Towards Turing Teaching

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Abstract

The technicity thesis and its T/V concept quality division is applied to education and three modes of learning, based on the medium used, derived. The medium of the mode designated Turing, has the computer as its medium. Primary school, being both the foundation and cognitively the most complex phase of education, is considered from traditional and Turing teaching perspectives. Proto-Turing practice is exemplified. Given that current method is inefficient and abusive, and transition to Turing teaching is inevitable, an approach method development is suggested.

Keywords (style: Keywords)

Technicity, teaching, primary school, concepts, mode, medium, method,, Turing machine.

Introduction

The relationship of computer technology to teaching in schools is confused. The commonly used term “ICT” (information and communication(s) technology) has been unhelpful and was recently roundly criticised as meaningless by the Royal Society (Furber 2012). The Cambridge Review of Primary Education (Alexander 2010) also found great difficulties with this curricular area. The author has always viewed such terms as administrative language, preferring to see the computer and its associated technologies as a new teaching medium with novel capabilities. Given that this medium can also emulate extant media, a term was required that clearly specified teaching that made use of the new capabilities. Given that, conceptually, the learner is interacting with a Turing machine, the term “Turing teaching” was proposed (Ó Dúill 2011a).

When a new term is introduced it is essential to try and make its meaning is unambiguous. For Turing teaching which uses Turing media, disambiguation is achieved by reference to the concept of technicity and the two qualities of concept that flow from this neurological adaptation. Technicity as a concept has been developed in the Eurologo/constructionist community (Ó Dúill 2010), reaching its final form in a companion paper submitted to Constructionism 2012.

On this foundation a sound, scientific basis for education may be built. This includes recognition that:

- the primary phase is cognitively the most complex and that, at present, deep understanding resides only in the unarticulated expertise of the primary school teacher;
- medium and method have a specific relationship with mental processes, which determines learnability and, where concepts collide, may be a cause of cognitive confusion and conflict;
- positive affect is crucial to the educational process: dislike signals cognitive difficulties.

Three modes of education are derived from medium considerations; two extant, the third Turing. These offer a new perspective on some well known difficulties that inhibit development of both literacy and numeracy; and challenge certain strongly held views and constructivist approaches.

With these considerations in mind, the character of Turing teaching begins to emerge: working with a medium that has the capacity to be attuned to the workings of the mind and thereby offers a more conducive, less oppressive educational experience. This notwithstanding, Turing teaching has prerequisites: the basics are outlined and exemplary practice identified. These considerations throw into sharp relief the difficulties, conceptual and practical, that transition from traditional to Turing medium in (primary) school entails: a challenge not posed for over six millennia.

Technicity

The technicity thesis proposes that the human capacity for technology came about by a very small extension of connectivity between prefrontal cortex and the rest of neocortex. The evolutionary history of hominines involved a large increase if brain size, reaching a maximum of some 1400cc in the Neanderthal. A significant factor in this increase was relatively greater enlargement of the prefrontal area, which is the site of working memory and has an executive function. It is the seat of creativity, gathering information from memory (other neurone circuits) and recasting it in a process of exploring alternative plans of action. It modulates and modifies the actions of older parts of the brain. This modulation is achieved by the massive invasion of most other parts of the brain by prefrontal neurones. Note that the evolutionary process of prefrontal expansion and invasion has no teleological aspect. Neuronal expansion, like any other cellular rebalancing will become genetically fixed if and only if, post facto, it is adaptive. For neurones this means that for any expansion to become genetically fixed the information prefrontal neurones source from the rest of the brain must turn out to be useful to the organism. An extension of this invasive process to primary sensory cortex is proposed by the technicity thesis.

Information quality

Certain areas of primary sensory cortex are particularly interesting because of the quality of the information structurally embedded in their neurone circuits. Information may be incorporated in neurone circuits for two purposes: instinctive behaviour; and processing sensory information. The former has a level of complexity commensurate with the environment. The latter reflects the way the sensory system processes incoming information. This processing proceeds by reconstructing the environment from inbuilt elemental information. This is obvious once it is understood that, for example a photon reacting with a receptor in the eye results in a nerve impulse. The correct interpretation of this impulse, formally equivalent to a symbol on a Turing tape, requires the nervous system already to possess information about colour in order to match the incoming symbol and reconstitute its physical referent. Because the nervous system is built on information about properties of matter available to the genome, these computational units express genomic information; in the example, on photon frequency in the visible light range. By extending their range of information sources to primary sensory cortex, prefrontal neurones opened a window onto the information possessed by the genome, as expressed in the neural processing system. This information is simple in form and therefore of far lower entropy than the environmental input to the sense organs so, by definition, more powerful. Some of the information available at primary sensory cortex, from which technology and art are constructed, is listed in table 1.

