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A NEO-DARWINIAN VIEW OF TECHNOLOGICAL LITERACY: A CURIOSITY GENE, TECHNICITY AND 'LEARNING BY DOING'

Abstract

Langrish's 5 basic requirements for Darwinian evolution are explored in the context of product development, particularly guitars. Thistlewood's three categories of designing – artefactual, evolutionary and historicist – are discussed and the constant probing at the boundaries of the guitar and other musical instrument families is noted. Doyle's concept of technicity as a potential explanation for such restlessness is examined. Evidence supportive of Doyle's concept from Loughborough University's 'polymer guitar project' is included. The paper concludes by discussing the validity of a product evolution analogy and the implications of a neo-Darwinian perspective for design and technology education. 'Learning by doing' is discussed and the view that the ultimate goal of design and technology education is bridging the gap between technological literacy and technological capability is suggested.

Key words: *neo-Darwinian**, categories of designing, technicity, evolutionary analogies, learning by doing, technological literacy and capability*

Introduction

In a 2004 paper, Langrish discussed the ideas associated with a Darwinian interpretation of product evolution and at the *2006 Design History Society Conference* concerning *Design and Evolution* presented the five basic requirements shown in Table 1. At the same conference, Norman (2006) discussed the strength of the product evolution analogy in the context of the

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1. The existence of variety – different kinds of things having mixtures of differing properties held in varying amounts

2. A competitive selection system which picks 'winners' from the different things, properties, amounts of properties or combinations of these

3. A system which replicates the 'winners' or some proxy for the winners. (e.g. male animals may compete but real competition is between the properties of the animals and only those properties which are linked to replicators get passed on). Preferential replication gradually replaces the 'losers'.

4. There has to be a system for the generation of new varieties because the above three on their own lead simply to a steady state (including oblivion as an extreme steady state). New varieties take us back to 1 and the continuation of the process.

To which it is necessary to add a fifth:

5. Even with the addition of 4, the system of change would slow down through diminishing returns, unless we have a fifth feature viz. changing the rules of the competitive selection system. Without changes in the environment or some other form of rule change, evolution would stop.

Table 1 Towards a general theory of Darwinian change: five basic requirements (Langrish, 2006:9)

development of the guitar and concluded that Doyle's (2004) concept of technicity might provide a fuller explanation for the associated human behaviour. These concepts, as well as Thistlewood's (1990) observed categories of designing, are explored here in order to provide a neo-Darwinian[1] perspective on some of the key issues concerning design and technology education.

Thistlewood's classification of products

When discussing the classification of products, Thistlewood (1990) identified three types: archetypal, evolutionary and historicist. Archetypes are products which have developed through the generations and where 'significant departure from these characteristics leads at best to less-fit artefacts and at worst … to retrograde mutations' (*ibid*: 14-15). Musical instruments are one of Thistlewood's examples of archetypes in daily use and the others he lists are bowls, jars, tables, chairs, traditional water-craft and age-old instruments, like spades, hammers and cutting blades. In discussing the possibilities that designing archetypes presents, he comments as follows.

> They represent a phase of human design enterprise before authorship was celebrated. The contemporary designer's contribution to their re-presentation consists in attending to secondary features such as materials, colours and decorative treatments: essential forms have ceased or virtually ceased evolving and are correspondingly non-negotiable. (*ibid*: 14)

Archetypal forms of guitars have undoubtedly developed and many examples of current makers addressing such secondary features can be found (eg early classical (parlour) guitars, steel-strung acoustic guitars based on the Martin designs and electric guitars based on the Fender Stratocaster).

Torres and the Spanish guitar: an 'evolutionary' step?

