2 Intelligences: a bricolage

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Abstract

Logo was devised in the 1960s as a computational approach to teaching mathematics. Herein lies error. The educational context for Logo, as articulated by Papert, is firmly rooted in the standard social science model; the work of Piaget; and a version of the 'two cultures' concept that provided a foundation for Mathalnd. A quarter century after Mindstorms, evolutionary psychology challenges the standard social science model and Logo lisplessly lingers in the ICT supermarket. This short paper seeks to situate Logo in the newer context.

Keywords

Logo, evolution, language, technicity, education, psychology, computer, algorithm, mathematics, learning

1. Introduction

A quarter century after "Mindstorms" Logo lies in the doldrums. Mathland for Children, if it is not a mythical land, is a long way over the horizon. Such a state of affairs has alternative explanations: either Logo was mistimed, or the concept was incomplete, or both. I will argue for the inclusive or. The more difficult aspect is the incompleteness: this is intimately tied into the Logo Philosophy, which is based on what Cosmedes and Tooby (Barkow et al 1992) call the "standard social science model." I take a Darwinian, adaptationist, evolutionary psychology standpoint, which leads me to hold that the social brain and the technological brain, which are reflected in the 'two cultures' notion, are two distinct adaptations, with only the later unique to Homo sapiens sapiens. This leads to the notion of two intelligences. With this context established, an analysis of the timing of Logo may be undertaken. Arguing from the analogy of steam motive power, I suggest that the 1980s was at least twenty years too soon. Timing and psychological framework were not the only inhibitors: the close association of Logo with mathematics led to conflict with extant foci, particularly in the teaching of shape and space. Indeed, in the multidimensional space of text-based School there is no place for Logo: because Logo is all about algorithms. The School of the Text has no place for the Algorithmic.

2. Matters Evolutionary

The advent of evolutionary psychology over the quarter-century since computers came to school has provided a novel perspective from which to view our educational beliefs. Re-reading Mindstorms (Papert 1980) in the light of work in this field over the past decade, an introspective grasp of learning that was poorly supported by the conceptual framework of the time emerges. Papert (1980:38) rehearsed the 'two cultures' notion, first articulated by Snow (1993) as the divide between 'humanities' and 'science', recast it in the post-Socratic division of philosophy (language) from science (mathematics), and sought to recombine into what he called 'mathetic' thinking. In searching for solid ground, Papert, like Martin Heidegger, mined Classical Greek for meaning relevant to today. Discovering that the Greek root 'math' related to learning, he conceptualised a Mathland, a learning world. Heideger (Krell 1993) took the same intellectual path in seeking out a rationale for the technological mayhem loosed in the Great European War of 1914-18. He believed metaphysics to be the root cause of the schism of science from the humanities and, finding the root of 'technology' (techne) associated with poetry in pre-Socratic Greece; saw the latter as the healer of the divide. Both authors were enabled to carry out etymological research because writing from that period is available to us today. Let us now attempt to solve the puzzle of the two cultures.

2.1. Matters social

Throughout Papert's writings runs a social thread. From an evolutionary perspective, from the perspective of the selfish gene (Dawkins 1989), our social arrangements are both unique in the animal kingdom and risky. This is true, to a lesser extent, of our primate cousins, particularly the great apes. From the early work of Goodall (1986) to more recent studies particularly of chimpanzees and bonobos, e.g. Boesch et al (2002) it becomes clear that we have much basic behaviour in common: hierarchy, consortship, tool making and social learning, warfare, but particularly alliance making. Alliances cemented by grooming, yet labile, are pivotal to primate social relationships. In chimp troupes, as in the human tribe, the dominant succeed more by social manipulation than by brute force. Evolutionary psychology (Barrett et al 2002) explores such parallels.

In modern humans cooperation is ubiquitous. The social brain hypothesis (Dunbar 2004) sees this as the driver for the expansion of the human neo-cortex. Underpinning the race towards complexity is a co-operator/freerider conflict. Our non-kin reciprocal cooperation is adaptive only if individuals don't cheat. But Darwinian processes guarantee that a cheater will evolve and, if unchecked, drive co-operators to extinction. Cooperation can only exist if cheaters are detected and neutralised. For this there are three prerequisites: a. ability to recognise individuals, b. a memory for events involving others, and c. a tit-for-tat rule of engagement. Under such conditions freeriders are suppressed, surviving only by exploiting the necessary weakness in the tit-for-tat algorithm: cooperate on first meeting. And this, it is argued, is why language evolved.

