Reversing Robotic Regression: Why our Culture Rejects Robotics in School

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***Abstract*–For over three decades robotics has been taught in primary school as a curricular enhancement. Analysis of old and new material suggests a reduction in cognitive content and regression from reality. The Technicity Thesis is introduced, from which it is possible to re-evaluate technology relative to language. From this cognitive basis the role of the computer in school is reconsidered and the notion of Turing teaching introduced. The requirement for a curriculum for mastery of the computer as a medium follows from this. In this context, the current economic constraints on robotics may be re-evaluated and serious consideration given to a curriculum consistent with neural development in childhood and constructionism.**

***Index Terms*—Robot(ic)s, primary school, historical perspective, technicity, learning medium, neurology, teaching methodology, exemplary practice**

I. Introduction

Our culture places a higher value on language than technology. This is because, to quote paleoanthropologist John Shea, we believe that: "One of the crucial elements of Homo sapiens' adaptations is that it combines complex planning, developed in the front of the brain, with language and the ability to spread new ideas from one individual to another..." There is no mention of the human capacity for technology. In this cultural milieu the development of language and discourse in seen as the prime objective of primary school. [1] In this context, the humanities and verbal arts are given high status along with mathematics, seen as cognitively complex. Science is also admitted because of its alleged hypothetico-deductive method. Technology is seen as making things, often in the context of 3D art made from junk.

For a quarter of a century, the computer has resided uncomfortably in a book-oriented institution. It has been treated, on the whole, as a multimedia teaching aid. As late as this year, it was necessary for engineers to descend upon politicians and demand a place for programming in the curriculum [2]. The situation for robotics, programming combined with construction, is worse. It is hardly possible to program a model built from breakfast cereal boxes and toilet-roll tubes

As the short historical survey below shows, there has been a retreat to the toy-box in primary school robotics over the past quarter-century. This is largely explained by the difficulties that manufacturers had found in selling to schools. The LEGO Company is one high-profile example: their Dacta educational division was so unprofitable that it closed and LEGO Education is a relatively new venture.

Whilst those who are engaged in trying to establish robotics at primary school level bravely struggle on with hopeful projects, the ethos is against them. The purpose of this paper is threefold:

1. To establish the veracity of the assertion of regression by a short historical review;
2. To present a theory about the evolution of technicity, the human capacity for technology, that displaces language as the highest cognitive capability of the human; and
3. To begin to mount a challenge to the book as the prime teaching medium in favour of the computer, the latter re-conceived as a Turing medium.

This framework offers a context in which to reconsider the regression of robotics; and to mount a challenge to the perceived economic non-viability of the subject at the primary school level. It provides a basis for discussion of a way forward; aided by consideration of two recently published approaches to robotics at primary school level.

II. History

The year 1979 saw the arrival of the Milton Bradley "Big Trak" in the toy-box. Within five years it was widely used in UK primary schools as a part of the Microelectronics Education Programme (MEP), a UK government initiative that has been forgotten by educational historians [3]. The MEP also saw the first computers in primary school, sometimes complete with a Logo floor turtle. By 1987 when the first EuroLogo conference took place Dublin, LEGO had introduced its LEGO Dacta Technic 9700 kit with Interface A and TC Logo. At the conference itself, a college lecturer and adviser to primary schools gave a Control Logo Master Class.

Roll forward a quarter century and we see the nostalgic release of a Big Trak clone (fig.1), the classroom place of which has been taken by BeeBot (fig.2). LEGO products have bifurcated into the NXT and WeDo systems. The former is more of an evolution from 9700, whilst the latter is a return to the toy-box. So, after 35 years, where are we?

We can clearly see two streams. The first is the robot in the classroom. Whether it appears as a bee or a tank, it is cognitively a 'black box' with buttons. (One version, Pip from Swallow systems was just this.) Their main use is in teaching left/right turns and distance estimation, which are more simply and economically incorporated in pencil and paper mazes. Playing with toy robots in the classroom, however they are clothed and with whatever play-mats or curriculum materials they are provided, is not constructive. Nor is it constructionist because nothing, no object, is constructed that is open to inspection [4]; and the toy itself is (like a Barbie doll) closed to inspection. It may be argued that this approach feeds the humanoid robotic fantasies children derive from entertainment media rather than the role of robotics as helpful disembodied automata.