Thistlewood's second category of designing refers to evolutionary steps, which …

> … obliges the designer to invent new forms that invalidate all their predecessors. Electronic typesetting has invalidated hot metal. …
> …
> 'Evolutionary' designing compresses (and in this sense emulates) the centuries-long processes of development that have produced 'archetypal' artefacts. Much of this emulation is effected by means of 'accelerated use' – by subjecting artefacts to harsh regimes of durability-testing and programmes of mechanical wear-and-tear. This is pragmatic research and

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[1] The term neo-Darwinism follows Langrish's use ie 'to mean Darwin's natural selection plus genes (which were discovered later). It is not suggested that design is somehow genetic. Design evolution is the evolution of ideas, and the Darwinian evolution of ideas is called "memetics" from the concept of self-replicating ideas called memes by Richard Dawkins (1976)' (Langrish:2004:4-5)

development. Much else, however, is achieved by imagining desirable but currently impossible outcomes - the opposite of pragmatism. (*ibid*:15-16)

Such a remarkable step took place in guitar making in Spain in the nineteenth century.

> The instruments played by Sor and his famous contempories – Dionisio Aguado (1784-1849) and Matteo Carcassi (1792-1853), for instance – were, however, far inferior to the guitars at the disposal of today's players. All that changed – with a quantum jump in the development of classical guitar construction – at the hands of a carpenter from San Sebastian de Almeria, Antonio de Torres Jurado (1817-1892). Better known simply as Torres, he was without a doubt the most important figure in the history of guitar design and construction. Musicians who played his guitars immediately discarded those of other makers. Throughout Spain luthiers adopted Torres' designs. In fact, to this day, classical guitar makers still construct their instruments in the manner of Torres   (Denyer, 1982:42)

The Torres construction guitars came to dominate the design of the Spanish guitar because of their superior musicality, but also because they were initially played by Francisco Tarrega – "the Chopin of the guitar" (Bonds, 2001:66); then by Andrés Segovia, who recorded their sound, thereby introducing the cultural power of exposure via mass media (Huber, 1994:12) and because they offer luthiers security for their reputation, established know-how and some flexibility (ibid:40-41).

The cultural influence is evident from the development in the USA of the only real alternative to the Torres construction guitars. Christian Friedrich Martin (1796-1873) brought his knowledge of European practice to America when he arrived in 1831, having been a foreman in Johann Staufer's shop in Vienna. The early guitars he made in America maintained their European influences, but over a period of 15-20 years his own designs emerged, most notably the cross- or X-braced top. 'The great majority of Martins from 1850 onwards have some form of X-bracing' (Gruhn and Carter,1993:18).

The search for volume: historicist designing

The third category of designing which Thistlewood identified was historicist, in which …

> … the designer is conscious of working within an historical continuum. Buildings are the most obvious manifestations of this tendency … They are compared with antecedents that are still evident in the world around them, which in effect constitute a museum of architecture and building. Although houses have a familiar symbolism and of course an archetypal function – shelter – they have no essential form …   (*op cit*:15)

The emergence of the electric guitar is a long and fascinating story, but it is noted here as an example of Thistlewood's historicist designing. The sound of the electric guitar is largely determined by the pick-ups used, the weight of

the body, and to some extent the type of wood selected, but there is no essential form. A huge variety of designs have emerged, including of course the Gibson Les Paul, the Fender Telecaster and Stratocaster, but there are many others. They appear in different colours and materials eg wood, of course, but also bronze, aluminium, acrylic, polymer foams etc

An interim discussion

So within one product family, it is possible to identify all three of Thistlewood's categories. Artefacts which have essentially ceased to evolve and where at least some designers have re-presented familiar forms. Clearly, some humans are not satisfied with simply reproducing artefacts, but wish to 'leave their mark' or to give the product something of their individual character. Evolutionary steps are constantly being sought and when no essential form is required (historicist designing) abundant variations ensue.   When Dasgupta was considering whether creativity could be considered to be a Darwinian process, the lack of randomness in the ideas which emerged was a key argument in his rejection of the idea (2004). He examined three case studies from the histories of natural science, technology and art[2] and concluded:

> … a fecundity[3] in the generation of variations on which the selection is supposed to work according to the variation-selection model is not evident in any of the examples.
> In none of the case studies presented here is there any evidence whatsoever of blind variations being generated. On the contrary, the cognitive process in each instance was goal driven and knowledge driven.   (411-412)

Certainly much of the evidence presented in relation to guitar development (see Norman, 2006a for more detail) supports Dasgupta's findings of goal-directed, rather than random activity, but there is also some support for designing which is more analogous to the concept of 'random mutations' (eg some electric guitar designs). The analogy is stronger when looking at a whole product family than particular case studies of individual design activity.