2.2. Language

There is a sizeable body of evidence to suggest that language (speech) co-evolved with the human brain (Deacon 1998 Pinker 1994, Dunbar 1996). Certainly language is a biological adaptation. Language needs no extra-phenotypic support: all that we need to communicate is our naked bodies. Although we make the anthropocentric assumption that language is unique to our species, the evidence points elsewhere. Dunbar's notion that the prime purpose of language is gossip finds support in the internal characteristics of languages. It seems that language developed out of alliance-making grooming to become a sophisticated adaptation that served multiple ends. Firstly, there is the simple negotiation needed for reciprocal cooperation to function. But then there is a panoply of additions, which may have been driven by a variety of socially-based arms-races. The clearest is linguistic diversity, which Nettle (1998) has shown to be related to freerider detection and social cohesion. Language is the adaptation that makes our hyper-co-operative livelihood possible. It keeps freeriders at bay, whilst offering them the means to seduce us. (Accents change within 25Km, Papua New Guinea has 850 languages.)

There is evidence that human species prior to us had language. Indeed, language might be said to be definitive of the whole genus. The larynx of Homo erectus was in a similar position to that of an eight-year-old child; so they could choke too. Archaic Homo sapiens, including the Neanderthals, had a speech physiology similar to modern humans. Given that our species, Homo sapiens sapiens, evolved only around 150Ka years ago, we can hardly claim language as our defining characteristic. Language did, however, provide the main pre-condition for our truly defining characteristic to evolve.

2.3. Technology

Heidegger got it wrong when he asserted that the metaphysics of post-Socratic Greece was the catalyst for technicity: "the attempt of modern man to dominate the earth by controlling beings that are considered as objects." The fossil record is clear: there is no unequivocal evidence of technology before we appeared. The tool assemblages of prior species Homo fit more comfortably within the extended phenotype concept (Dawkins 1999) than with the social learning seen in modern chimpanzees. Rephrasing Heidegger, I assert: *technicity is the capability of behaviourally modern humans to dominate the earth by controlling beings that are considered as objects*. It defines us as a species.

Social learning is risky. If, like a bird you inherit a template for a nest or as H erectus you inherit the template for a bifacial hand-axe, then your home or toolkit is dependent solely on a supply of raw materials. Social learning (culture) demands a stable and cooperative social group. A primate example would be termite-fishing sticks: two troupes have similar techniques, employing sticks stripped of leaves but of differing length. The skill is passed down the generations. Such solutions are the norm for our species. It appears that because of the complex yet stable social systems that can arise from reciprocal altruism, learning in this vein becomes adaptive. In this milieu, creativity: the capability flexibly to deconstruct an environmental object and re-form it appears. No species prior to our own was creative. So, there must be something within the social learning mechanism, and/or our brain organisation (which may be to say the same thing), that makes innovation and continuous technological improvement possible.

2.4. Diversity

Social animals, including primates, have a relatively simple group structure. In humans, the interweaving of primate heritage, language, and technicity into a three-dimensional diversity space offers a range of social niches of similar status. Most notable is the division of temporal from spiritual power in human society, which Dunbar (2004) sees as quintessentially human. Alongside the dominant male (warlord) sits an ally who provides social cohesion through stewardship of the myths of origin and technology. We may validate this assertion by taking any pre-industrial society: my preference is for Sumer. Here, the temple complexes were not only highly technological in themselves, but supported realms of resident technologists: metalworking, administrative, irrigation and canal design, and so on. Compare this with medieval Europe where cathedrals were at the technological cutting edge. Then consider the diversity of crafts with their 'trade secrets' and restrictive guilds. In this arrangement we see two factors at work: the need to split technological knowledge and skill into human-size chunks, and management of risk. Technology is intrinsically risky: it treats nature as an object to be deconstructed and reformed. In the absence of science, in the modern sense, the social brain demands that this risk be minimised: this brings language into play: ritual, incantation, prayer, taboo, disputation, discussion, and so forth. Technology is the source of diversity.

