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ENGLISH ORTHOGRAPHY AS A METAPHOR FOR EVERYTHING THAT GOES WRONG IN E-LEARNING OF MATHEMATICS

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1. *Why can learning mathematics go so wrong?*

In mathematics, the understanding that not every problem has a solution is a part of collective wisdom of the professional community.

I have a nagging suspicion that, perhaps, it is impossible to find a uniform way of teaching mathematics via a universal state-run programme that reaches out to every child in the country. Each child is different; it could happen that a uniform approach to teaching mathematics inevitably leaves out or even harms some groups of children.

We all had met people who proudly claimed that they never understood mathematics and lived happily without it. Could it happen that we have to treat them as victims?

Alas, math phobia is too common and too widespread to be ignored. For me, an explanation of its roots lies in Stanislas Dehaene's quip [†]:

> We have to do mathematics using the brain which evolved 30,000 years ago for survival in the African savanna.

There were no books in the savanna, and arithmetic textbooks were even more conspicuously absent. All that stuff was invented and developed later, in a tortuous trial-and-error process spreading over millennia. The results are not perfect, as illustrated by the insane English orthography, which contributes to the epidemics of dyslexia in this country—and I will use orthography and dyslexia as principal running examples in my paper.

Indeed orthography, as well as arithmetic notation, is a result of a cultural evolution. By its nature, evolution does not produce optimal results: it produces only survivable results which are forever affected by conditions for survival at the earlier stages of evolution. Over the

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www.borovik.net/selecta

†S. Dehaene, *The Number Sense*. Penguin Books, 2001.

centuries, selection factors of evolution of orthography or arithmetic did not include suitability for use in a compulsory mass education.

People who developed math phobia, and, I conjecture, a significant proportion of people who are diagnosed with dyslexia and dyscalculia, are simply victims of neurological damage which they suffered at earlier stages of their education.

I have the moral right to say this in a brutal way because I am myself a fellow sufferer—I am, in effect, tone deaf. I have reasons to believe that my sense of musical pitch was damaged during my primary school years by a perpetually drunk music teacher with his out-of-tune accordion. Unfortunately, the system of mass musical education in my country was very patchy—I happened to grow up in a musically deprived area.

The fundamental flaw of all educational discourse is the undisputed and unmentionable assumption that education is always good, and that the influence of education is always positive. Any proposed reform of teaching of a particular subject is assessed by looking only at what it promises to improve; there are no compulsory checks for side effects and contra-indications. In pharmacology, the same attitude to development of new medication would constitute a criminal offence.

This is why I refrain from any recommendations on educational policy. I am afraid that any serious change in mathematics education might simply shift the damage onto a different group of children. I have even a worse fear—that we do not know, and will not know until this will have happened, what will this new group of victims be.

But our ignorance should not be taken for justification of suppression of an open and honest discussion. Also, we have no right to dismiss neurologically grounded maths phobia and dyscalculia as minority issues. In the environment of unavoidable exposure to damaging factors (and exposure to being taught arithmetic at school is as unavoidable as death and taxes), issues concerning small minority of population have tendency to become human rights issues. To take an example from outside the education domain, right now we witness debates around the "shadow flicker" from wind turbines which can allegedly trigger epilepsy attacks in a small number of sufferers, and this statistically minor side effect is likely to block erection of wind farms near populated areas. Will you disagree with such decision?

2. *Music*

So, I am functionally tone deaf—and no-one cares, this is my personal problem. Dyslexia is covered—and rightly so—by the provisions of Disability Discrimination Act 2005; tone deafness and amusia are not covered. The explanation of their different status is simple: reading and writing are compulsory in the modern society, while playing a violin not.

As it is the case with literacy, a number of difficulties encountered by mathematics education arise from it being compulsory and delivered in one-size-fits-all fashion. The cult manifesto, *A Mathematician's Lament* by Paul Lockhart [†] starts with a comparison with music.

> A musician wakes from a terrible nightmare. In his dream he finds himself in a society where music education has been made mandatory. "We are helping our students become more competitive in an increasingly sound-filled world." Educators, school systems, and the state are put in charge of this vital project. Studies are commissioned, committees are formed, and decisions are made—all without the advice or participation of a single working musician or composer.

So let us take a closer look at the analogy between music and mathematics.

3. The Art of Piano Playing

The non-compulsory nature of music education and its non-universal scope masks underlying difficulties and failures. Let us turn to the expert opinion, to the classical book *The Art of Piano Playing* [‡] by the famous pianist and piano teacher Heinrich Neuhaus (he taught in Moscow Conservatoire from 1922 to 1964 and had a brilliant succession of students from Sviatoslav Richter to Vladimir Krainev).

In his book, Neuhaus does not pull his punches and very explicitly describes the mainstream (instrumental) music education as a combination of two processes:

– development of musical skills in a student;
– accumulation of neurological damage.