For guitar development, Thistlewood's concept of evolutionary designing can be seen as related to periods of static technology and fixed goals.   It is interesting to note how the emergence of new materials technology has re-awakened some innovative ambitions. Carbon fibre has been explored by Greg Smallman (in collaboration with the guitarist, John Williams) as a material for Spanish guitar components in order to improve the soundboard response. It has also been explored by the Rainsong company in order to make complete steel-strung acoustic guitars. The 'polymer guitar project' at Loughborough University has been seeking to develop guitars using expanded polycarbonate soundboards, resulting in the business venture, Cool

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[2]The case studies were in natural science, Jagadis Chandra Bose (1858-1937) and his 'Monistic Thesis'; in technology, James Watt (1736-1819) and his 'Separate Condenser'; and in art, Pablo Picasso (1881-1973) and his 'Picture from Afar' (Guernica)).
[3] Within biology or demography fecundity refers to the ability of an organism or population to reproduce

Acoustics (www.coolacoustics.com). There is comparable experimentation in the violin family (Revkin, 2006).

The 'natural evolution' analogy: technicity

The development of the guitar seems to be characterised by issues relating to 'technical and cultural lock-in' of particular designs, but with a constant probing at the boundaries of the guitar family. Whether it is re-presenting archetypal designs, seeking new evolutionary steps or generating more historicist possibilities it seems impossible to stop. Why do designers re-examine the existing boundaries of the guitar family? Certainly the reality that at least some of them do provides supporting evidence that the first of Langrish's five basic requirements for a Darwinian model can be met, but can this be explained by anything more fundamental than some perceived dissatisfaction with some aspect of a product's performance? (Petroski, 1993). It is possible that Doyle's concept of 'technicity' (2004) can help to move the argument on. This term might be seen as one of many expressions of a similar concept eg 'graphicacy' (Balchin,1972), 'technik', (Fores and Rey, 1979), 'designerly ways of knowing' (Cross, 1982), 'technacy' (Seemann, 2006), or indeed Archer's concept of 'cognitive modelling' perhaps (1981). It is not appropriate to review and distinguish these concepts here, simply to note that 'technicity' is but one expression of a number of related ideas.

Technicity

> Technicity might best be characterised by a creative capacity to:
> a) deconstruct and reconstruct nature, and
> b) communicate by drawing   (Doyle, 2004: 67)

At DATA's 2004 international research conference, Doyle explored this concept of technicity as the fundamental driver for human evolution.

> I make no apology for borrowing a term from philosophy and bending it to my purpose. Design and technology, unlike traditional academic fields, seems to lack an intellectual core: it's all about making things. For longer than I care to think, this has concerned me. Our technical capacity has transformed our planet and ourselves, and continues to do so. On an evolutionary timescale these changes have happened instantaneously. Developed over the last two decades, the field now called 'evolutionary psychology', offers interesting insights into how we came to be. Unfortunately, neither this new field …, nor its academic precursors …, has anything to say about how we are able to make things…
>
> In this paper I hope to do two things:
> 1) Tease out and clarify 'language' as an evolutionary adaptation.
> 2) Draw out the core of modern human behaviour: our ability to create and innovate   (ibid: 65)

The polymer guitar project

At DATA's 2005 conference, Norman and Pedgley reported an analysis of Loughborough University's innovative polymer acoustic guitar project in terms of this concept. This project was established as a case study to support a PhD research programme exploring the role of knowledge in design decision-making (Pedgley, 1999). A secondary focus was the establishment of a complete chronological record of a design innovation. The patent that resulted from the work is evidence that innovation did indeed occur (Norman *et al*, 1999). This chronological record also provided research evidence against which the technicity hypothesis, namely that 'innovation is to be expected [and that] technicity is its intellectual driver' (*op cit*:71) could be tested.