Colour	Line	Motion	Pitch	Chemical
Pigment Art Spectrum Photons	Shapes Architecture Symbols Geometry	Projectiles Choreography Machines Entropy	Tone Music Time Relativity	Flavour Cuisine Molecules Particles

Table 1. Some sources of genomic information expressed in neurone circuits and behavioural correlates.

Note the relationship with the aspects of child development so clearly seen in kindergarten and absence of a direct link to language.

Provided that an organism can make use of this information in a way that proves to be adaptive, the genetic organisation that underpins it will be retained. It is self evident that this has proved to be so for the human technicity adaptation.

Two qualities of concept

The information available at primary sensory cortex is very simple. From the image of a tree at the eye, a complex percept is created. From simple straight lines at different angles sourced from the so-called feature detectors, a simple form like a square may be constructed. This concept may be superimposed on the environment to organise it. For example, a square may be folded from a roughly torn piece of paper. However, this form has characteristics that differ from that of a tree. A tree leaning at a forty five degree angle remains a tree. Rotate a square by the same amount and it is perceived as a different object: a diamond. This indicates that there are two routes to concept formation, leading to concepts of differing quality.

The first, characterised by the square/diamond, is the normal perceptual route. Such concepts are naively congruent with the environment, and of commensurate entropy. Expressed with language, with which they co-evolved, they are socio-perceptual. Vigotsky described this route to concept formation, including its associated internalised speech. The term V-concept is used to denote it.

The second, characterised by the ideal square, is the technicity route. In this case the information source is genomic information expressed in neural structures and directly accessed by prefrontal cognitive processes. The concepts are prefrontal creations unconnected to perception or language. The simple elements from which they constructed are of low entropy, commensurate with that in the genome, and thereby they are powerful relative to their perceptual counterparts. In describing the eponymous machine, Turing was employing this mode of conceptualisation. It is the source of troubling notions such as Platonic ideals and counterintuitive scientific theories. Derived from the technicity adaptation it is uniquely human and expressed as inspectable physical constructions. The term T-concept is used to denote it.

The crucial difference between the two is that, whilst a V-concept may be accepted because it has internal linguistic consistency, T-concepts must be shown to be consistent with the behaviour of the physical world; to which technicity uniquely provides the human with cognitive access.

Three modes of education

The technicity adaptation, though genetically inbuilt, differs from genetic predispositions such as language. Speech begins to come on stream in infancy and is learned through immersion in a language community and with caregiver tutoring. Technicity, as evidenced by drawing, begins to emerge somewhat later and is as much a personal exploration of the attributes of the medium as a means of expression. Unlike language, which is equally expressive regardless of the culture that owns it, the technological sophistication of societies has varied markedly. Thus, immersion in the domestic culture is inadequate for the effective development of technicity capability and a formal system of education becomes necessary. Based on the two qualities of concept outlined above, it is possible to derive three modes of teaching and learning.

The first mode is purely V-conceptual. It makes use of capabilities that evolved in the primate and hominine lineages and which reached their apogee in the twin species of Neanderthal and human. These are: a) spoken language communication; and b) a capacity to learn by observation from demonstration: learning by rote, repetition, reproduction, and by inner-speech rehearsal.

This mode is sufficient to conserve the knowledge base and provides a platform for some limited innovation. It was well described by Vigotsky (1962) and will be denoted by the term Vigotskian.

The second mode is technicity-based and makes use of graphic forms both to express T-concepts and to provide external memory storage. The most important innovation is the development of systems of notation that provide insight into mental processes. Written language and numerical notation are the foundation of this mode. The former is a technology that notes the grammatical and lexical aspects of speech, omitting all prosody. The latter, in its decimal place-value form represents the way humans think about number. This education system, which Alexander (2010) so fully describes, has been in use for at least five millennia. The key that unlocks access to the knowledge base is literacy and numeracy, the apprenticeship in the 3Rs that dominates current primary education practice. It is an onerous apprenticeship. Not all children master the grammar of the medium and there are collateral casualties as a consequence. This mode of schooling has a name with historical depth. The institution where the grammar is mastered is a Grammar school.

