

Logo: an object to think with

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Abstract

When Logo was first developed it had no Turtle and was seen as an aid to learning mathematics and a means of introducing adults to computing. Seymour Papert failed to see why children shouldn't program computers (rather than being programmed by them) Logo came to school.

In this piece I aim to turn turtle on the Turtle and treat Logo, or rather what happened in school with LOGO, as an object through which to think about human learning and creativity. But most of all, given that we have no conception of how it is that humans can draw, I want to address the question concerning graphics.

My Turtle came to school in 1983 without Logo but with a BASIC implementation of Abelson & diSessa's Turtle Graphic commands. I liked neither the Turtle, reduced as it was to a graphics plotter nor the computer – speechless with the typewriter keyboard that school had previously rejected. Working with the kids in my class we soon had a set-up that helped them learn. This was achieved by creatively changing the technology (fig A1). It didn't catch on.



Figure A1. Topless Turtle

After a number of years, it became very clear that LOGO in school was all about drawing with the Turtle. This was followed by graphics in MicroWorlds, Imagine or MSW Logo. Why graphics?

It is very difficult to notice something that is not there. So, it was a number of years before I fully appreciated the import of the absence of knowledge about drawing. It was a trifle difficult to research a field in which there is not any knowledge. It was only by researching language and its evolution that I began to understand why drawing was so important. All the artefacts that steadily advanced technologically after we evolved are assembled from simple geometric components: Hence the question concerning graphics.

When I enquired into how children drew; the question arose: From whence comes the data?

The search for data and its processing led me to Darwinian evolution, feature neurons, the silent prefrontal cortex, the nature of children's drawings and why a square becomes a diamond when rotated. The outcome is a notion of how humans are creative and why technology is intellect.

Keywords

LOGO, Logo, Turtle Graphics, drawing, evolution, language, brain, learning, creativity, school

Introduction

In England, there is a national shortage of teachers who can take the lead in ICT in the classroom. This is despite, or perhaps because of, a quarter century of Government investment in the use of computers in school. A part of the problem is that ICT is skills-based, with little or no intellectual content. Given the importance of the Turing machine for developing our understanding of matters as fundamental as the origins of the universe and the nature of mathematics, this seems perverse.

Unfortunately, the programming of computers – writing for a Turing machine – is not considered a mental skill like mathematics or language literacy. The curriculum of our schools emphasises capability: the practical skills that 'Capability' Brown celebrated in landscape gardening rather than the scientific enquiry into things natural that was the foundation for Darwin's speculations.

The source of this approach to ICT is the character of learning and teaching. Education is the exercise of craft skills and technique within a well established, print-oriented, knowledge-based, conceptual framework. Here, the computer, as evaluable writing, has no place. Its role is as a magic cupboard brimming with classroom resources. The interactive whiteboard is the apogee of this gadget oriented, class teaching, approach to ICT in School.

The present approach to ICT contrasts with the child-oriented group-work classroom into which Logo was first introduced. The change in ethos and organisation was initiated in England by the British Government in the form of the English National Curriculum (Graham 1993); and then consolidated by a target-driven approach to educational outcomes. Logo should have been, and could yet be, the counterpoint, but aspects of the early promotion of Logo brought it into concert.

I would like to rehearse some of the early history of Logo (in the UK) and then take a step back to reflect upon some initial findings of the pioneers. Thereafter I ask a rather different question about how human beings learn, one more in tune with technological fluency and construction.

A little history

As Margaret Thatcher came to power in the UK, Seymour Papert published *Mindstorms*. The two had rather different ideas about education. Margaret Thatcher imposed the English National Curriculum. Papert was less dogmatic: he wrote of the LOGO Turtle as an object to think with (1980:11). He likened it to the physical gears of his childhood play, which helped him visualise his maths. This gave him the notion of a mathetic (1989:39), learning, microworld. Papert's ideas were attractive to the English primary education tradition, which at the time, influenced by Piaget, was child-centred and revolved around group-work within an integrated school day. The manner in which "LOGO" entered the classroom was nicely described by Anderson (1986), who brought out the two major strands: Turtle Graphics and Control.

