



This item was submitted to Loughborough's Institutional Repository by the author and is made available under the following Creative Commons Licence conditions.



**CC creative commons**  
COMMONS DEED

**Attribution-NonCommercial-NoDerivs 2.5**

**You are free:**

- to copy, distribute, display, and perform the work

**Under the following conditions:**

**BY:** **Attribution.** You must attribute the work in the manner specified by the author or licensor.

**Noncommercial.** You may not use this work for commercial purposes.

**No Derivative Works.** You may not alter, transform, or build upon this work.

- For any reuse or distribution, you must make clear to others the license terms of this work.
- Any of these conditions can be waived if you get permission from the copyright holder.

**Your fair use and other rights are in no way affected by the above.**

This is a human-readable summary of the [Legal Code \(the full license\)](#).

[Disclaimer](#) 

For the full text of this licence, please go to:  
<http://creativecommons.org/licenses/by-nc-nd/2.5/>

# Innovation in design and technology: the polymer acoustic guitar and the case for the relegation of 'the design process'

Dr Eddie Norman, Senior Lecturer, Department of Design and Technology, Loughborough University, UK

## Abstract

*Innovation and creativity are key aspects of design and technological activity. The development of the polymer acoustic guitar at Loughborough University has been recognised as a highly innovative project having received three innovation awards from major bodies. This paper describes three key aspects of the development, in particular the capability to imagine future possibilities, the role of knowledge and appropriate prototyping. These aspects lie at the heart of the innovation, although, of course, the whole activity was supported by key design skills, such as drawing and CAD. Some aspects of design epistemology (ways of knowing that facilitate designing) are discussed using evidence from this project, for example, the roles of 'knowing that' and 'knowing how' and the supposed tension between 'craft skills' and 'modern technology'. The importance of fitness for purpose when prototyping is emphasised and the link to the problems associated with product outcomes and innovation noted. A model of design and technological activity is discussed which emphasises the role of knowledge in realising design possibilities. This model was first presented at DATA's Millennium Conference (Norman 2000) and is a modification of one discussed by Roberts (1992). It incorporates the idea of technology for design as the summation of knowledge, skills and values (Norman, 1998) and provides an alternative way of thinking about design and technological activity. It is argued that existing ideas surrounding 'the design process', as represented by a series of stages derived from systems analysis, are a significant stumbling block to promoting innovation.*

## Keywords

*innovation, imagination, knowledge, prototyping, polymer guitar*

Innovation and creativity are becoming anticipated aspects of successful design and technological educational activities and teaching, learning and assessment strategies that facilitate innovation and creativity are at the heart of many current debates. This paper seeks to address these issues using the development of the polymer acoustic guitar as a case study. This project began in 1992 and the possibility of gaining greater understanding concerning 'technology for the purposes of those engaged in designing' (referred to here as 'technology for design') was published in a special edition of Physics Education in 1993 (Norman). It was pursued as a case study for a PhD from 1995–99 (Pedgley, 1999). The author was awarded an Invention and Innovation Fellowship by NESTA<sup>1</sup> in November 2001 to pursue the development of the polymer acoustic guitar, and jointly with Dr Owain Pedgley, a HEROBC<sup>2</sup> Innovation and Regional Fellowship in July 2002 and a Gatsby Innovation Fellowship in January 2003 to continue this work. It has been recognised as a highly innovative project in the design and technology area. So what can be learnt from it?

This paper covers three areas:

- imagining future possibilities
- knowing that and knowing how
- prototyping and presentation.

## Imagining future possibilities

From a design perspective an all-polymer acoustic guitar offers the possibility of low cost components and assembly, engineering accuracy and repeatability, new forms, finishes and styling opportunities. From the player's perspective there will be good playability (because of the low action resulting from the precise assembly), and reduced tuning and instrument care issues (because of the improved environmental stability of polymers in relation to temperature and humidity).

From an environmental perspective, recycled polymers could be used instead of tone woods, some

<sup>1</sup> NESTA stands for National Endowment for Science, Technology and the Arts

<sup>2</sup> HEROBC stands for Higher Education Reach Out to Business and Community

of which are banned under trade agreements. From a social perspective, polymer acoustic guitars could be competitively assembled in advanced economies, whereas the manual assembly of wooden instruments cannot now compete with the developing world. But ... can an appropriate sound quality be achieved?