The third mode, the subject of this paper, barely exists. Its medium is the Turing machine and it brings into focus those constructional aspects of education that have been relegated to technology and art in current school curricula. The Turing machine, by definition, can read, write, and, with a little instruction, do arithmetic. Represented in classrooms by a stored program digital computer, this medium has the capacity to assist children in mastering the grammar and the animation of its content. Text in this medium, which stares silently from the page of a book, may be animated in a multitude of ways. It relationship with cognitive processes differs from that of text. The medium conceptually being a Turing machine, the term Turing teaching will denote it.

Vigotskian	Grammar	Turing
Socio-verbal / observational	Textual	Computational
Shared with Neanderthal	Uniquely human	Uniquely human
No external medium	Externalised memory	Externalised processing
High memory load	Demanding apprenticeship	Assistive
Environmental entropy	Mixed entropy	Genomic entropy
V-conceptual	V/T-conceptual	T-conceptual

Table 3. Some major differences between the three modes of learning now available to the human.

The main differences between the three modes of teaching and learning: Vigotskian, Grammar and Turing, are listed in table 3.

Technicity thinking

During the primary school years children learn increasingly to apply the capabilities of technicity. Therefore the purpose of education, often defined culturally, may now be given a more species oriented perspective: the development of T-conceptual thinking. The starting point for this is the V-concepts that children bring to school (Bransford et al 2000). At present this transition begins with the literacy and numeracy. Children learn to use the power of letters, numbers and shape to bring speech and perception under T-conceptual control. An important question in terms of the need for transition to Turing teaching is, “How well does Grammar school method work?”

Literacy

At first sight it is reasonable to take spoken language as the starting point for reading and writing.

There is a problem, however. Text does not represent speech. Computer speech engineers have shown that only the lexical and grammatical aspects of speech are represented in writing and the sounds and music of speech, the prosody, is not (Taylor 2008). From a V-conceptual perspective, this is surprising. It seems obvious that alphabetic writing should represent the sounds of speech. Reflection shows this cannot be so: There are many dialects of any language and speech sounds vary enormously. Writing is a technology for noting the unvarying aspects of a given language and cannot represent such diverse pronunciations as Cockney and a Scot. This notwithstanding, Grammar schooling does elect to work from speech to writing: the phonics approach maps letter groups to the sounds of Received Pronunciation or General American. Mapping between RP or GA and text is very poor (vide dictionary pronunciation guides). Whilst most children do learn to read, the misconception that text is speech written down is a major source of spelling errors and inhibits the writing of many children and adults. Grammar schooling has no answer to this problem. Administrative and academic interventions have had minimal effect: teachers have had some six millennia to hone their technique. Put quite simply: the book is a demanding medium that offers no help to the child in decrypting and animating its contents or in creative encryption. The failure rate is high and associated with demotivation and dislike of school.

Numeracy

The number of children and adults who hate mathematics is legion. Traditional teaching takes 2 parallel approaches: a) oral, where children learn the language of number and mentally and orally to compute; and b) structural, where they count objects and measure. It seems obvious that these approaches will and do complement each other. Technicity considerations suggest other wise.

Counting is V-conceptual: a verbal-perceptual activity. Objects are counted and collected up into base-related bundles: eggs by the half dozen, Dienes blocks by tens. In the latter case connection to the fingers of two hands, which are available to mediate one-to-one correspondence, is clear.

The language of number is T-conceptual. It represents numbers in a different way and in so doing opens a window on the working of the mind. Number, though familiar in technological cultures, is not natural, humans prefer to name people and things, and number words had to be invented. The language of number appears to mirroring counting; but it does not. Language works from the absence of anything through enumerated objects up to, but not including, ten. The brain appears to have a register system, as do real (as opposed to conceptual) computers. Written language does mirror this way the mind works but place-value number systems do so with greater clarity.

The cognitive conflict between the perceptual and linguistic methods is dramatically illustrated if a chequerboard "hundred-square" is enumerated using decimal place-value numerals. The first and last lines of such a chequerboard, found in many primary schoolrooms, are shown in figure 1.

1	2	3	4	5	6	7	8	9	10
91	92	93	94	95	96	97	98	99	100

Figure 1. Segment of chequerboard hundred-square marked with decimal place-value numerals.

The cognitive conflict with language is clear: humans mentally count to nine and then increment the succeeding register by one. Place-value numeral systems are a T-conceptual technology that is representative of mental operations. Perceptual counting is V-conceptual. Here is a cause for cognitive confusion. By counting and carrying out practical activities with bundles of ten children do not come to an understanding of number, already embedded in language, rather the reverse. What they say requires unambiguous means of external verification. Sawing a unit of abacuses, colouring hundred squares, and using Dienes blocks for model-making might be a good first step.