3. Weaving Humanity

Rather than write of two cultures, I would like to take language and technicity as the warp and woof of the fabric of humanity. I believe that it is possible to weave these two adaptations, imprinted with our evolutionary legacy, into the fabric of our behaviour.

3.1. Papert's daisy

As an example, let me take an experience related by Papert (1993:98). Seymour had an embarrassing learning difficulty in naming flowers. He set to to address this. He was interested to learn that the carnation was also known as a dianthus. He was shocked to discover that (horticulturally) a daisy is not a flower. Let us deconstruct his experience.

If we look back to our environment of evolutionary adaptedness (EEA) and run forward to aspects of the behaviour of recent hunter-gatherers, we see that 'flower' denotes any attractive bloom which signals the later availability of a protein-rich seed, starch-rich tuber or sugar-rich fruit. For Papert, a behaviourally modern man of recent evolutionary origin, the woof of technicity also enables him to deconstruct (dissect) the bloom of a daisy to see that it is composed of a multitude of tiny florets: going beyond the signal.

3.2. Welding

I had just left college when I had the chance to learn oxy-acetylene welding. Instructed on how to light and adjust the flame and told to move it in a figure-of-eight; I was given a piece of steel and filler rod and told to try and do a straight-line surface weld. Through dark green goggles I saw first a bright light and then a hole burnt through the steel plate. With practice I avoided making holes. And then my vision cleared and I saw a bead of molten metal with an oxide film moving on its surface. With a touch from my flame, I could move the bead hither and thither. I had learned to see a different scene: But how?

Clearly, all the information was available at my eye from the beginning. Equally clearly, my brain had privileged the information relevant to making a weld. Like Papert's daisy, the scene had been deconstructed into elements; relevant features had been amplified, non-relevant ones quashed (Carpenter and Grossberg 1987 1995). Language played no part – though I could later relate my experiences – the instructions to move the flame in a figure-of-eight were about heating the optimum area of metal to make a strong weld.

3.3. Of George Stephenson

The (Northern) English pioneer of steam railways, George Stephenson, was renowned for his creativity, and organisational and problem-solving skills. In later life, reluctantly, he joined a New-Year house party given by the then Prime Minister, Sir Robert Peel. The following is reproduced from Smiles (1857):

> At Drayton, the conversation often turned upon such [scientific] topics, and Mr Stephenson freely joined in it. On one occasion, an animated discussion took place between himself and Dr Buckland on one of his favourite theories as to the formation of coal. But the result was, that Dr Buckland, a much greater master of tongue-fence than Stephenson, completely silenced him. Next morning before breakfast, when he was walking in the grounds deeply pondering, Sir Willian Follett came up and asked what he was thinking about? "Why, Sir William, "I am thinking over the argument I had with Buckland last night. I know I am right, and if I only had the command of words which he has, I'd have beaten him." "Let me know all about it," said Sir William, "and I'll see

> what I can do for you." The two sat in the arbour, where the astute lawyer made himself thoroughly acquainted with the points of the case; entering it with all the zeal of an advocate about to plead the dearest interests of his client. After he had mastered the subject, Sir William rose up, rubbing his hands with glee, and said, "Now I am ready for him." Sir Robert Peel was made acquainted with the plot, and adroitly introduced the subject of the controversy after dinner. The result was, that in the argument that followed, the man of science was overcome by the man of law, and Sir William Follett had at all points mastery over Dr Buckland. "What do you say, Mr Stephenson," asked Sir Robert, laughing. "Why," said he, "I will only sat this, that of all the powers above and under the earth, there seems to me to be no power so great as the gift of the gab.

In this extract is encapsulated the tension between the creativity flowing from technicity and the conservative force of pre-existing language. That the professional advocate with only a brief brief could carry the day says much about the power and evolutionary depth of language and the fragility of our grasp of technology.