Figure 1: A vision of an all-polymer acoustic guitar (Dr Owain Pedgley).

This is not the first time that this possibility has been considered. Figure 1 shows Dr Owain Pedgley's vision of what an all-polymer acoustic guitar might be like, and Figure 2 shows a design by Mario Maccaferri that went into mass production. (Maccaferri was a luthier, famous for the Maccaferri-Selmer guitars played by Django Rheinhardt). However, these polymer guitars were generally felt to have a 'thrashy' sound.

'Although Maccaferri continued to believe in plastic – as late as 1990 he performed a recital on a plastic violin – the plastic guitars were not successful. His plastic ukuleles however, were runaway best-sellers in the 1950s.'

(Gruhn and Carter, 1993: 220)

Irrespective of the technological hurdles to overcome, the first step in such a project is being able to imagine the desired outcome. A model of designing which emphasised this idea of a mismatch between the existing and desired states of affairs was put forward by Roberts in 1992. Figure 3 shows a visual representation of this idea of problem resolution and Figure 4 shows this model developed to suggest the nature of design and technological activity (Roberts, 1992: 39-40)

The need for this kind of starting point is reflected in the backcasting technique often advocated for imaginative approaches to sustainable design i.e. 'considering desirable future scenarios and working



Figure 2: Maccaferri's polymer acoustic guitar.

backwards to determine what needs to be done to get there' (Charter and Tischer, 2001: 128). It also echoes Peirce's idea of 'abduction' (as opposed to deduction) (Buchler, 1978). In the context of sustainable design it is often argued that it is conventional thinking that has created many of the issues and it is more creative thinking that is going to show the way forward.

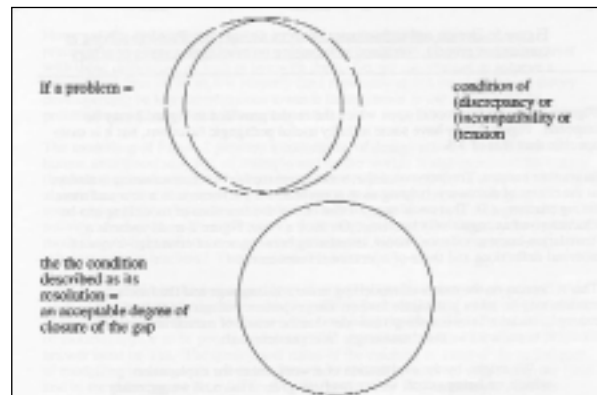


Figure 3: Designing as problem resolution (Roberts, 1992: 39)

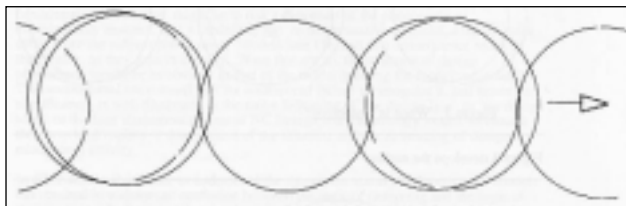


Figure 4: On-going design and technological activity  
(Roberts, 1992: 39)

### Knowing how and knowing that

The nature of knowledge in relation to designing is best thought of in relation to the writings of Gilbert Ryle: ‘knowing how’ and ‘knowing that’ (1949). Pursuing a vision can engage both categories of knowledge. Knowing that something is possible gives it a low priority in the consideration of the feasibility of a task and helps to focus attention on the more ‘problematic areas’. That is not to say that knowing that something can be done means that it is easy. Figure 5 shows the polyurethane (PU) back and fingerboard mouldings designed in collaboration with Beechcraft Ltd for the all-polymer prototypes. David and Norrie Beech are experts in designing for the reaction injection moulding (RIM) process. It was known that this could be done, but it still took considerable time, expertise and money to achieve it.



Figure 5: RIM polyurethane back and fingerboard acoustic guitar mouldings.

(The funding for this stage of the project was provided by NESTA). It was also known that PU was not recyclable, but similarly it is known that injection moulded thermoplastic versions would be. This would cost even more money to demonstrate, but it is not really in doubt.