Kitchen maths

The cognitive difficulties that underlie the failure of Turtle geometry have already been discussed (Ó Dúill 2011b). The same considerations apply to the notion of "kitchen maths" (Papert 1993,) which, noting the skill with which inumerate individuals handled quantities and proportions in cooking, sought to find a means of constructing mathematical ideas from these capabilities. This appears, in principle, to be similar to working from naïve concepts to scientific ones. However, the danger is of conflating V-conceptual thinking with the T-conceptual. The key V/T difference is that the former is derived from perception, from individual experience, and the latter is constructed from species-level information concerning properties of matter. T-concepts are superimposed on perceptual experience and not extracted from it. Whilst direct experience to develop craft skills is possible in the Vigotskian learning mode, practical experience cannot lead directly to T-conceptualisation. It is necessary for the teacher to propose such concepts for the learner to project onto their experience, i.e. the scientific method of checking against reality. Given that the V/T concept distinction was not available at the time constructionism was first proposed, some early examples of constructionist practice may require reconsideration.

Turing teaching

In childhood, Alan Turing played with Meccano, the mechanical precursor of LEGO Technic. He thereby exercised the technicity adaptation is ways that Grammar schooling did not encourage. As a consequence, his PhD on computable numbers could be based on the brilliant insight that it is not possible to divorce mathematics from the mathematician. The Turing machine, cf. Carnot's waterfall image, is based on the image of Turing himself sitting at his desk with paper, pencil and eraser. The mechanical Turing can read, write, and erase symbols on an infinite tape; the process of so doing altering the state of the machine, based on its existing state. At a stroke of his pen, the second law of thermodynamics was inserted into the field of mathematics and mathematicians. From an educational viewpoint, the computer in school is a Turing machine with the capability to read, write, and, with a little instruction, do arithmetic. This contrasts markedly with text media.

The phrase "with a little instruction" gives the clue. As Papert so rightly said many years ago and the Royal Society echoed this year, programmability is an intrinsic property of the medium. This does not imply that programming is an entrée to mathematics, as the originators of Logo claimed. It is programmable in the same sense that a surface is capable of taking a mark. Mark-making on paper is a natural childhood activity, so is talking. Writing an instruction is a combination of the two; with the possibility that the medium may respond. Programming is, therefore, no more an introduction to computer science than is the activity of drawing an introduction to architecture; and no less so. As a form of writing, there are necessary precursors to programming. It is the role of the primary phase of education to establish them in a manner congruent with its curriculum.

Primary precursors

Given that the computer is the medium of Turing teaching, it follows that mastery of the medium is the first priority. It is essential that children have one-to-one access to it. The sharing of pencils is not considered acceptable, no more so is the sharing of keyboards, screens and graphic input device. New technology is not necessary: any computer less than twelve years old is suitable.

The start is at the beginning. Primary school runs from the end of kindergarten to the secondary school. It is the foundation for all that follows. Like the foundations of a building, the remainder of education relies on its stability. Similarly, the effort that went into its construction is invisible in the final product and unconsidered in its use. A quick resume of its nature is therefore required.

A child entering the primary school years has a complete language system. Gone are the strange structures of infant speech, but discoursive speech is still to be formed. Childhood might better be called chatterhood as children exercise the prime social networking medium of their species. It is the phase where the technicity adaptation comes strongly on stream. The beginnings of are seen in the geometrical drawings and primary colourings of kindergarten. Covering classroom walls, they attest its importance. Sound making, with voice or instrument; the crude flavours of snack foods; and choreographed movement in playground games attest its emergence.

Neurologically, this is the period when prefrontal cortex establishes connections with the rest of the brain. Although the basic architecture of the nervous system is complete at birth it is pruned and tuned by experience. A) Orbitomedial fibres find their targets in the older part of the brain, so moderating and modulating affective factors such as attention, motivation and emotion. These connections are mature by the onset of puberty at the end of the primary school years. B) Lateral prefrontal cortex, which connects to neocortex and is cognitive in function, matures more slowly. The majority of connective growth takes place during the primary school years though maturation continues into tertiary education. Primary school experience is the foundation for all that follows.