Control evolved into LEGO®/LOGO and the RX brick. It forms a separate strand, both in Logo and school-subject terms: mechanics as opposed to mathematics. Its intellectual home was MIT.

The route to "LOGO" in school began with a programmable toy: the Milton Bradley tank *Big Trak*; followed by the Floor Turtle; and finishing up as an arrow the screen. This remains basically so today. The Valiant *Roamer* and *Pip* and *Pixie* from Swallow Systems have replaced Big Trak and Floor Turtle. Computer generation children find a screen turtle, now turtle shaped, easier.

Logo vTurtling

The most notable aspect of Anderson's (op cit) survey was the discussion of the relative merits of a full (sic) Logo over a Turtle Graphics package. This was not trivial, because it went to the heart of School's approach to the computer. The Logo that schools were offered was very different from the Logo originally devised by Wally Feurzeig (undated) at Bolt, Beranek & Newman or McArthur (1980) at the Edinburgh University DAI the late 1960s and early 1970s.

This Logo is to be found in Harvey's (1985, 1986) three volume *Computer Science Logo Style* Goldenberg & Feurzeig's (1987) *Exploring Language with Logo*; and somewhat in *LogoWriter*.

Logo, as it came to school, was about the aspects of shape and space that the new *Turtle Geometry* (Abelson & diSessa 1980) explored. As these authors explained, Turtle Graphics packages could be written in any computer language – they noted Pascal and appended an implementation of their Turtle Procedure Notation in BASIC, whilst remarking that their notation was very close to Logo. Papert's (1980) seminal work *Mindstorms*, with a Turtle on the dust jacket (fig.1) and the title "Turtle Geometry" for Chapter 3, set the scene for School.



Figure 1. The illustration on the dust jacket of *Mindstorms*

Personal history

This is how I, as a teacher of children with learning difficulties, was introduced to Logo. I already had a BBC Microcomputer equipped with a Star Microterminals *Concept* (overlay) keyboard and a *Votrax TypeNTalk* (text-to-speech synthesiser) because I didn't want my kids to fight with a typewriter keyboard and text-to-speech could help with beginning reading – but that is another story. So, my Edinburgh Turtle came with *DART*, at Turtle Graphics package, modelled upon Abelson & diSessa (op cit) and written in BASIC. This was presented to me as "LOGO". I had great fun making my Turtle talk and designing overlay control panels for the kids to work it with.

I was not entirely new to the notion of the Turtle. In 1969 I had been introduced to William Grey-Walter (1961:113), the designer of its precursor, a cybernetic tortoise called *Machina speculatrix*. Hence, it is unsurprising that my approach to Turtling as a teacher of children with special learning difficulties focused both on its cybernetic character and communication possibilities.

Out of the box, my 1983 Edinburgh Turtle was little more than a mobile graphics plotter, which was a disappointment. Furthermore, unlike the structural apparatus I was used to, it gave little help to the children. Why, I mused, were they to be restricted to the geometers 360° notation when I was teaching points of the compass, the time, and fractions? Why were children expected to 'discover' what numeral sequences related to which distance and turn when I had protractors and rulers to hand? And for children who were uncertain about their left and right, why was the colour coding strategy I used not encouraged. I decided that maths teachers were a very odd bunch. So, I cut the top off the turtle's dome and replaced it with a platform on which to mount a protractor and pointer. The children drove it around a model village using an informative overlay for control with the computer 'speaking' the commands entered so that the child guiding it could monitor the instructions it had been given by his or her partner (fig.2a).

Interested in combining Control with Turtling, I devised a much modified Edinburgh Turtle (fig.2b) that had 'senses' of sight, sound and touch, and which knew which way to turn and by how much when the pointer was rotated to its new heading. All great fun! Annaturtle had her début at the first (proceedingless) Eurologo Conference in Dublin, where she blew up a BBC Microcomputer. (We only use it for word-processing.) There is a short description of both in Denis (1992) and a longer one in Doyle (1886). None of this work used Logo, just a hacked-about *DART* package.