Sound quality from a polymer soundboard was quite a different matter however. It was not known that this was possible. ‘Know how’ was the way forward.

‘When a person is described by one or other of the intelligence-epithets such as ‘shrewd’ or ‘silly’, ‘prudent’ or ‘imprudent’, the description imputes to him not the knowledge, or ignorance, of this or that truth, but the ability, or inability, to do certain sorts of things. Theorists have been so preoccupied with the task of investigating the nature, the source, and the credentials of the theories that we adopt that they have for the most part ignored the question what it is for someone to know how to perform tasks. In ordinary life, on the contrary, as well as in the special business of teaching, we are much more concerned with people’s competences than with their cognitive repertoires, with the operations than with the truths that they learn. Indeed even when we are concerned with the intellectual excellences and deficiencies, we are interested less in the stocks of truths they acquire and retain than in their capacities to find out truths for themselves and their ability to organize and exploit them, when discovered.’

(Ryle, *ibid*: 28-29)

Rob Armstrong is a world-renowned luthier from Coventry who knows how to achieve sound quality in guitars. He has made approximately 700 guitars, all different. He knows how to respond to the materials he is working with (cedar, spruce, rosewood, mahogany – yes – but also polystyrene!). My Rob Armstrong guitar is number 673 and Figure 6 shows it with its maker.



Figure 6: Rob Armstrong with No. 673.

Rob Armstrong has been a collaborator for the polymer guitar project almost from its start and in the early stages we discussed the issue of sound quality with him. Figure 7 shows the sketch he made in explaining to us that polymer would be a suitable material, but that we needed to get air into it. Loughborough University now holds an international patent related to this technology.



*Figure 7: Rob Armstrong's sketch of the need to get air into the polymer resin.*

Figure 8 shows Rob deciding on the soundboard bracing for the first all-polymer prototype which was built in one afternoon. This was another of Rob's skilled performances. Knowing that and knowing how are both important to the realisation of a dream. Tensions between 'craft skills' and a knowledge of 'modern technology' can be seen in the light of this project to be rather contrived.



*Figure 8: Rob Armstrong deciding on the bracing pattern for the first all-polymer prototype.*

'Learning how or improving in ability is not like learning that or acquiring information. Truths can be imparted, procedures can only be inculcated, and while inculcation is a gradual process, imparting is relatively sudden. It makes sense to ask at what moment someone became apprised of the truth, but not to ask at what moment someone acquired a skill. 'Part-trained' is a significant phrase, 'part-informed' is not. Training is the art of setting tasks which the pupils have not yet accomplished but are not any longer quite incapable of accomplishing.'

In the early 1980s, the nature of a designerly way of knowing was an emerging area of discussion (e.g. Cross, 1982), but it has become neglected. The need to explore the area further has been noted by McCormick:

'The way those involved in design and technology have refined their views on processes, albeit slowly, now needs to be developed to incorporate those of knowledge. My exploration of this kind of knowledge has sought to suggest that we should not look in the first instance to the abstraction of science and mathematics, but to the practical knowledge used by technologists. This search does not imply a swing from 'process' to 'knowledge', but the search for the relationship between the two.'

(McCormick, 1999: 13)

### Prototyping and presentation

Guitars are essentially archetypes in the sense described by Thistlewood (1990), in that their essential form is largely fixed. The role of the designer in relation to archetypes is restricted to paying attention to materials, colours and decorative treatments. The design development of the guitar has also been characterised by evolutionary spurts associated with particular guitar makers (e.g. Antonio de Torres and the Spanish classical guitar and Leo Fender and the solid body electric guitar). In these respects, the design development of guitars is not too far removed from the project work typically undertaken in schools and colleges in order for parallels to be drawn and the nature of design innovation to be explored. Many design projects carried out in schools, colleges and universities are seeking innovation in archetypes.

Prototypes are made for a reason. Figure 9 shows the first of two prototype polymer guitars featuring a wooden neck (P1, P2). These were made to establish the properties of the soundboard, which is responsible



*Figure 9: P1 - The first prototype polymer guitar (with a wooden neck).*

for the greater part of the guitar sound. The neck only affects the sound quality at the margins and it was the only conceivable prototyping route at this stage. (The mould tool for a polymer back would cost approximately £10K). P1 was filmed by *BBC News24* in 1999 being played by Gordon Giltrap and the quality of the sound was acknowledged, but no investors could be persuaded to get involved. In Gordon Giltrap's words

'... this instrument does not sound like plastic (whatever that's supposed to sound like) and I believe anyone listening to it will hear a sound usually associated with a good quality acoustic guitar of the wooden variety ... I am delighted to be a part of this guitar's early history.'