Turing basics

Because the Turing medium can carry out processes, it may be tuned to the mind of the learner. Because the Turing medium can carry out processes, it may assist the user. Because the Turing medium can carry out process it can also, and currently mainly does, emulate non-Turing media. Tuning to the mind and providing assistance have little explored because both these capabilities conflict with traditional teaching method. The character of this conflict and the pressing need for its resolution may be illustrated through literacy and numeracy method. Technicity, recall, is a constructive cognitive process executed by prefrontal information gathering and composition.

Writing is a technology that notes only certain aspects of spoken language, so it is plausible that learning to read and write entails access to appropriate information in the brain rather than signal processing on perceived speech. This idea is supported by second language intelligibility studies and the sign languages of deaf people. Therefore, phonics approaches probably do not do what is claimed for them. Adults who have spelling difficulties report using a method that uses a sound model of the text. Though difficult for a human to articulate,(although children do it in the early stages of reading) this would be a trivial application within computer speech technology. It would not be an alternative accent, like RP or GA, more a parallel stream that reflected the equal weight of letters on the page and the spaces between them; and thereby more in tune with technicity. The assistive aspect comes from possibilities that the medium offers for working with text without the need manually to form letters; keyboarding as a means of playfully to investigating text's nature.

Number, as discussed above, is a conceptual mess. Turing media add in the way the mind does. It follows that playing with the symbols in the medium, not counting, is a good precursor to mathematical understanding,. There is no developmental issue in working from the symbols to physical reality. Young children exercise the ability to create geometric forms from a very early age. A written number is a shape as much as is a square or a letter; and as learnable. The problem comes in animating number/operator expressions. The textual method of Grammar schooling makes this an unnecessarily tedious exercise. As with reading, the medium is obstructive. Turing media offer a multiplicity of assistive means of entry into computation. Once learned, the symbol system may be tested against physical reality: i.e. counting comes after number is understood. Competence with symbols is the key to higher mathematics.

Medium mastery is a precondition for its effective use. This is as true of Turing media as pencil and paper. It follows that children need systematically to be taught to work with the medium from the start of formal schooling. Attainment expectations need to be determined and set. But there is a very great difference between mastery of Turing media and mastery of text media. The medium has the capacity to assist in the process of its mastery. Thus, instead of tedious practice exercises children may create from the outset. This enables a graded project-oriented approach to be used. Such and approach was developed in Bulgaria by a primary school teacher, has been reported to a number of Eurologo conferences, and is sanctioned for use in primary schools in that country and Macedonia (Ilieva 2010). It comprises a suite of small programs called "ToolKID", written in Comenius Logo, that cover all the possibilities of working with the computer through a project oriented approach based on the normal activities for the age of the children (fig.2). In addition to this introductory software, the curriculum included the option to work with external devices. This introduced the principles of computer control and Logo programming in a context that reflected the children's knowledge of their world using the language and writing skills they were learning. Additionally, this approach greatly emphasised the aesthetic aspects of constructional activity.

A five-year-old who today began to follow this exemplary curriculum would six years later enter secondary education with new capability. Secondary education would then have the challenge of new child competences, for example a child whose writing fluently flows from fingers to screen without a glance at the keyboard; and a window of six years to adapt. Tertiary education would have a lead-in time of a dozen years.

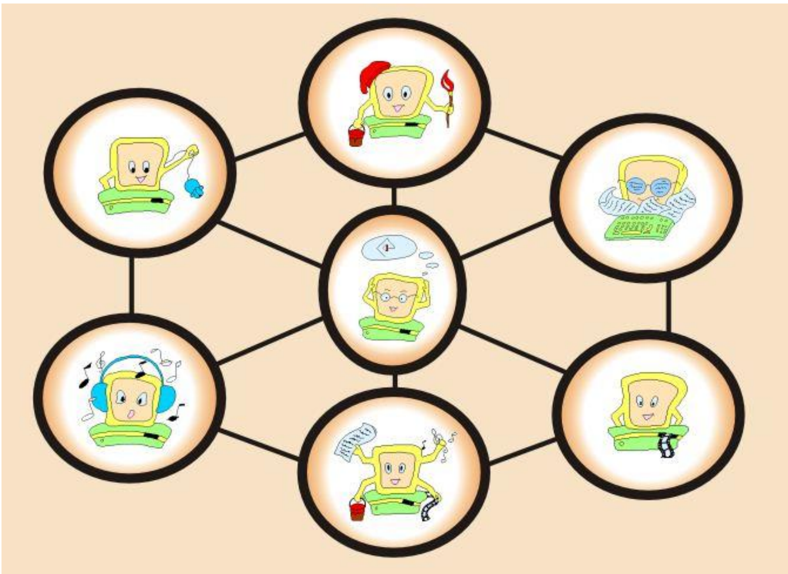

Figure 2. The "ToolKID" suite of programs used to introduce all the possibilities of working with the computer through a project oriented approach to children in the five to seven year age range.