Figure 1. The reincarnated "Big Trak" and its keyboard layout.

Figure 2. The modern "Bee-Bot," with keyboard layout and jungle jackets.

The second stream *is* constructionist. The LEGO system enables the child to learn to create, using a limited range of well designed elements, a host of imagined or realistic objects. Computer controllable elements: lights, motors and sensors add robotics. With the LEGO 9700 kit constructions related directly to the child's experience of 'hidden' robotic systems in the world with which they were familiar. This may be something a simple as street lights coming on at night. Their program might be simply 'lamps on' written in Logo. In primary school, this model will not be an isolate but part of a discussion of why we need lights, how we got light in the past, where the electricity comes from and the effects light has. It is not an isolated robotic experience. Moreover, the children needed to be taught the skills of constructing the model before they program it. There was a realisation that learning needs to be situated (cf. Vigotsky's [5] zone of proximal development). This was 1987.

A comparison between Big Trak and Bee-Bot keypads, mirrored in programming environment differences between LEGO 9700 and WeDo (fig.3), raises issues of curricular integration.

Figure 3. The WeDO programming environment.

The older technology enabled children to apply number and letter knowledge in a new context; a context that gave immediate feedback. The numerical keypad and Logo programming contributed to numeracy and literacy: the core objective of the primary school curriculum.

When the constructions supported by the instructions supplied by LEGO are compared, we see a similar effect. No longer are representations of reality provided, the toy-box is returned to; as the drumming monkey (fig.4) illustrates. No blame may be laid at the door of LEGO for this change: it is a toy company and needs to sell outside education. Pictorial programming is consistent with their pictorial instructions.

Figure 4. The toy-box WeDo drumming monkey.

A few primary school teachers have worked continuously with robotics or "controlling external devices" from 1987; and there is at least one nationally approved curriculum that includes robotics [6]. Economics impact on its, uptake however; the school must make a case for extra funding that is frequently not forthcoming. A few determined school teachers and university researchers manage to keep alive robotics in school by taking what opportunities come along; a strategy that relies on good fortune but is hostage to the material that is on the market. Robotics is not alone. Programming for children was kept alive in computer clubs through Scratch, which Furber [2] commends to primary schools.

Consequently, lunchtime and after-school Scratch clubs are being launched in the UK; whilst the EU supports similar clubs for robotics in Bulgaria.

The feeling of a cognitive decline is supported by a re-awakening of interest in the basics of computing, albeit nostalgic, e.g. the Raspberry PI (a Linux Micro on a chip), and inquiries such as that by the English Royal Society into computing in schools. However, the motivation for these stirrings was not the interests of the children. Furber [2] was open in his desire to see more students of computer science; cf. RiE papers dealing with the primary phase [7, 8].

As the ghost of Big Trak returns, it is time to reflect on why there has been regression not progression.

II. Theory Matters

The presupposition that language is the highest cognitive capability of the human was alluded to in the introduction. A consequence of this presumption is that language is given far higher a status in education than technology. Moreover, surprising though it might seem, there is no established idea about how humans, unlike all other animals, has a capacity for technology. The Shea quotation makes no mention of it. Psychology is silent on the issue. Both Piaget and Vigotsky [5] worked from the perspective of language-primacy. The latter, now academically fashionable, saw learning as socio-verbal and thought as inner speech. The only academic to question this was Papert [4], who claims that 'constructing objects open to public inspection' is educationally more "felicitous" than verbal instruction. Intuition is insufficient. Before technology may be seen as integral to a cognitively balanced education, it is necessary, as a minimum, to demonstrate its cognitive equality with language. This entails a foray into scientifically unexplored territory. Heidegger called it "the question concerning technology." For students of human evolution it is modern human behaviour. How is it, as Heidegger put it, that other animals use material at hand but humans challenge forth raw materials from the earth, which they see as a standing reserve? How is it that only the human makes use of godless straightedges, as Hundertwasser remarked? And why is the artist's palette a wrapped-round rainbow rather than a linear sequence as in the sky? The Technicity Thesis developed by the author offers an answer to these questions.