With such an endorsement, you would have expected it to be in production for the New Millennium, but no. It took until November 2001 to be awarded the funds from NESTA in order to build the first all-polymer prototype, P3, built to establish the sound quality of the all-polymer version. (This cannot currently be mathematically predicted.) Four 'fully-finished' prototypes were then built to take to the Frankfurt Musikmesse in March 2002, with full support from Loughborough University's publicity department. Figure 10 shows P3 (all white in order to be able to see the form in a pure sense), Figure 11 shows one of the Frankfurt 'presentation' prototypes and Figure 12 shows the Frankfurt 'Cool Acoustics' stand.



Figure 10: P3 – Constructed to test sound quality.

This is what it took to get the attention of the major guitar companies. The key issues to reflect on are:



Figure 11: One of the four all-polymer prototypes for the Frankfurt Musikmesse, 2002.

- P1 was enough for us and Gordon Gitrap to be convinced, but did not convince others
- P3 was the only way of establishing the sound quality that would be achieved
- it took four fully-finished, all-polymer prototypes and an expedition to the largest musical instrument exhibition in the world to attract the attention of the major brands.

The innovation could arguably be most strongly tied to P1 – a 'proof of concept' prototype that made a point. However, there is an unspoken pressure to make fully functioning working prototypes just like a 'real one' would be, as we had to for the Frankfurt Musik Messe. P3 demonstrated the feasibility of an all-polymer guitar and its sound. The four presentation prototypes enabled people to see the possibilities, but were very difficult to make. It is from the need to communicate possibilities unambiguously and the values associated with quality finishing that some of the problems with promoting innovation stem, and the associated concerns relating to the 'tyranny of products' arise (Martin and Riggs, 1999: 155). The idea of design and technology being dominated by designing and making seems to be becoming viewed as a problem (e.g. Breckon, 2001), but this depends critically on what is understood by 'making'.

#### **A model of design and technological activity more suited to promoting innovation**

The knowledge, skills and values relating to design and technology were identified and classified in work done by the Assessment of Performance Unit in 1982. At that time there was little emphasis on the idea of 'a design process'. Since then, and despite philosophical



Figure 12: The stand at the Frankfurt Musikmesse 2002.

arguments (Norman and Roberts, 1992, Roberts and Norman, 1999) and emerging empirical evidence to the contrary (e.g. Welch and Lim, 1998), the emergence of design and technology in school curricula has been dominated by discussion of at best, 'design processes' and, at worst, 'the design process'. This has led to both unrealistic and ill-founded expectations concerning designing as a transferable skill, and the neglect of the development of understanding concerning the knowledge, skills and values that underpin designing in particular areas. As

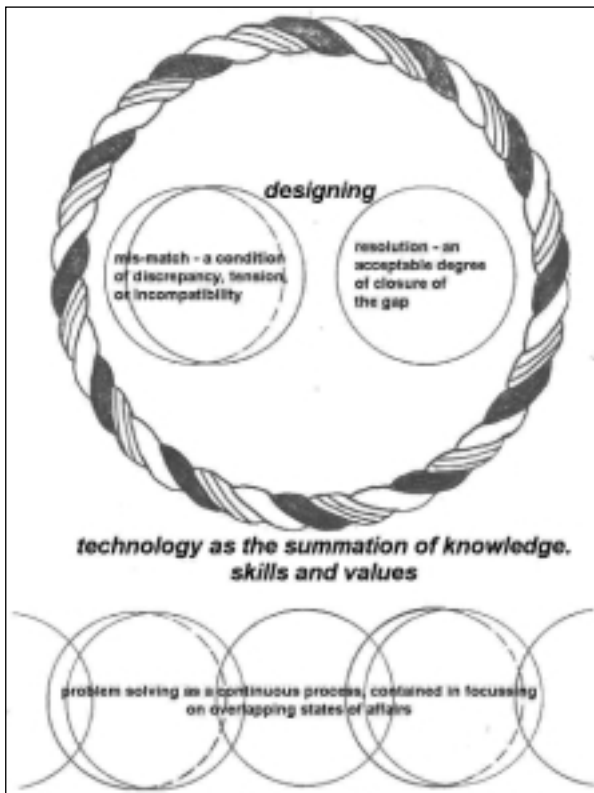


Figure 13: A model of design and technology which emphasises the role of knowledge.

the rhetoric of designing as a transferable skill has developed, it has been possible to find writers suggesting that there is no knowledge base for designing (rather than no fixed knowledge base, which is clearly true).