The problem is that this curriculum is not obligatory so only certain children in certain schools develop any real level of competence. Resources were very much the inhibitor a decade ago but now computer systems that are perfectly suitable for primary education being thrown away as users upgrade. Computer supply is not the problem: the problem is perceptual and conceptual.

Tradition and transition

In the minds of both academics and educational administrators, including some constructionists, the traditional medium and methods with which they succeeded are perceived to be superior to the computer: they clearly exercise the little grey cells. Socrates had similar objections to writing.

A new medium inevitably causes concern, particularly where it affects high status skills. Hence in literacy and numeracy traditional method has been prescribed and the computer proscribed. In this climate, the transition to Turing teaching is inhibited and "ICT" integrated into the tradition.

A consequence of traditionalism is a disregard of work children produce using Turing media. An illustrated piece of writing is devalued as 'done on the computer,' a higher quality of thought and expression notwithstanding. This is illustrative of a factor that might be termed "academic blight" that currently infects computer application in education. The fragmented, subject led organisation of academe leads to a partisan approach to school: their must be in the curriculum. Furber (2012) is exemplary: A shortage of applicants for computer science motivated an inquiry into computing in schools by the Royal Society. Primary education merited only a half page of consideration, and then focussed on the final year; yet Furber, arrogantly and ignorantly asserted:

> *"We aspire to an outcome where every primary school pupil has the opportunity to explore the creative side of Computing through activities such as writing computer programs (using a pupil-friendly programming environment such as Scratch)."*

The derogatory words require justification. The problem is the conflation of writing and Scratch. Scratch uses words on labels that are grammatically colour-coded. The technique is identical to that used in certain remedial reading approaches; used when there is a learning difficulty. Scratch serves precisely this role (Wilenski 2010, Harvey & Mönig 2010). Primary school children learn to write by constructing words from letters and sentences from words. Programming is a way of writing a story. The teaching method should not differ. Scratch (LEGO WeDo software is worse) teaching method introduces splinter-skill learning, abhorrent to primary education. Here lies the ignorance; the arrogance is in gratuitously recommending an inappropriate teaching method to expert professionals. From a Turing teaching perspective, University is part of the problem.

Risk and technological transitions are always associated. The transition from atmospheric to high pressure steam power is an obvious historical example. Development of railways accelerated only when economic conditions were conducive. More importantly, the engineers and entrepreneurs who drove the development had little association with traditional horse powered transport. Rail viability was tested in parallel with road and canal, not in association. This may offer a model for transition from text to Turing media in education. It is also clear that change can only begin in primary school; attempts at secondary level can lead only to the teaching of splinter skills and to assimilation to traditional conceptual frameworks; or to disappearance without trace.

Teacher R&D capability, a way forward?

Expertise in the developing child's mind, at a level necessary for the effective implementation of innovation, is to be found only within the primary school teaching profession. To this must be added mastery of the medium. This suggests an engineering R&D based approach: a continuous cycle of pilot, assessment and scaling up. The cyclic aspect of the change process contraindicates the traditional academic project model, which has not been notably successful. A way forward is an R&D class in school, publicly or privately funded but independent of both the educational and political establishment, where a Turing teacher can develop method interactively with children. A source of technical assistance and software development would be required. It would help were such classes to operate on a regional basis, cf. EU Comenius programme, so that teachers and children could interact with colleagues. This is similar to the R&D model used for ToolKID.

Conclusion or?

The technicity proposition offers a solid base for constructionist change in education. Necessarily this starts in the minds of primary school children. The modes-of-learning analysis shows Turing teaching to be assistive and tuneable to emerging minds. Traditional method is obstructive and abusive, leading to an inadequately tamed language instinct. This reduces capacity for scientific relative to perceptuo-linguistic thought. The transition to Turing media is inevitable but fractured academe is seen to lack the necessary catalytic knowledge. Expertise resides, unarticulated, in the minds of primary school teachers who have mastered the medium. The implication is that R&D is best carried out in classrooms by practising teachers rather than through professorial projects. The original idea of Eurologo was to bring teachers and academics together as equals. It has failed to.

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