An implication of the nature of the technicity adaptation is that technological thinking is cognitively more powerful than linguistic thought; which will be seen to be obvious on reflection. Thus, the argument for the status of technology is made. No longer is it only an economically vital practical subject, it becomes the cognitive foundation of science.

This established, it is possible to re-evaluate teaching method and medium. Seen as a medium, the computer's capabilities may be compared and contrasted with the book. This comparison needs to take into account the fact that rapid neurological maturation that takes place through the primary school years, and experience has a major influence on the configuration of the mind.

Alan Turing's speculation on the relationship between the 'universal machine' that his thought experiment gave birth to, and the brain that thought the experiment prompts the replacement of the term "ICT" with the term Turing medium and a possible transition to Turing teaching

A. Technicity

From an entropy and information perspective technology is simple relative to the organic forms built by biology. This includes the human brain and the information it receive via the senses. This makes a problem with the second law of thermodynamics: It is not possible to generate simplicity from complexity without doing a large amount of work. The converse is far less work intensive. The classic example is a cup of tea: to infuse the compounds from the tea leaves and add sugar is far easier than trying to recover the original pure ingredients. If the process is irreversible, like making a cake, it is impossible.

It follows that the source of information on simplicity must be other than environmental. The Greek Platonists understood this when they raised the question of ideal forms and how we know that the pure colour red is red. The only non-environmental information is within the brain. This raises the question of where that information might be, how it is accessed and how it is processed. The clue to the source of the elemental information is found in the human capacity for drawing. This aspect of human behaviour is fundamental to technology; and yet nothing is known about how humans come to be able to draw. In addition, there is no evidence that our cousin species, the Neanderthal, had this capability. But it is undeniable that children begin to draw soon after they have learned to speak and that their early drawings are composed from simple linear shapes. The requirement is therefore a source of elemental information on shape. The most likely source is primary visual cortex where Hubel and Wiesel found what they called 'feature detector' neurons in the late 1950s. O Duill [9] suggested that somehow this was the source of the information necessary for drawing ability and demonstrated the 'square/diamond' effect (figure5.) If a square presented in a horizontal/vertical orientation rotates by a one eighth turn its name changes. The word 'diamond' is unthinkable in the first orientation but immediately comes to mind in the second.

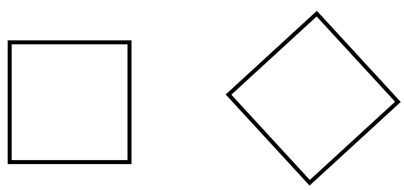

Figure 5. The square/diamond effect.

This immediately raises the question of the cognitive status of language: If a single concept can generate two different verbal responses, where does thought reside?

This finding is indicative of a plausible source of low entropy information. It triangulates with child development.

From the information on line length and orientation found in the brain, all the shapes humans create including letters, geometric shapes, and numbers, may be formed. However, the question remained open because the question of access and processing remained unanswered; and it is but a single phenomenon.

Paleoanthropologists offer a second angle of attack. One of their earliest indicators of modern human behaviour is evidence of red ochre use. This implies the capacity to seek out, mine and refine this iron oxide; i.e. the possession of an abstract concept of red. There are two information sources for colour: the retinal cones and Hubel's 'blobs' in primary visual cortex. The latter offer a colour space defined by the opponent pairs red/green, blue/yellow and black/white [10]. This wraps the rainbow around on itself to give the colour wheel, which includes non-spectral purple.

Parenthetically, humans share this mechanism with fish. So, primary visual cortex offers another source of elemental information that triangulates with human concepts and with child development where undiluted primary colour features in every kindergarten, cf. Bee-Bot. As the source of colour concepts, this would guarantee that all humans possessed the same concept of red.

Primary sensory cortex in general, and its homologue in olfaction, offers information that triangulates with uniquely human behaviour including choreography, music, scent and flavour blending.