Figure 2a. Two of my 1984 class driving our Topless Turtle

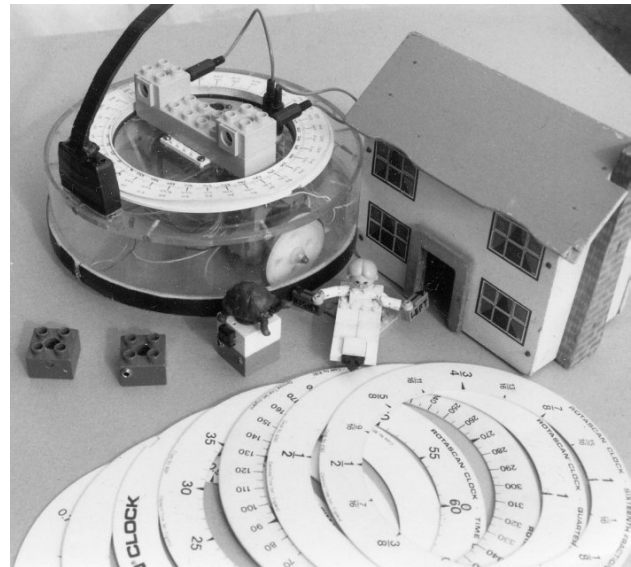


Figure 2b. The Turtle in its Dublin form

Logo and the Turtle were as disjunct in school as the authors of *Turtle Geometry* had asserted. It was only when I came to use *LogoWriter Robotics* that I, and the children I was teaching, had real need of Logo's LISP heritage. Even then, I found an overlay keyboard (LCSI interfaced a Concept keyboard) a far more informative interface to *LogoWriter* projects than the computer keyboard – a problem later solved by the advent of mouse and on-screen graphic environments.

Did the Turtle do for Logo?

The Turtle and Logo are disjunct¹. When you look at the research undertaken on Logo (Hoyles & Sutherland 1984) and the materials produced for schools (Blythe 1990, The Advisory Unit 1990, SMP 1990), it is obvious that the Turtle with its drawing capability had educationalists fascinated. But it is more than the Turtle: the Turtle is told, is programmed, to draw. The Turtle is an object to be taught to draw geometric shapes and childish drawings: in the name of mathematics.

The same has been true within the Eurologo community. At least four conferences featured the Turtle on the cover of the Proceedings; and Geomland, an honourable exception, is graphics-oriented. Of course the Turtle is a totem, a symbol; as the flyleaf photograph of Papert holding a live one demonstrates. But of what so humanly important and unique is it a symbol?

We have been held in thrall by this ancient shelled metaphor. And it has distracted us from the original notion of Logo as a notation for helping children 'teach' the computer rather than being drilled by it. The proof that we have let 'writing for the computer' fall by the wayside is the growth of graphic devices, point-and-click, and dialogue boxes relative to the effort put into making the editor helpful; LogoWriter an honourable exception. Comenius Logo, and Imagine, embraced the

¹ Such was the confusion over just what 'Logo' might be – confusion compounded by another rather less than Classical Greek usage of 'logo' to denote a graphic device or emblem – that Turtle Graphics packages were marketed as Logo without qualification. Consequently, in England, the term "Logo" may now legally be applied to any Turtle Graphics package (NYCC 1993) written in any computer language

graphics of the screen by including shapes (rather their names) in its list processing capabilities and then facilitating the direct manipulation of lists of graphics in the LogoMotion shape editor. So, what is it with graphics?

The question concerning graphics

Before I try to answer this question, I will take a short detour into language. Papert, immersed in an Artificial Intelligence culture that was highly engaged in language processing, saw computer programming as “talking to your drawing” by using TURTLE TALK (1980:56). The best way, therefore, to learn Logo was the immersion method used to teach a second natural language. And this, undirected, structured by the microworld, approach was that adopted in schools. All the research cited assigned great importance to the quality of discussion engendered by Turtle Graphics. But a computer language is not 'speech' and nor is mathematics: both are graphics.

The evolution of speech

Our capacity for speech is a Darwinian adaptation that evolved over the two to three million years it took our species to evolve (Pinker 1995). The suite of physical adaptations include finer control over breathing and the oral cavity, and a descended larynx; plus finger and eye pointing. Two parts of the brain, Broca's and Wernike's areas are associated with productive and receptive language respectively (Carter 2000:21). Palaeontological evidence, taken together, situates the emergence of a modern language capability with the common ancestor of our species and the Neanderthals, about half a million years ago (Dunbar 2004:122, Leakey 1993).