The chronological record of the polymer guitar project

During the polymer guitar project, various uses were made of 2D and 3D modelling media to assist with product design and development. Over the course of the project, these built-up into an archive including sketch sheets, logbooks, card and foam models, and working prototypes, as is usual for product design activity. Unusually, however, a detailed diary of designing was kept (Pedgley, 1997) in parallel to the product design activity, to satisfy the research objective of generating documentary evidence of designers' decision-making in relation to materials and manufacturing processes. The diary was generally completed at the end of each day's designing and often made specific references to design thinking embedded within 2D and 3D media. The resulting catalogue of diary entries comprised a chronological 'running commentary' of designing, spanning 227 project days over approximately two and a half years, with over 500 individual entries. For Owain Pedgley's PhD, the catalogue was analysed to track various aspects of materials and manufacturing decision-making, including the nature of cognitive modelling and information searches (Figure 1) For the 2005 conference paper, the diary catalogue was re-analysed for evidence of technicity.
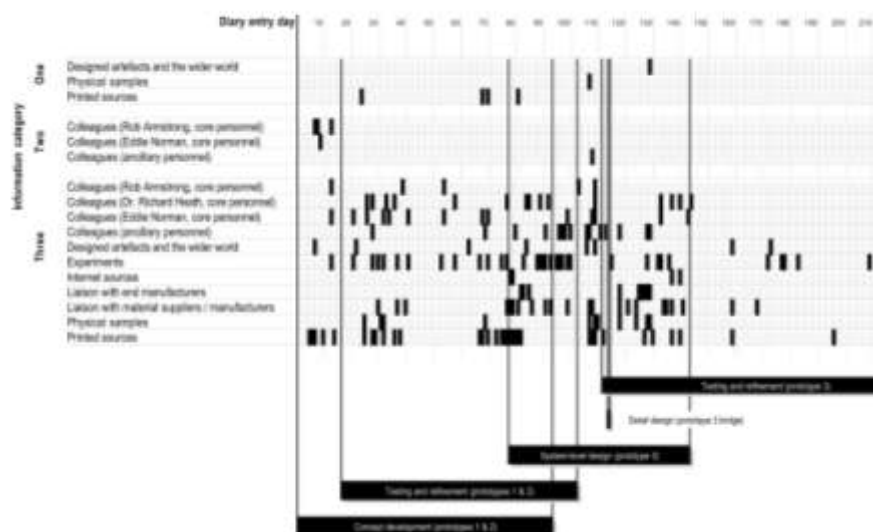

Figure 1 Materials and manufacturing information searches for the polymer acoustic guitar (Pedgley, 1999:231)

Mining for evidence of technicity

Table 2 shows some characteristics of technicity identified from Doyle's paper (*op cit*, 2004) grouped under three headings: language, deconstructing and reconstructing, and drawing.

Grouping	Technicity characteristic	Page	Comments
Language	an organ of social cohesion	68	'Creativity is not in language, though creativity co-opts language'. (70)
	intentionality	68	… related to our theory of mind
	shared memories	68	… essential for meaningful descriptions
Deconstructing and reconstructing	identifying different making strategies	69	… described in terms of making a ring
	rehearsing alternative scenarios	69	… linked to imagination and the human theory of mind
	a secure cultural foundation	69	… historical evidence is cited suggesting that this is a requirement for innovation
	blindingly obvious	69	… a characteristic of 'creative leaps' in retrospect
Drawing	use as an external memory system	69	… part of the construction process
	development to serve a novel application	70	… sketching styles relating to particular aspects of deconstructing and reconstructing?
	use of drawing instruments	70	… indicated as drawing tools, but would clearly extend to CAD

Table 2 Ten characteristics of technicity identified from Doyle's paper

Many of the entries in the diary catalogue could be identified with one or more of the characteristics of technicity listed in Table 2. The following diary entries (Figure 2) illustrate some of these characteristics (for more examples see Pedgley & Norman, 2005:134-137).