The origin of this information is critical to the idea that technicity is an evolved adaptation. The mechanisms that have been found in primary sensory cortex do not derive their information from sensory input. The information is put there by the genome when it constructs the phenotype. This is obviously the case because the information carried by, for example, photons interacting with cones at the retina loose their information in the chemical reaction they trigger. All that remains is a nerve impulse indistinguishable from any other nerve impulse. The information that it represents can only be provided by structures within the brain that embody information about photons in the visible range. The same is true of the other so-called feature detector neurones; they embody information on elemental properties of matter built into the genome over geological time. This information is of far lower entropy than the sensory experiences of a fleeting phenotype. As such, it is more powerful than sensation.

The source of information for technology is established, as is its low entropy. All that remains is to explain, in terms consistent with evolutionary principles, how humans gained access to this information and how it could be processed to construct, as Papert put it, objects open to public inspection. Fortunately all these issues may be resolved together. The thrust of hominine evolution was a brain expansion that followed the mammalian trajectory, with an emphasis on the prefrontal area [11]. The mechanism underpinning prefrontal expansion was the invasion by prefrontal neurones of most parts of the brain. The prefrontal area provided an executive function and working memory for manipulating information gleaned from within the brain. This neuronal advance turned out to be adaptive and led to the Homo lineage. The role of prefrontal cortex has been described as inventing futures from the past. It creatively recombines information it receives and then stores that new information back in the older brain, thereby modifying its circuits. This is a creative and constructive process. But it also includes evaluation in terms of the goals of the organism. From the perspective of the prefrontal area, it is irrelevant where the information comes from; the only requirement is that it turns out to be useful. Hence, the processing mechanism for technicity was in place. All that was required was for prefrontal neurones to slightly extend their range to include primary sensory cortex and its homologues. This, uniquely in the human, is what the technicity thesis proposes. It offers an explanation for the both simple character of technology and its power. In so doing, is dethrones language and makes the highest thought verbally inarticulate. Herein lies the concern about language development expressed by educationalists. Herein is the explanation of the drawings and writing that covers classroom walls.

The primary phase of education is when technicity comes on stream as prefrontal cortex makes is connections and matures; a process that is virtually complete before puberty. Hence, experience in primary education is critical to the full flowering of this uniquely human mental capacity.

B. Differential concepts

A consequence of the technicity adaptation is that there are two different qualities of concept: those derived from perception and directly expressible in language; and those that flow from technicity. The square/diamond effect is one example. In general, the difference is that between scientific and naïve thinking. The classic example is the controversy surrounding the heliocentric universe. It is obvious to all who can see that the sun and moon revolve around the earth. This is the view from perception, from the evidence of our unaided eyes. This view may only be corrected, as in the case of the square, by a higher level of concept. For the motion of the sun, this was a combination of concrete and cognitive technology: the telescope and mathematics; the latter aided by the relatively new arabic numerals.

It is necessary to differentiate these concepts. Concepts derived from technicity will be prefixed with the letter t, those based on perception prefixed with a letter v. The differences between t- and v-concepts are summarised in table 1.

TABLE 1
SOME DIFFERENCES IN QUALITY BETWEEN T-CONCEPTS AND V-CONCEPTS

T-concept	V-concept
Technicity based (genomic)	Perception based (experiential)
Non-linguistic (constructed product)	Verbal (internal and spoken utterance)
Low entropy (simple and powerful)	Environmental entropy (complex)
Species level (universal)	Culture level (local)
Tested against properties of matter (scientific)	Tested for cultural (internal linguistic) consistency

III. Medium Matters

By displacing language and assigning cognitive primacy to technology it is possible to view human endeavour from a different perspective. Remarkably, though not surprisingly, language reflects this new status. An example is William Shakespeare, who is described as a playwright. This places him in the company of wheelwrights and millwrights: an artisan plying a trade using technology; in his case writing. This places him apart from the oral story-teller, who uses no concrete medium, despite the fact that he is called the Bard of Avon. The use of both words as a descriptor reveals the failing of language, as it did with the square. In this case it also highlights another phenomenon: the invisibility of the medium. Whichever word is used, it is the performance not the process of creating the script that is the focus of human interest. The same is true of education. Talk is of knowledge and skills, not the properties of the medium. This tends to be assumed and is only remarked when, like the computer in the classroom, it is novel. But the novel is not perceived as a medium, rather as technology; which word connotes the novel. The technicity framework enables us to shift focus to the medium and its properties. Table 2 lists the three modes of education and associated media that this approach defines.