Dunbar (1996) suggested that speech evolved from primate grooming to provide for community cohesion in larger groups. This rather begs the question. For what reason might speech be a successful adaptation? Trivers (1977, 2002) proposed an evolutionary driver: reciprocal altruism. This individual strategy can only be successful in a defensive culture of cooperation; otherwise defecting free-riders become ascendant. Such a culture makes high cognitive demands: good memory, recognition of self and others, and sanctions on defectors. Communication is the co-operator's defence and defector's weapon. This leads to a linguistic arms race (Nettle 1999).

Language evolved for gossip and negotiation. Linguists (Burling 2005) note that hunter-gatherer conversations revolve around debts and relationships. Practical instruction in tool use is restricted to “Do it like that”. Language is spoken and heard. We carry the necessary equipment around in our evolved bodies. Where the language function fails properly to develop, as in certain autistic children, much of what we consider human vanishes with it.

The language trap

In concert with Papert, and most academics and philosophers, I fell into the language trap.

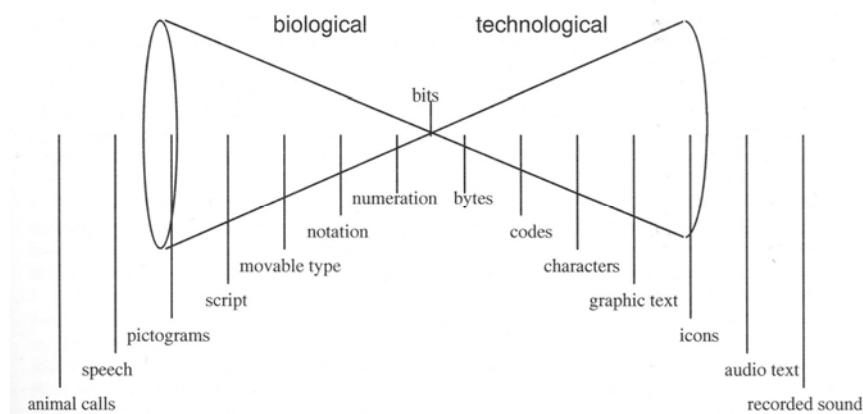


Figure 3. The Athens Language Cone

My Athens Eurologo2003 paper included what I called the “language cone” (fig.3). Looked at today, it clearly has little to do with language and more to do with what we use language to talk about. I mistook the medium for the message.

My error became glaringly apparent, as I read more about the evolution of our species. The very earliest date for the appearance of modern technology: component-built tools to flexible designs using material to hand was a quarter of a million years ago (McBrearty & Brooks 2000). Before this artefacts were a phenotype extension constructed to an inbuilt template, like a bird's nest.

Graphics is unique to our species: our evolutionary adaptation. The archaeological and genetic evidence converge on a central date of about one hundred and fifty thousand years ago in Africa or its, and our, emergence. All the elements I placed in the Language Cone are graphic-based.

The Bugged House

Both Mindstorms and Turtle Geometry open with a discussion of bugs, errors in thinking. Papert (1980:14) emphasises the Bugged House (reproduced as fig.4a), whilst Abelson & diSessa (1986:7) choose to give the Triangle Bug (reproduced as fig.4b) pride of place.

