crusaders. We don't see just fighters, we see Mongol Warriors. By providing a very specific point of reference, the toys come equipped with a rich pre-history. The components of each collection provide adequate cues to allow kids to recombine their toys in a way that better preserves the larger cultural context of each piece. When children play with Playmobil, they recombine units of cultural relevance — metermaids, chimney sweeps, frothing beer mugs, airport security checkpoints. In so doing, they gain a richer understanding of the individual meanings of cultural markers through experimenting with their hypothetical recombination in circumstances outside their original sphere of influence.

Experimenting with new combinations of familiar elements is a vital characteristic of the procedural literacy toys like Playmobil and videogames like *Civilization* engender. But effective procedural literacy education through play need not entail the unexpected recombination of many small components.

The Nintendo GameCube videogame *Animal Crossing* is an "animal village simulator." Players move into a town filled with cartoonish animal characters, buy a house, then work, trade, and personalize their microenvionment. The game offers a series of innocuous, even mundane activities like bug catching, gardening, and wallpaper designing; like *The Sims* (Maxis 2000), *Animal Crossing*'s primary metaphors are social interaction and household customization.

While the GameCube does support simultaneous play with up to four players, *Animal Crossing* only allows one player to play at a time. The game can store up to four player profiles in one shared town, and human players can interact with their friends or family members who play the game, but only indirectly, by leaving notes or gifts, completing tasks, or even planting flowers or trees. Furthermore, *Animal Crossing* literally binds the game world to the real world, synchronizing its date and time to the player's GameCube clock. Time passes in real-time in *Animal Crossing* — it's dark at night, snows in the winter, and the animals go trick or treating on Halloween. Since game time is linked to real time, a player can conceptualize the game as a part of his daily life rather than a split out of it. This binding of the real world to the game world creates opportunities for families or friends to collaborate in a way that might be impossible in a simultaneous multiplayer game (see Bogost 2004). Since the whole family shares a single GameCube, the game's persistent state facilitates natural collaboration between family members with different schedules. For example, a child might find a fossil during the afternoon, then mail it to her father's character in the game. At bedtime, she could let dad know that she needs to have it analyzed at the central museum so she can take it to the local gallery the next day. As critics Kurt Squire and Henry Jenkins wrote of the game, "Families (of all types) live increasingly disjointed lives, but the whole family can play *Animal Crossing* even if they can rarely all sit down to dinner together. When families do gather, the game offers common points of reference and common projects to discuss" (Jenkins and Squire 2003).

For my five year-old, the most challenging project was paying off the mortgage on his house. *Animal Crossing* allows players to upgrade their houses, but doing so requires paying off an extremely large note the player must take out to start the game in the first place. While the more punitive intricacies of long-term debt, like compounding interest are thankfully left out of the game, improving one's home does require consistent work in the game world. Catching fish, hunting for fossils, finding insects, and doing jobs for other townsfolk all produce income that can be used to pay down mortgage debt — or to buy carpets, furniture, and objects to decorate one's house. The process of amassing capital and then choosing how to expend it is a kind of procedural literacy that continues to haunt many adults. *Animal Crossing* offers a sandbox to experiment with the ways you can recombine personal wealth.

Procedural Literacy

Procedural literacy has often been relegated to the domain of computer programming — a valuable and worthwhile project to be sure. But the value of procedural literacy goes far beyond the realm of programming alone; indeed any activity that encourages active experimentation with basic building blocks in new combinations contributes to procedural literacy. While Wise and Bauer's neoclassical trivium can revise pedagogies that ignore crossdisciplinary interconnections, such a formal approach risks hiding other connections. While written and spoken language do require conceptual effort, it's fallacious to think that visual media like toys and videogames do *not* demand conceptual effort. Engendering true procedural literacy means creating multiple opportunities for learners—children and adults—to understand and experiment with reconfigurations of basic building blocks of all kinds. •

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FOOTNOTE

[1] Xerox PARC was a hub of computer innovation in the 1970s. Among many other innovations, Kay and his colleagues developed the graphical user interface, incorporated into the Xerox Star, which was the basis for the Apple Macintosh.