TABLE 2
Some Major Differences Between the Three Learning Modes

Vigotskian	Grammar	Turing
Socio-verbal / observational	Textual	Computational
Shared with the 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

All children start school with the well developed spoken language and social skills that Vigotsky focused upon. They can learn by observation and imitation and can talk about their learning. They can begin to relate what they learn to the wider world; and they can bring their naïve knowledge of that wider world to their learning, sometimes confusedly [12]. They can develop skills, such as playing music or riding a bicycle. Vigotsky's notion is easy to apply in such situations; and where a skill is not open to observation children's language is a good indicator of their state of knowledge. However, we are all aware of language disabled children for whom this is not so. Another weakness of this mode is that for those with good recall and a facility for language, rote learning without the capacity to apply it is possible, which may mask poor understanding. From any perspective, this medium that has no medium and which we share with Neanderthals with whom we intermarried, places a premium on memorisation and recall. There is no use of the uniquely human technicity adaptation. Nevertheless, it has been the prime means of generational information and myth transmission.

They also have the green shoots of the technicity adaptation in the beginnings of drawing and an interest in colour, shape and other properties of matter. The technicity adaptation makes the construction of meaningful marks possible. Black marks on white paper may be used to construct and communicate non-verbal ideas, as an aid to thought, or as an aide memoire. The book, the second in the triumvirate of media, is far more powerful than speech or demonstration. This is a direct consequence of the lower entropy of the symbols used. (A simple information theory comparison of speech and writing demonstrates this.) These symbols extend well beyond the communication of language over distance and time. Writing includes number, musical notation, circuit symbols, and more. The drawback of this powerful medium is the requirement to learn the grammar and semantics of a given symbol system. Whilst a musical score records the notes and tempo of a composition, it is but a desiccated husk of the original. The player must not only accurately replicate the notes and timing of the original but must add the unrepresented musicality. The same, seen most clearly in a play-script, is true of written language. Thus, this medium imposes a long and arduous apprenticeship in its grammar and re-animation. We may think of the book as a flash drive – its data is only transformed into information if there is an appropriate application. A competent reader is unaware of the medium but where it has not been mastered learning is inhibited. Teachers are aware of the limitations of the book. Some children readily learn to decode, but with limited comprehension, (reading better backwards because the meaning does not get in the way). For the dyslexic, the book is closed.

The book is a product to be consumed. Pencil and paper, on the other hand is constructive. Thoughts may be sketched and reflected on and, as a consequence, may change the state of mind of the writer. Having reflected, the writer may move on or write or erase what is written before moving on. This is the description of a Turing machine.

[Parenthetically, because the Turing universal machine is mathematically equivalent to the lambda calculus, it is often perceived as a purely cognitive entity, not the specification of a physical machine. This is to misread Turing. A read-write head and an infinite tape is a physical construction, even when mental. Turing talked in terms of disregarding the time taken for a computation. In reality, by creating a machine, Turing introduced entropy and the uncomfortable constraints of the second law of thermodynamics into the field of mathematics.]

This powerful idea is a partial expression of the interaction of the mind with the book – the medium that the technicity adaptation made uniquely available to the human. It is partial because access to thought remains linguistic: computability is a linguistic expression encoded arithmetically. The read-write head and tape, like the notebook and pencil, are constructed from information of a different quality; the low entropy information made available by the technicity adaptation. The difference between a computer and a book is that the former may change state and thereby assist the learner. For this reason the term Turing medium is preferred, leading to the idea of Turing teaching with an assistive medium. The Turing medium may function in consumer or constructive mode.

The perception that a computer is 'technology' obscures its function as a Turing medium that can read, write, and, with a little instruction, do arithmetic. Comfortable familiarity with, and indeed reverence for, the book misdirects attention from its defects.