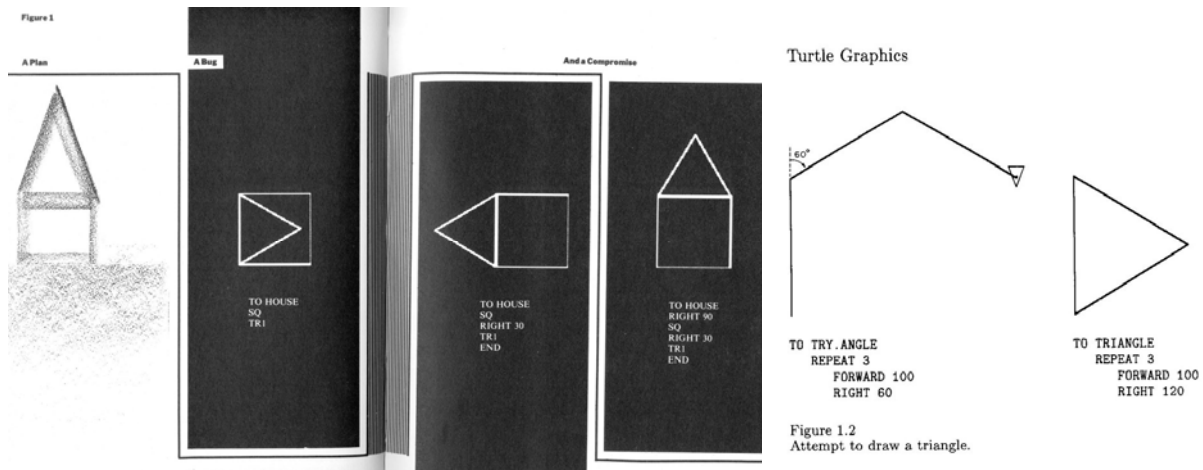


Figure 4a Papert's Bugged house

Figure 4b. Abelson & diSessa's Triangle Bug

In the case of the Triangle Bug, the authors considered transfer knowledge of internal angle from classic geometry to be the cause: the Turtle turns through the external angle. For the House, the bug is a failure to keep in mind the position of the turtle and its heading. Two solutions are proposed. Walking and talking Turtle (body geometry); and encouraging children to understand the need for an 'interface' procedure. Thus was any conflict between a Turtle Geometry of paths in space and a Euclidean Geometry of Platonic forms worked around.

When Sendov introduced the Plane Geometry System (Filimonov & Sendov 1989), later called Geomland, the psychology of the two systems of representation could be considered in a Logo context. Sendov's point, line, and arc were mechanical objects, the products of a metaphorical compass and ruler: live things that could be animated into mechanisms, not just a dead trail.

Children and shapes

Children begin by stacking blocks, cubic blocks. How less natural a form than a cube? Houses are triangular blocks on top of square ones. Children assemble components: bricks, wheels, gears, motors, and sensors. The 'interface' – picking up a suitable brick and transporting it to the appropriate location in an appropriate orientation – is not a part of the mental plan. The 'named' procedure of Turtle Graphics denotes the form. Procedural arrangement is cognitively different

The Triangle bug occurs only where a shape is to be drawn and the apex is associated with “60”. The bug never happened in my set-up where the pointer on the turtle was physically turned to

the new heading. The context influenced the response, as has been noted with Piagetian tasks. The findings from Gestalt psychology, and Mme. Montessori, all point to there being something very fundamental about Platonic. The very earliest 'modern' component-built technology entailed the replacement of flakes off a core by retouched geometrics (McBrearty and Brooks op cit).

Squares and Diamonds

Below is a 'bug' known to all mathematics teachers. In Turtle Talk: 'sq' and 'left 45 sq' (fig.5).

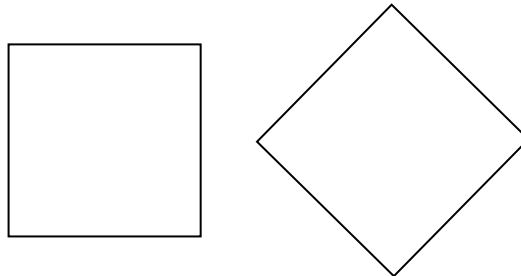


Figure 5. Two shapes.

You can carry out the experiment very easily – a restaurant table napkin is a good object. Hold it up and rotate it. All will agree that it is still called a napkin – our perceptual capacity to maintain object constancy – whatever its orientation. If you hold it with the edges horizontal and vertical, all will confidently announce that the shape is a square. Rotate it one eighth of a turn, however, and suddenly it has another name: diamond. This phenomenon is not peculiar to English. Humans see a different shape when a square is rotated. (One said “triangle” for the diamond.) The conundrum is why.