1. Language: shared memories

Date 13.6.96	Day 7	"Continuing product analysis exercise at the moment. → formulating ideas/getting to know 'guitars' rather than specifically designing a new one …"

2. Deconstructing / reconstructing: rehearsing alternative scenarios

| Date 28.10.96	Day 20	"To have bridge interconnecting with soundboard (i.e. 1 mould) would be tricky. Bridge= reasonably intricate = std. moulding with non-reinforced plastic (i.e. a different material to the soundboard, so, therefore, could not be integral). Fibre reinforced would not allow for such intricacies (also, means soundboard is no longer a flat 'sheet' which could, if appropriate, be cut out - a lot cheaper than moulding)."
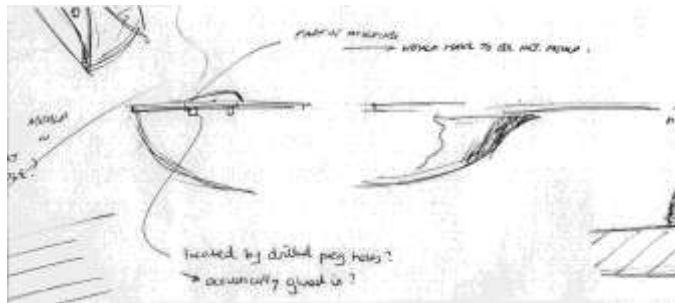
Rehearsing alternative scenarios

3. Deconstructing / reconstructing: a secure cultural foundation

Date 16.7.97	Day 39	"[Meeting with Rob] Rob explained to me how I should go about building the top-plate, and gave an indication of the materials to use, giving me confidence and a 'green light' to go ahead with building something that he was happy with. It had been a long time since I had seen Rob, so I wanted to get his 'stamp of approval' on the work done and the direction now being taken, especially concerning what materials to start with. It had been up to me though, to find a design direction from the conflicting ways of working of a crafts-designer client (Rob) and a materials specialist (Dick)."

4. Drawing: use of an external memory system

Date 27.4.98	Day 143	"I used this left-hand drawing to remind me of how the prototype will be constructed around the neck. It led me on to thinking about the same in the mass-manufactured proposal… the block was providing stability, and rigidity in particular - how could this be achieved in the mass manufactured version, using lay-up/moulding? A web of walls I thought, rather like strengthening ribs in injection moulded components… The idea was then superseded on DS55 main."
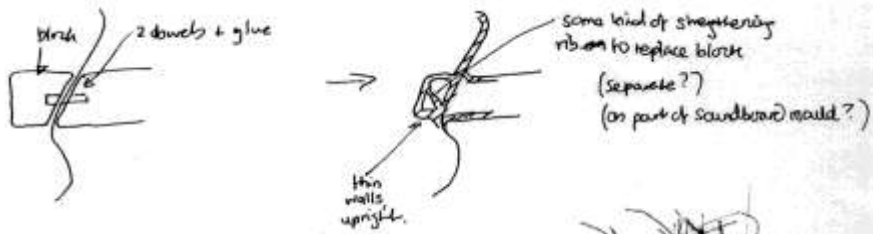
Use of an external memory system

Figure 2 Entries from the diary of designing supporting the technicity hypothesis (Norman& Pedgley, 2005)

A neo-Darwinian perspective on design and technology education: learning by doing

Is it plausible to take the 'technicity hypothesis' view that to be human is to be innovative and, if humans engage in activities of this nature, then innovation is inevitable? Human decision-making is an expression of the art of making judgements based on incomplete information about existing factors and future consequences. This is the essence of design activity, and hence then of the existence of products and their associated technology. In the same way that each game of chess is highly likely to be different, so with product design dependent on a multitude of sequential decisions, the designs will inevitably be different. So, in some respect, every resolution of a design problem could be seen as innovative, in the sense that with respect to some factors it is a 'better fit' for the design intentions than its predecessors. It is a matter of judgement as to whether the better fit is of more value than other better fits. So, on the view that technicity can be understood as the capability underlying human decision-making in the face of uncertainties, perhaps innovation can be interpreted as inevitable and product evolution considered the survival of the most valued.