The fundamental difference may be illustrated with the following text, combining computer and natural language:

First, write a procedure that makes sense in terms of natural language.

```
to polygon :side
drawpolygon :side :side
end
```

Second, construct a functional procedure that draws the general shape. Note that instead of using a repeat instruction, recursion is used to halt the drawing process once the shape is finished. I.e. the number of sides is explicitly counted. It is thereby possible to draw a shape of zero sides. This is conceptually different from a loop.

```
to drawpolygon :side :tally
if equal? :tally 0 [stop]
forward quotient 360 :side right quotient 360 :side
drawpolygon :side difference :tally 1
end
```

Once the general polygon procedure is written, separate procedures may be written to draw polygons by name. For example:

```
to octagon
polygon 8
end
```

(Do not try this in primary school.)

This text, when pasted into the procedures page of LCSI Microworlds Logo, even if accompanied by its surrounding paragraphs, would enable the user of the medium to draw a polygon of any number of sides by typing the words 'polygon' followed by the number of sides and pressing enter. Were the shape names to be programmed, e,g, the octagon procedure, the meanings of the shape words could be explored by the learner. Note that the learner would write the words and so discover their meaning rather than try to rote-learn captions written on the page of their text-book. Furthermore, it would be possible to perform a search of this paragraph for the word 'octagon' and ask the computer to evaluate it. (To emphasise this, the text of the program is not given a separate font, or shown as a figure. On-screen it has the same status as the body text, only when printed does it cease to be alive.)

IV. Turing Teaching

Turing teaching is simple to define: the use of assistive Turing media as the basis of education. The term was first introduced by the author in 2011 as conceptually preferable to the terms ICT and technology, which misdirect thought away from the capabilities of the medium and hence its educational consequences [13]. These latter include standards defined by an obsolescent apprenticeship in mastery of a prior medium: the book of the library of Alexandria.

A. Reason for Regression

It is impossible for an institutional infrastructure founded on a learning medium as obstructive as the book to change: all teaching methods are based on techniques to work-around the pitfalls it places in the path of the learner. At primary level, the major emphasis is on the mastery of the book as a medium and the techniques for constructing text. Handwriting, for example, is prerequisite. In such an environment a medium that does not make these demands has no place. The same is true of computation. The capacity of the computer to do sums, for which every shop-keeper is grateful, (salespeople get the bill correct and stock control is simplified), is seen as mathematically antagonistic and the possibility of the medium to aid the learning of arithmetic and the understanding of number is denied.

To paraphrase Marshall McLuhan, the medium makes the mind and there is an implicit belief that the mind will not be well-made if a learner uses a medium that carries out mental operations. This is the argument against writing that was used by Socrates. We know much more about brain maturation than we did a quarter century ago. Specifically, we know that the executive of the brain is in the front part, which is massively connected to the rest of the brain. These connections mature in the years of primary school and their strength is very highly influenced by experience. Interaction with a medium that requires an apprenticeship in grammar before its content may be accessed will mould a developing brain differently from that with a medium that can assist and may also be tuned to the developing mind. It is arguable that by doing away with the arduous grammatical apprenticeship the development of the mind may be improved. Consider the beneficial effects of writing, which eliminated the need to memorise everything. A more capable medium may well build more capable minds.

So intrinsic are traditional media to education that they are invisible. Educationalists are unaware of them and they make use of them unconsciously. This is not true of the computer. It is an alien intrusion into the process of education. For this reason it is classed as technology: information and communication technology (ICT) now abbreviated to 'technology' alone. But, a medium it is, which is why 'Turing medium' is a far better term to use henceforth. However, the failure to view it as a medium powerfully explains the regression we see in educational robotics.

If the medium is alien to education, children will not be taught to master it. Neither will the teacher have mastery of it as a medium. Their use of it is on a conscious rather than automatic level. This disrupts the process of teaching. Thus, those who wish to introduce computer-based elements into the curriculum are well advised to mask any aspects that might cause conflict with traditional teaching method.