The silence of Psychology

We have no idea how human beings draw. The science of human behaviour, classical, e.g. Gross (2001) or evolutionary, e.g. Barrett et al (2002), is silent. Gregory (1998) demonstrates our susceptibility to illusion with a plethora of illustrations, the genesis of which is unknown.

The failure of psychology to consider the behaviour that makes technology possible is made all the more poignant by the decision of graphic designers to use prehistoric cave paintings on the covers of Gaulin & McBurney (2001) and Dunbar (2004). The latter cites the work of Lewis-Williams on shamanistic rock art. He found that trance-induced hallucinations can be similar to geometrics like those on the walls of the caves at Lascaux. This does not provide enlightenment on the evolutionary 'how' question. On the other hand, it is interesting in the light of the failure to teach a language-using chimpanzee the art of joining dot-to-dot (Inversen & Matsuzawa 2001), which we may compare with their skill in direct manipulation and use of stone tools to crack nuts. But in general a look at the index of any introductory psychology text will confirm that drawing appears to have been forgotten since the Harris-Goodenough “draw-a-man” test fell into disuse.

We have some idea how graphic capability develops in childhood (Cox 1992 Anning & Ring 2004), but this tends to be from a representational art perspective. We also know that our drawing adaptation develops after speech. It is profusely displayed on the wall of elementary classrooms. Below (fig.6) is a collection from the three to four year-old age range.

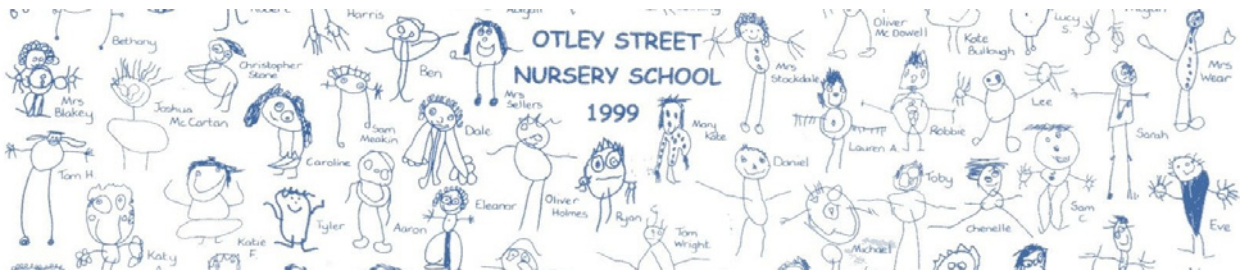


Figure 6. Children's early drawings.

This form of drawing lasts into adulthood, as a pioneering engineer's sketch (fig.7) shows.

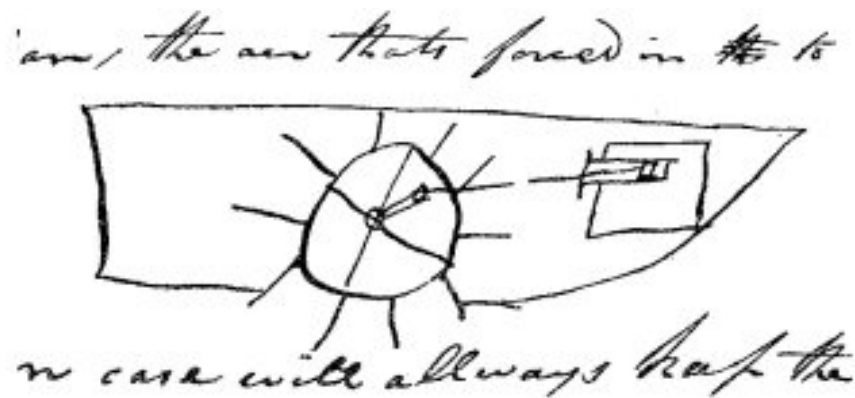


Figure 7. Richard Trevithick's 1806 sketch for a steam boat

The lower illustration is not a representation but a concept. What of the children's drawings? From whence comes the data for these figures? The image at our eyes is nothing like these drawings. The natural world is all irregularity. So why are the drawings composed of geometrics?