3.4. Engineering

It is at this point that I wish to make an assertion: We are engineers. As a species, we make things. The two cultures is not a divide between humanities and sciences but between the social and engineering brain, between language and technicity. Galileo will be my example. For millennia our ancestors had quantified the behaviour of sun, moon and stars. The everyday perception that all the celestial bodies revolved around the earth, supported by a model described by Greek astronomer Ptolemy, had become a dogma of the medieval Christian Church. The sixteenth century saw the spectacle-maker's art co-opted to make high-technology maritime telescopes. Galileo backward-engineered and improved the technology to look at the heavens and check whether the heliocentric notion of celestial mechanics revived by Copernicus fitted the clockwork of reality. The capability to engineer an enhancement to the sensory capacity of the human phenotype enabled Galileo to see the detail necessary to validate the Copernican model.

3.5. Taboo

Galileo's subsequent involvement the Inquisition further illustrates how language and technicity interweave. He wrote a letter that attempted to square the Copernican view with the Bible. But, the Bible is also a product of technology: It is written. Writing is a collection of technologies that provide an external memory to note certain information carried in speech. The record, in the main, is of the names of entities, real and imagined, their attributes and actions. Because language is a highly complex biological adaptation intimately intertwined with the social brain, this record is suffused with interpersonal and social relationship. Where technicity offers a multitude of creative alternatives, the social brain seeks to manage risk. All societies stabilise themselves by adopting a semi-consistent set of social rules and myths of origin. The maintenance of these is usually assigned to selected individuals: a priesthood to provide interpretation. Galileo went wrong when he crossed over from using technology to interpret reality to applying his novel perceptions to re-interpreting the Scriptures: the province of others with a conservative remit. He challenged a taboo, and thereby stability, outwith his authority.

3.6. Big and little c creativity

The capacity to engineer, to create novelty, weaves its peculiar pattern into our cultural fabric. We all recognise Big C creativity, which tends to the patronage of power as in Galileo's case, and is associated with genius: Newton, Leonardo, and so on. But there is also the genius of the widget and the vernacular creativity of the domestic gardener, cook, decorator, dressmaker, builder, bodger and bricoleur that are seen in the ebb and flow of fashion. Logo is a product of this creative process: it did not emerge from a cocoon fully formed, but was rather a development of an existing product crafted for a new purpose. It is to this piece of little c creativity that I wish now to turn our attention.

4. Computer

Before I deal with Logo specifically, I need to establish a view of the computer which I consider to be fruitful. Recall the entscheidungsproblem. Kurt Goedel got half way to a solution by using a numbering system to show that arithmetic is consistent or complete but not both. Alonzo Church and Alan Turing followed through, demonstrating that interesting formal systems are undecidable. If this seems obscure, worry not. I want to draw your attention to the disparate methods (technologies) used: a numbering system, a formal calculus, and an imaginary machine. The later, Turing machine, is an idealised stored program digital computer. It reads, acts upon what is read according to rules in its head, and writes a response: like a mechanical mathematician. The Turing machine differs from a person in that its rules of thumb, its algorithms, must be made explicit.

4.1. External memory

The computer is: a development of the human external memory system that technicity has made possible. The mechanisms we make: telescope, cooking pot, or motorbike, are extensions to our phenotype. They extend our senses, food range, and mobility. We mislead ourselves when we talk of computers in terms of artificial intelligence. Just apply the same denotation to a motorbike: both extend our phenotype within mechanical constraints. My motorbike extends my motive power. My personal computer extends my capacity to execute algorithms. Both require a massive technological infrastructure for their deployment. Drawing and writing on a plane surface provides external data storage. To external data storage, a computer adds the external capacity to process data.

4.2. Literacy machine

To the extent that science provides us with data and algorithms, the computer can 'write down' any natural language, convert it to another natural language and 'speak' in it. The constraints of computability, the state of scientific knowledge, and the precision of the technology determine the quality and accuracy of translation. No aspect of this process differs from classic engineering. On a personal level, my PC makes my writing legible and my spelling correct, though I use keyboard rather than speech input. Far more interesting from a conventional literacy viewpoint, is that a PC can make text audible. In contrast to teacherly phonic skills, a so-called text-to-speech synthesiser lets children into the secret of which bits of speech get written down (Doyle 1986), and which don't.