This, it may be argued, was the case from the outset. The Logo Turtle was a novelty that apparently did not impinge on traditional maths. Unfortunately, it was all too easy to go beyond with Logo and challenge tradition. The arrival of the graphic user interface provided a welcome diversion. Use of small pictures to convey notions does not conflict with the traditional learning and nicely misdirect children's attention from the potential conflict. From this perspective, the WeDo interface is to be preferred to Scratch, which retains writing on its blocks (figure 6).

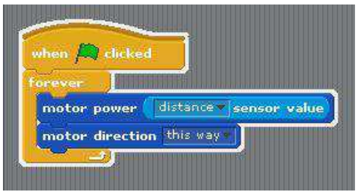

Figure 6. The Scratch equivalent of the WeDo program in fig.3..

The subject matter is also kept at a distance. The return to the toy-box, as illustrated by the WeDo models, is a good strategy to avoid any curriculum conflict whilst introducing the engineering elements that are considered necessary. This reflects an engineer's ploy of great antiquity: mechanical amusement to defuse fear of the unnatural. The drumming monkey captures this spirit beautifully. Similarly, the software is a toy-box version of an adult programming environment made as pictorial as possible. If letters and numbers are used, they are inserted in little boxes by clicking rather than writing. Finally, WeDo comes as a complete package ready to use out of the box. Thus, it is curriculum enhancement not curriculum intrinsic; and no conflict arises.

B. Reason to be Cheerful

Looking back toward 1987, a very different world comes into view: no mobile phones, no internet, no computers built into cars; no digital cameras. The Kindle e-reader and the tablet were undreamt of. The world was analogue. Today, primary school children starting school carry with them their mobile phone – so they can call home at any time. But the safety link provided by mother also has a camera and a range of apps that are ready to build a mind different from that of their parents. They carry a keyboard and screen, and a clock, calendar and calculator with them. Alexander [1] begins to recognise the change, as the following extract shows:

"Now … children are increasingly autonomous. Much of their out-of-school learning is electronic and beyond the reach of either parents or teachers. … They seek material pretty well at will, using mobile phones, PCs and laptops which are increasingly standard property in English households. … not passive surfers who read, watch and listen, but 'peerers' who use electronic media to share, socialise, collaborate and create."

But he seems unable to make the cognitive connection to the concept of a new educational medium. His focus is on evaluating information, internet danger and the purported but unsupported neurological dangers of screen-based learning.

Nevertheless the zeitgeist is hugely different from 1987 and children, if not educational traditionalists, readily embrace the new medium. Moreover, the economics have significantly shifted in favour of Turing media. Now that the infrastructure is in place, digital publication is far more economic than its paper counterpart.

C. Towards Turing Teaching

The development of teaching method intrinsic to the new medium requires a conceptual shift from traditional method and standards. Three steps may be identified.

1) Understanding the medium: One hundred years on from the birth of Alan Mathison Turing we live in a world of Turing machines. A Turing machine, by definition, is not of itself intelligent; although it can be made more clever, faster and accurate than any human. I.e. it offers mechanical support to thought; as clothes offer mechanical support to temperature regulation or the book supports memory. Like a human or textual memory it may store information. In addition it can process that information according to rules that the human capacity for scientific enquiry has elucidated. The relation of the Turing medium to verbal instruction and the book requires dispassionate evaluation, and the intellectual presumptions of traditional teaching demand challenge.

2) Understanding the human: The technicity adaptation proposal radically reconfigures our perception of what it is to be human. Technology displaces language as the cradle of cognition whilst revealing the capacity of language, once it is a publicly inspectable object, to open a window on the cognitive process. It shows that humans have an additional and more powerful quality of concept that provides entrée to science and explains its explanatory success. This adaptation comes on-stream pari parsu with prefrontal maturation during the primary school years.

3) Catalysing a transition: To date research into both computers and robotics in primary school has been limited by the constraints of traditional teaching method. The effects of the constraints of traditionalism are nicely illustrated in the Arlegui et al paper at RiE2011 [14]. It is noteworthy that traditional method has been reaffirmed in relation to the processing capabilities of Turing media in all jurisdictions. It is only in those few locations where a curriculum is in place to teach mastery of the medium, and where that curriculum is professionally taught, that indicators of how teaching might be are to be seen.