Data

The question is the classical philosophy question about the origin of Platonic forms and the redness of red. The experiment with rotated squares points to a source of data in the brain. Our brains are mammalian, of the primate variety (Carter 2000). Compared to reptiles, mammals have additional nervous tissue which confers a greater capacity to recognise the environment, learn from experience and communicate. The brain decomposes sense data and stores it.

The way incoming data is analysed into discrete features was determined by Hubel & Weisel (Hubel 1995). Lines (edges) of different inclination excite specific neurones in the primate cortex. Thus, our square in its two orientations will produce separate and distinctive neurological activity. That we name these two sensations differently tells us that we somehow know this.

The most significant difference between our species and *H. erectus* and *H. neanderthalensis* is that we have a much larger prefrontal cortex (Leakey 1993 Stringer & Andrews 2005).

The 'silent' brain

Highly connected to older parts of the brain, which it dominates (Deacon 1998:265), activity in the prefrontal lobe appears unspecific. The prefrontal neurones seem to 'live off' the data from the older parts of the brain. This was adaptive in a species with a reciprocally altruistic lifestyle.

The square/diamond experiment suggests that the 'new' brain has access to the earliest stages on visual processing. The evolution of the prefrontal cortex appears to have given access to a 'knowledge of line' that is embedded in the nervous system. A consequence is that we can draw. The very character of children's drawings, once infant's limited fine motor control is allowed for,

is geometrical: points, curves and straight lines assembled to represent the major engineering features of the human figure. The same is true of children's house drawings – and Trevithick's boat. Writing is also a collection of geometric forms, later run together in adult scrawl.

Feature neurones extend beyond simple shape. They abstract colour and sound: the atoms of art and music; and they also abstract movement. With movement, the sense data goes beyond the expressive capability of speech. For all that an infinity of utterances is possible, language is only able to 'name' entities. Movement can only be spoken of. It takes a Turtle to express movement and the Turtle is a machine, as is the computer within which it resides as data.

Data alone is not sufficient, it has to be processed. It appears that our prefrontal lobes may function as a creative workspace where atomic features can be combined to produce entirely novel data. Exported to the natural world, this would alter the sense data input, and thereby expand the database. The process is recursively creative leading to a capability to improve and redesign artefacts and transform natural materials in a manner radically different from primates.

Education

With this source of internal atomic data in mind, we can begin to look at what education does. The first step, however, is to take as read the prior evolution of the human social lifestyle and language. Schools, as institutions, place much store by language development, socialisation, and equity. The latter reflect the lifestyle of our species, with an ever present tendency to defect; language is the capability we deploy to negotiate within the cooperative/selfish social milieu.

Default to speech

Because we arrive in school speaking, it is an easy option to redirect the graphic elements that emerge in our earliest drawings into graphemes. Deeply embedded in our social structure is the ethics of reciprocity; the wariness of strangers; the fear of defection; and our inherited primate troupe structure. The gossip that serves us in these settings, once creatively recorded, becomes the literature and stories that hold us in thrall. Writing stories is the easy option in school. The effect selects for amenable aspects of mathematics: computation is the most obvious. Learning 'number' by oral methods fits the default-to-speech mould. Speech offers School an entrée. It offered an entrée for Turtle Graphics on the grounds that Turtling encouraged group discussion.

Education, it seems, is at the same cultural stage as philosophy: Sussure's 'langue' our crowning achievement as a species, the while begging the question of how we are able to speak about it.

Default to speech, "speaking computer," has led to intellectual problems elsewhere. An area close to my heart is text-to-speech synthesis. Production of intelligible synthetic speech from text by grapheme-phoneme mapping is straightforward. But our Pygmalion tendency made a natural sound the goal. When computing prosodic features proved impossible: the work-around was a large speech database. Speech engines like those for Imagine obscure the graphics of text by introducing the schwa and elisions to mimic speech. We lost an educational entrée to writing.

Graphicity

Although the neural mechanism I have hypothesised can access all sensory areas – hence we can colour and make music – it is the graphic capability that education, and our success as a species, makes most use of. From a social viewpoint, a mark has the merit of setting in stone the spoken contract. But more importantly graphicity is the entrée to technicity. Once we are able creatively to generate non-extant images, we are able to plan construction.