4.3. Numeracy machine

The computer will do the sums that Pascal hated. A simple calculator will let children into the secret of how the numbers play with each other. I have two children. To my son, numbers are reliable well-behaved friends. To my daughter the digits are dancing dervishes. Neither child can understand the other. Learning number is not simple. Many children fail. The Hindu Arabic numeral system is a superb technology. European mathematics blossomed after its adoption. It is made for digital representation. Why not let children toy with the notation and its operators before we reveal that it is maths?

4.4. Social intrusion

Enter, stage left, the social brain. Within the social milieu that education sits, literacy and numeracy are highly valued – as is the learning a second language. But conditions apply. Literacy and numeracy must be learned traditionally, as a craft skill; and a second language must be academically acceptable (dead even). Thus, in reverse order, a second language cannot be one native to an immigrant community and machine translation software has no place in language teaching; a calculator is a convenience for use after mastery of the mental skill is achieved (and has no place in teaching number); reading, the most highly regarded academic skill, must be learned traditionally and (robotic) text-to-speech systems have no place in teaching literacy. These "basic skills," which almost define a social elite, have now been mechanised, as spinning and weaving were. Some in positions of power perceive this as an assault on the very fabric of society. Their response is to ensure that ICT is deployed to support learning, not to change it. And even then, children are not taught prerequisite skills. Children who will later use a computer at are taught handwriting but not keyboarding, so two-fingered hunt and peck.

5. Logo

We are now in a position to consider Logo, its past and future. First, we need honestly accept that Logo is a technology. Second, we need shed the philosopher's gown. By this I mean, unweave the effects of the social brain from those of technicity. In analysing Papert's complaint about School, the institution, let us be careful to accept that it is highly developed around the technology of text. Text cannot process information, only store it. (This is true of 'digital' technologies treated as text.) Logo is about algorithms.

5.1. Rules of thumb

In considering algorithms, I use Turing's (1952) wording as my sub-title. The algorithm has been a long time in the cooking (Berlinski 200). In language it's the active verb to the datum of the noun. In the world it's the actions, processes, events that affect the entities. It's the diffusion-reaction process that Turning (ref) was working on at the time of his death. It is the operations that we had to do in our heads if we couldn't devise a machine, e.g. a differential analyser, to do one for us. Drawing a line of a given length, a task almost impossible for a chimp, is one operation that we have machines (rulers) for; and for an arc: a compass. The Turtle can carry out such operations to command.

5.2. Turtling

Oh dear. Papert (1980) describes the now classic 'house' bug: a triangle and square are combined to make a house-like shape by a procedure that draws a square followed by a triangle. It goes wrong because children fall back on their shape-box notions of putting a triangle against a square: the shapes are explicit but the process of their juxtaposition is implicit. In Logo, children are expected to make explicit this process of assembly, without any of the post-natal acculturation that they have had to the shapes involved. A second so-called 'bug' is the use of 60 as an input in making an equilateral triangle. In this case we have a classic transfer of learning effect: children who have learned that the internal angle of an equilateral triangle is 60 degrees (an arbitrary number founded in pre-historic cosmology) they thoughtlessly use it in their turtle graphics procedure. The stage is set for systemic confusion between the Euclidean gestalt of the internal angle and the turtle's external turn. (I vividly recall being appalled by Hoyle's (1984) account of children using 88 as an input for right angle and then 'mystically' using double digits as inputs.) My own solution to children's lack of practice in making process explicit was to chop the top off my turtle and put on a pointer and protractor. Today, the successor to the floor turtle (and BigTrak) is a floor robot like PIXIE, which moves in units of its own length and turns through right angles. This teaches process explication.