Ilieva's TRTWR2010 poster shows what might be. Here robotics is an integral part of the curriculum for mastery of the computer as a medium and the teaching of LEGO construction (table 3). An investment in LEGO bricks and Control Lab interface and (Win95) Logo some fifteen years ago provided a conceptually appropriate environment that remains better than any available. For primary education the controllable elements fit the children's world-knowledge and the software makes explicit the relationship between program and action. The longevity of the LEGO system components when depreciated over their lifetime makes investment in robotics economically viable. It becomes possible to construct a curriculum that is continuous throughout primary school. From inspection of the grid it is immediately apparent why Logo has been preferred over pictographic programming: Logo enhances literacy and numeracy whilst introducing the basics of computer science.

TABLE 3
FACSIMILE OF ILIEVA'S CURRICULUM GRID FOR ICT AND LEGO

	ICT	LEGO	TEAMWORK
1st grade	Introducing the computer. Learning to use the mouse. Working with graphics and sound. Using ToolKid, specially designed software	Getting to know the construction material. Make the first simple models. Using LEGO bricks	Individual work to a teacher example. Individual work on their own idea. First steps to learn to work in a team of two. Outcome: individual projects
2nd grade	Learning to use the keyboard. Working with graphics, text, animation and sound and combinations of these. Using ToolKid.	Make a variety of more difficult constructions. Make more realistic models with many details. Learn to recreate a first simple situation. Introducing controllable models and programming.	Working individually or in twos or threes on one common theme discussed with and agreed by all children. Every construction part of the common project. No isolated models allowed. Outcome: class project.
3rd grade	Individual and class projects that combine different types of information. Using ToolKid, MS Word and Paint and the Internet. Product: movies, stories, comics, slide-show.	First robotics projects using sensors. Programming with procedures. More complex situations.	Freedom to choose and change team membership in the context of each new class project. Learn to cooperate with the work of younger children on school projects.
4th grade	Use of the Internet, Paint, Word and PowerPoint to make individual and class projects based on the curriculum for other school subjects.	Larger and more complex projects. Programming with super-procedures and conditions.	Coordinate the work of all classes on whole school projects. Organise a presentation, introducing the work of all children, to the school and parents.

The catalytic step to transition would be a switch from using the computer to enhance traditional teaching of literacy and mathematics to using it as the prime medium. The institutional structure of education militates against such a transition at present. The pressure for change will come from app-happy mobile device wielding children and the primary school teachers who have to resolve the conflict that results, rather than from academe.

V. NO CONCLUSION

This paper set out to consider three issues. The first is proven: there has been conceptual regression in robotics. The second has been achieved: there is a compelling argument in favour of the technicity adaptation; which offers a new and exciting perspective upon what it means to be human.. The t/v concept distinction with its associated entropies explains the power of scientific over perceptuo-linguistic thought. The third has the merit of shifting focus from the technology to the characteristics of the medium; which is shown to possess greater cognitive power than text. The terms Turing medium and Turing teaching are commended for future use, in contrast to ICT and technology, where the new medium is used to its full capacity. Robotics is seen as intrinsic to Turing teaching.

The paper concludes with a rallying cry. There was a tradition in 1960s student politics for the engineers to keep a low profile. However, when they felt matters were getting silly they descended en-masse to vote down the hotheads. Engineers do not, in general, involve themselves in politics; they leave it to the lawyers. But there are times when they feel that their voice must be heard and then they do so powerfully. Now is such a moment. The traditionalists who determine what and how children learn in school do not come from an engineering background. They come from language and the social sciences. Innovation is alien to their mindset. They are alienated from the world that children are being born into. Increasingly, children arrive in school with a skill-set well attuned to Turing teaching but poorly adapted to traditional method; and their classroom behaviour shows it. Perhaps it is time for innovative engineers to make an assessment of the relative cognitive benefits of the book and computer in the beginning phase of education and demand, as a minimum, that all children are systematically taught mastery of the medium by a properly qualified teacher. The alternative is another quarter century of educational stasis in a technologically progressing world.

ACKNOWLEDGEMENT

The author wishes to acknowledge the contribution of Vessela Ilieva of NSOU "Sofia" to the thought in this paper.

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