The entities we call 'symbols' are constructions. We can assemble systems of graphic creations to perform many tasks. The 'words' of speech may be recorded using grapheme-phoneme mapping, as in Korean. They may also be represented independently of any dialect, as in Chinese – which may be 'read' in English. Numbers and their manipulation may be represented mechanically, as on an abacus, or graphically as in the decimal system. Construction can be

carried out by bricolage manipulating the materials directly, or graphics can be used to plan. A drawing may be a geometrical exercise or a blueprint for a construction, static or mechanical.

From the Logo perspective, the atoms of graphicity accessible within our brain led, after about one hundred and fifty thousand years of recursive constructive refinement and elaboration, to the electronic stored program digital computer and its mathematical counterpart, the Turing machine. This has taken the graphic medium into a new phase where the graphics may move. It is for this reason, I believe, that the Turtle held in thrall a profession that could not understand.

School's dilemma

The schooling versus learning debate in education is more than a philosophical one. The former capitalises on our superb memory and language; adaptations that evolved in precursor species. The latter accesses internal data and creatively constructs; and is founded on our own peculiar adaptation. The former guarantees a goodly supply of 'internal data' but mainly in linguistic form. The latter runs into trouble with differential access to data, its availability and validity. Thus, our social heritage of speech and superb memory is counterpoised a recent constructional creativity.

The academic, language-based approach is institutionally more reliable and standards can be set and performance assessed using written essays. The constructional approach demands projects and portfolios, is idiosyncratic and difficult to assess to common standards. However, in an increasingly technological world, verbal fluency is not adequate we need to be technologically fluent, as Papert put it (LCSI 1999). Our species cannot 'write' itself out of global warming.

Discussion

Logo, as promoted by Papert, never was just computer programming for kids, although it is that. It carried a philosophy derived from Piaget and formed in the image of MIT. This philosophy carried a view of learners that went beyond concern for equity to self-realisation and autonomy. This approach resonates with the concerns of a teacher of children with learning difficulties.

However, from the same perspective, philosophy is inadequate: it is pre-scientific. Philosophers weave words in an attempt to understand through language. Evolutionary evidence suggests that language does not have the intellectual power required: it evolved for other ends. We need good science behind our educational practice (Piaget 1971) rather than a craft and tradition from pre-computer eras. A 'philosophy' (Logo or otherwise) is not the way forward.

In this piece Logo has been taken for what it is: an object to think with. The history of the Logo project tells us that the computational is not understood in education. Logo projects, exciting at germination, have not flourished: the institutional ground was too stony. It is impossible to cause a system change without good scientific evidence. This the constructionist agenda has lacked. In looking at Logo as an object and asking the question concerning graphics we can begin to build the necessary scientific base. But in so doing we need to recognise that the intellectual power of science is in the technology that we create to extend the capabilities of our gene's phenotype.

The Darwinian perspective deployed here was founded in graphic data. This perspective, by the observations and conclusions it has guided, has produced a body of evidence that enables us firstly to challenge the primacy of language; and secondly – given the economic cost of the silent brain – to suggest a mechanism for creativity and argue its fierce intellectual power. This notion is not directly supported by evidence. It was developed from the problem of explaining how we are able to draw, why children draw as they do, and why a square becomes a diamond. The part of the brain that enlarged hugely in our species alone, has access to the database of the older primate, mammalian, brain. Given that we are able to isolate atomic perceptual data, the idea that Darwinian processes drove the adaptation of creativity into technology does not run counter to our understanding of evolution. All that is needed is the realisation that the genetic event that caused the step change from reptilian to mammalian brain structure – a step that proved adaptive – could occur again to further increase data processing capacity; if it proved adaptive.

There is a new balance to be struck in school. Present practice elevates elegant language above other 'subjects' whilst it relegates technology to the utilitarian or to decorative arts. Science, a subject that bridges language and technology does have a reasonable status in school, third place to language and mathematics. But this is a recent phenomenon, a product of the pressures of the process of industrialisation. But neither science nor stories would exist if we did not have an evolutionary adaptation that enables us to create and then refine our creation.

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