Muscular spasms resulting from absorbtion of a wrong technique—and turning

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[†] `http://www.maa.org/devlin/LockhartsLament.pdf`.

[‡] H. Neuhaus, *The Art of Piano Playing*. Kahn & Averill, 1998. ISBN-10: 1871082455. ISBN-13: 978-1871082456.

> living hand with its nerves, muscles, flexible joints and pulsating blood, into a piece of wood with curved hooks

—are seen by Neuhaus as one of the main reasons why a piano learner stops in his or her development and cannot move to the next stage. Another reason is the growing disconnection between the technical and emotional sides of music. Neuhaus recommends, as a first exercise on a piano for a 5–6 years old child, an exploration of a single note, or piano key—a child is invited to play just one key, but play it gently, or firmly, or loudly, or in a quietest possible way, etc. From day one, piano playing is learned as a nuanced technique for the expression of the internal world, and a deeply interiorized attention to subtle technical details is encouraged and supported in the student. It goes without saying that the technique has to be correct.

But let Neuhaus speak for himself. Here are few random quotes:

> Let me cite two simple facts to prove that playing is easy: first, the keys move extremely easily, slightly more weight that that of a matchbox will suffice to make a string vibrate; for the finger this is an insignificant effort. Secondly, by raising the hand not more than twenty to twenty-five centimetres above the keyboard and from that height (h) dropping a finger or several fingers on to the key (or keys) with the "pure weight" of the hand without any pressure, but also without any holding back, *come corpo morto cadde* (as dead body falls) as Dante puts it, you get the maximum volume of sound, the dynamic ceiling of the piano. [. . .]

> . . . how many hundreds and thousands of of pitiful beginners—and during how many years—when brought by their teachers into contact with the keyboard for the first time tried to turn their living hand with its nerves, muscles, flexible joints and pulsating blood, into a piece of wood with curved hooks, to extract from these hooks such offensive combinations of sound . . .

> Subsequently, and even at the Moscow Conservatoire and at times even now, if a pupil did not have full control over his body, in other words when a pupil did not have sufficient freedom, I suggested the following exercises away from the piano: stand, letting one arm drop "lifelessly" like a dead weight alongside the body; let the other "active" hand pick it up by fingertips gradually raising it as high as possible and having reached the highest point suddenly leg go so that it should drop just *come corpo morto cadde* (as dead body falls).
> Would you believe it? The simplest of all exercises was at first beyond the possibilities of many of the frightened and cramped brigade.

Alas, every mathematics teacher has seen his own "frightened and cramped brigade": the similarities with learning mathematics are so

striking that Neuhaus' book can be read as a study in mathematics education.

4. *Dyslexia*

I have already mentioned dyslexia as a better known cognitive difficulty encountered by the system of mass education; for me, it is a paradigm of neurological problems of education. I take liberty to re-use some passage from my paper [†].

One of the world leading experts on dyslexia, Elena Grigorenko, succinctly summarised the causes of the current epidemics of dyslexia [‡]:

> The basic dyslexic impairment is caused by a unified mechanism, valid and functioning in all languages in which individuals with dyslexia have been identified. However, the manifestation of this unified mechanism is language- and culture-dependent. Dyslexia is only noted by educators, psychologists, and biologists and then investigated if these three conditions are met:
> (1) the phonological structure of the language must be sufficiently challenging to impose a serious obstacle for dyslexics,
> (2) the frequency of normal reading in society must be high enough to make failures noticeable, and
> (3) there must be a societal demand for mastery of this skill and an adequate number of professionals to support this demand.

I can only look in horror at the suffering of children taught to read English with its non-phonetic and non-transparent orthography.

Still, a look at teaching and learning to read could be useful as a parallel to teaching and learning mathematics.

5. *The Rubicon: compulsory versus optional use of ICT*

Everything run-of-the mill is immediately
perceived by me as propaganda. [. . .]
The future, because of its abundance, is propaganda.

Iosif Brodsky

Although these notes are concerned with mathematics education in general, their original motivation comes from debates around the use

[†]A. Borovik, A personal take on synthetic phonics. Selected Passages From Correspondence With Friends 1 no. 5 (2013) 29–44. http://www.borovik.net/selecta/wp-content/uploads/2013/08/Selected_1_5_Phonics.pdf.

[‡]E. L. Grigorenko, Developmental dyslexia: An update on genes, brains, and environments, J. Child Psych. and Psychiatry 42, no. 1 (2001), 91–125. DOI: 10.1017/S0021963001006564.

of Information and Computer Technology (ICT), or the so-called "e-learning", in mathematics teaching, please see [§] for a discussion of the wider context of these debates.