The constant probing at the boundaries of the guitar family could be seen as a demonstration of technicity, perhaps a 'curiosity gene', or, given the potential planetary consequences, even a 'self-destruction' mechanism. Much recent research by Baynes has focused on understanding the behaviour of very young, pre-school children when designing (1992, 1994, 1996)[4]. The playful behaviour of the young of a species is often strongly indicative of what the adults must do to survive, and the exploratory behaviour of young children demonstrates the fundamental nature of 'learning by doing'.

Learning by doing is one of the ways in which designers develop the 'recipemes', a form of memes (Dawkins, 1976) which Langrish describes as transmittable ideas about how to do things' (2004:17). He uses Abu-Risha's concepts (1999) in order to describe designing in terms of the 'purposive pattern recognition (PPR)' between the recipemes and the 'selectemes', which are 'ideas about the sorts of thing you want to do. Selectemes are involved in making decisions between alternatives. They provide motivation; they are values' (*op cit*: 17). As Langrish noted both recipemes and selectemes can 'sometimes be transmitted without formal language' (*ibid*:17), and this view of designing is supportive of Doyle's analysis of technicity as the essential human characteristic which has led to human domination of the planet. Some of the replicators of product evolution are the products themselves, which embody the thinking of their designers, and hence the importance of museums for design education. Similarly, other replicators are embodied in the skills and know-how which are passed from one generation to another through 'teaching by showing' (Norman, 2000).

Langrish also describes a third type of meme.

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[4] These 'Orange Series' publications are dowloadable from Loughborough's Design Education Research Group website at www.lboro.ac.uk/idater/

> … the "explaneme," must be added because of the human propensity to ask "why?" As long as humans have had a language, they have told stories, and good stories get replicated. If someone discovers a new recipe, people will ask why it works. Explanemes ar the ideas that provide the basis for answering the "why" questions. They range in sophistication from simple stories to complex mathematical concepts, but they have two things in common, they offer an explanation and they need a language to be transmitted." (2004:17)

The designers' judgements (Norman 2006b) and the discipline of the market provide Langrish's second basic requirement for a competitive selection system, and design and technology education can be seen as providing the third ie a system 'which replicates the 'winners' or some proxy for the winners'. However, what view emerges of the role and shape of design (and technology) education, should such a neo-Darwinian perspective be taken?

Probing at product boundaries and the generation of alternatives can be seen as inevitable consequence of human behaviour. No design 'strategy' or process, singular or plural, is needed for this to be the outcome, and design education can perhaps be best seen as taking the form of 'sports coaching'. Sport for all' programmes from which the most talented emerge, and the recipemes available to these few are gradually increased until the 'PPR' associated with highly skilled designing becomes routine. Technological literacy is largely about the understanding of the selectemes that enable participation in a democratic society. Technological capability, if this concept is interpreted as the ability to intentionally bring about a specified outcome, requires 'PPR', and bridging the gap between technological literacy and technological capability could be considered to be the ultimate goal of design (and technology) education. Explanemes are the province of science, and on such a neo-Darwinist view, they are not an essential feature of designing or product evolution, and consequently neither are formal languages a requirement.

Returning to guitar development, many people have relevant selectemes which could define worthwhile goals (literacy), a small minority have the recipemes required to do anything about them (capability). Science provides few explanemes and their foundations are not secure (Norman 2006b). That is why luthiers exist, and at Cool Acoustics we work with Rob Armstrong, who has now made around 750 instruments, all successful and all different, and nobody gets lucky that many times in a row! Rob Armstrong believes in self-enlightenment and learning by doing, and, although guitars are but one product, they nevertheless illustrate the potential strength of the case for taking a neo-Darwinian perspective on design (and technology) education.

The optimistic outcome of such a view is the steady-state that Langrish predicted: a guitar perceived to be perfect. So, perhaps a key aspect of design (and technology) education should be minimising the changes in the

product environment that lead to innovation and the related over-consumption of the world's resources. Products that are 'eternally yours'[5].

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[5] The home page for the Eternally Yours organisation is http://home.planet.nl/~muis/eternal.htm

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