5.3. And language

I fell into this elephant trap, as did Papert. Mindstorms has a chapter called "Languages for Computers and for People," which likens learning Logo to learning a language. I hope that my 2 intelligences construct is a convincing challenge to this. There is an unbridgeable chasm between language, an evolved adaptation, and the description of such a language. To do its job, language is required to distinguish between things and events, and their respective attributes. Technicity, our own peculiar evolved adaptation, enables us to describe natural language – as if it were a technology. We use language to describe language. Hence, the words used (descriptors) are culled from the storehouse of natural language. But the words so co-opted no longer live in the domain of natural language: they are technical terms. When we co-opt the word 'language' to talk about Logo, because the connotation is useful, we must be on our guard against the slide into denotation. Logo is not a language. Logo is a technology. Metaphors may mislead.

5.4. Environment

For any technological innovation to prosper, the conditions must be right. The lives of Richard Trevithick (Trevithick 1872) and George Stephenson (Smiles 1857), the former preceding the latter by but a decade, is instructive. Trevithick developed the integrated high-pressure steam power unit. He prototyped road, rail and water steam powered transport. In Cornwall, where coal was scarce, horses that ate hay and oats were more economical. He went up to Northumberland to build a railway engine, and had tea with George Stephenson. But that came to nought. So he sailed for South America to (fail to) make his fortune. In the meantime, the Napoleonic wars had hugely increased the cost of horse fodder. So, back in Northumberland where they mined coal and steel it was economic to use both materials to construct railways to move those same materials to market. This enabled both the technology with its supportive infrastructure and the new human skills to develop to a point where the railway boom was possible. Now transfer this scenario to education. We can see that by the 1980s we were hardly at the 'Stockton and Darlington' stage. Add an educational culture that is immersed in text and sees no reason to change – cf. the English National Literacy and Numeracy strategies of the late 1990s – then it is doubtful if we are there yet. There are signs of change, however. Traditional teaching is not improving standards. Computers are now consumer goods. Homes have more powerful machines than schools.

5.5. Diverse talents

In considering children, teaching and learning, I take the part of a participant observer. My participation in education is as teacher of children with diverse learning difficulties. I work to individual's strengths and work-around their weaknesses. My fellow teachers I observe trying to bring a class of diverse children up to a required standard; the while trying to enthuse them with a love of their particular subject. That there is the need to segment learning into subjects, and the finding that some teachers are better at some subjects than others, should cause us to stop and ask questions about diversity beyond the ethnicity of the pupils. School and the classroom, systemically, is an instrument of social cohesion within which individual personality must negotiate its place. It is also the nursery of technicity: here children prepare themselves to contribute their addition to the store of human knowledge. Hence, it is where the social brain and technicity meld.

5.6. Next steps

From my perspective, there was a moment when Logo offered to escape from the thrall of Maths and Turtle: when Brian Silverman developed LogoWriter and Bojidar Sendov produced Geomland. Both offered a route away from the circularity of Turtle Geometry into the wider world of algorithmic thinking. Both Microworlds and Imagine continue these trends to some degree, as do object-oriented implementations such as multiple-turtle Star-Logo. However, none address the fundamental issue: Writing algorithms for implementation on a stored program digital computer is a new skill. How do we best help children to learn this skill, given that teachers have never learned and/or taught it? This is a hard question to answer. School and its institutional infrastructure cannot help because it is book-bound. Curriculum may be an obscenity to constructivists and constructionists but from where I stand it is simply the task of engineering a learning environment. Given that teachers can have little understanding of algorithmic thinking, they need help. Fortunately, though teachers are not maestros they can help children to learn to fly. To do this they need an instruction manual so they can stay a page ahead of the kids, at least to start with. We have laid a firm foundation on which to build, but we should explore the world beyond Mathland for the design and materials of our house.

6. Conclusion

An evolutionary perspective has helped unweave our humanity and the dichotomy that underpins the ‘two cultures’ perception: recent complementary adaptations. The first is language and the social brain; the second is technicity and the constructive brain. The latter enabled us to construct our external memory system: initially for data only but latterly, with the advent of the physical Turing machine, for active algorithms as well: Logo is for creating algorithms. The social brain and language add a persuasive conservative caution. The social brain requires reassurance. Language needs to find words to express the new, against which it will be used to argue. Timeliness is vital to a novel enterprise, as is the context. I have argued that Logo was launched too soon and in an unfortunate domain. The evolutionary scene I have painted may inform a relaunch.

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