I watch, with ever increasing fascination, the e-learning bandwagon blissfully rolling towards a quagmire of a dyslexia kind. Indeed, e-learning of mathematics approaches a critical threshold: its proponents want to make it from optional into universal and compulsory. But unforseen neurophysiological and cognitive side effects of the use of computers could happen to be stronger than that of reading (where they lead to dyslexia)—we simply have not accumulated sufficient data of consequences of *compulsory* and *unavoidable* exposure to new technology. Indeed, so far most people who felt uncomfortable with computers could avoid or restrict their use. The compulsory use of computers, especially in school level learning, has a potential of blocking escape routes and may push hundreds of thousands of children to the neuropathology end of spectrum.

What strikes is that the "end users" of ICT feel that they would prefer to decide themselves whether they should use specific ICT solution. A report from the National Union of Students states unambiguously that

> Students prefer a choice in how they learn—ICT is seen as one of many possibilities, alongside part-time and traditional full-time learning, and face-to-face teaching. [†]

Unfortunately, many (if not overwhelming majority) of developers of ICT solutions do not consider this as an option—who will wish to develop an online assessment system, for example, if the students will have to be given freedom not to use it?

The aim of my notes is to formulate a warning (but I still need to think about the best way to communicate it) that such attitude could continue to exist only at our peril. We may expect that in a few years penetration of ICT into university teaching will start to reach saturation levels. Developers (and commissioners) of ICT either have to give their student users a legally protected (and binding on schools and universities) right of opt-out from the use of ICT, or to take responsibility for its potential unforseen consequences.

Besides somatic disorders already sufficiently prominent in the ICT

[§] A. V. Borovik, Information and Communication Technology in University Level Mathematics Teaching. The De Morgan Journal, 1 no. 1 (2012) 9–39. http://education.lms.ac.uk/wp-content/uploads/2012/02/Mathematics_and_IT.pdf.

[†] Student perspectives on technology—demand, perceptions and training needs. Report to HEFCE by NUS 2010, p. 3. http://www.hefce.ac.uk/pubs/rdreports/2010/rd18_10/rd18_10.pdf.

environment—such as repetitive strain disorder, tendonitis, "BlackBerry thumb", Carpal Tunnel Syndrome—we may well encounter a host of new psychopathological conditions.

To mention just one of many potential pitfalls, big American health insurance companies like Blue Cross and Blue Shield already cover treatment for computer game addiction as a psychopathological condition. In my personal experience, TARSKI'S WORLD [†], a brilliant piece of software for playing with Predicate Logic—I was using it 10–15 years ago—had already had a sufficiently disturbing side effects for a small number of students who got hooked and were prepared to spend the whole Easter break fighting with formulae in a simplistic, almost TETRIS-like interface. In my humble opinion, this was not normal.

I emphasise: I write about potential minority issues, which, by their nature, are usually recognised and acknowledged *post factum*. A cynic might say that what matters is the threshold size of the affected minority. Will schools, colleges and universities be prepared to decide what proportion of their students they are prepared to sacrifice?

Let us return to Elena Grigorenko's summary of the causes of the current epidemics of dyslexia. One of them is institutionalised compulsion to read and, crucially,

> ... *[...] an adequate number of professionals to support this demand*

For the e-learning movement, this is a killer formulation because, in respect of e-learning, this condition appears to having been met.

6. *Conclusions*

I would like to advise e-learning technologists to pause and reflect before crossing the Rubicon separating the optional and compulsory exposure of students to e-learning. In mathematics, we already have maths phobia and dyscalculia; I will not be surprised if some new form of mathematics-and-IT-related cognitive disorder is added to the list.

And I would like to repeat a question that I have already asked in my paper on dyslexia and synthetic phonics [‡].

[†]I used an early version of TARSKI'S WORLD: J. Barwise and J. Etchemendy, *The Language of First-Order Logic: Including the IBM-compatible Windows version of Tarski's World 4.0*. Cambridge University Press, 1993. ISBN-10: 0937073903; ISBN-13: 978-0937073902; an improved version is now available as D. Barker-Plummer, J. Barwise and J. Etchemendy, *Tarski's World*. Chicago University Press, 2008. ISBN-10: 1575864843; ISBN-13: 978-1575864846. `http://ggww.stanford.edu/NGUS/tarskisworld/`.

[‡]A. Borovik, A personal take on synthetic phonics. Selected Passages From Correspondence With Friends 1 no. 5 (2013) 29–44. `http://www.borovik.net/selecta/wp-content/uploads/2013/08/Selected_1_5_Phonics.pdf`.

Why are we so sure that the "alphabet" of mathematics, as we teach it—all that corpus of terminology, notation, symbolism—is natural? It is a result of a long cultural evolution. But, as I have already tried to explain, evolution does not produce optimal solutions, it produces acceptable and survivable solutions. English orthography, with English language dominating the world, is definitely survivable—but it is obviously not optimal, for otherwise we would not have the plague of dyslexia. Imagine that there were no other languages in the world—would we suspect that there were problems with English orthography?

We have nothing to compare our mathematical language with—how do we know that it is optimal?

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