A discussion of technology for design as the summation of a designer's knowledge, skills and values was published by the author in 1998 and a model of design and technology incorporating this idea, and excluding any reference to a process or processes, was presented at the DATA Millennium Conference and is shown in Figure 13 (Norman, 2000).

Designing proceeds by:

- imagining future possibilities
- knowing that some things are possible and that some things are not
- knowing or learning how to tackle other areas

... and if you want your innovative ideas accepted ...

- appropriate presentation.

Learning how is the source of innovative technology and, as is widely acknowledged, must precede scientific understanding (e.g. Ryle, 1949: 31). Understanding appropriate modelling strategies must therefore be part of the innovative technologist's repertoire.

### The relegation of the design process

Would anyone consider it appropriate to describe the composing of a symphony, the writing of a poem or the painting of an artwork as a process? In a creative context the word is simply inappropriate. Baynes and Roberts described human cognition as embracing ...

'... all those processes of perception, attention, interpretation, pattern recognition, analysis, memory, understanding and inventiveness that go to make up human consciousness and intelligence.'

(1984: 8)

The models of design and technological activity that consist of four or five 'boxes' starting with identifying a 'need or want' and ending with the evaluation of a 'solution' are essentially (and possibly essential) assessment models. Retrospectively design and technological activities can be categorised by such models, but that does not mean that such models are a good representation of the reality. (This seems to me a clear case of going forwards not being the reverse of going backwards.) As models of designing, such

models are inadequate and tend to suggest a simple process lying at its heart. Nothing could be further from the truth. Such models undermine the key role that knowledge must play and lead towards ill-founded notions of 'the design process' as a transferable skill between different contexts. Nonsense indeed!

### References

- Baynes, K. and Roberts, P. H. (1984) 'Design Education: the Basic Issues' in R. Langdon, K. Baynes and P.H. Roberts (Eds), *Design Policy: Design Education*, London: The Design Council
- Breckon, A. (2001) 'DATA Chief Executive Challenges Design and Technology Paradigm', *DATANEWS*, September 2001: 14-15
- Buchler, J. (1978) (Ed), *The Philosophy of Pierce: Selected Writings*, New York: AMS Press: 150-156
- Charter, M. and Tischner, U. (2001) *Sustainable Solutions: Developing Products and Services for the Future*, Sheffield: Greenleaf Publishing
- Cross, N. (1982) 'Designerly Ways of Knowing', *Design Studies*, 3 (4): 221-227
- Gruhn, G. and Carter, W. (1993) *Acoustic Guitars and Other Fretted Instruments: a Photographic History*, San Francisco: Miller Freeman Books
- Hicks, G. *et al* (1982) *Understanding Design and Technology*, Assessment of Performance Unit
- Martin, M. and Riggs, A. (1999) 'Lost Contexts and the Tyranny of Products', *IDATER99* in P. H. Roberts and E. W. L. Norman (Eds), Department of Design and Technology, Loughborough University
- McCormick, R. (1999) 'Capability Lost and Found? The Maurice Brown Memorial Lecture', *The Journal of Design and Technology Education*, 4 (1): 5-14
- Norman, E. (1993) 'Science for Design', *Physics Education*, 2 (5): 301-306
- Norman, E. (1998) 'The Nature of Technology for Design', *International Journal of Technology and Design Education*, 8 (1): 67-87
- Norman, E. (2000) 'The Teaching and Learning of Technology for Design' in R. Kimbell. (Ed), *Proceedings of the Design and Technology International Millennium Conference*, Wellesbourne: The Design and Technology Association: 128-134
- Norman, E. W. L. and Roberts P. H. (1992) 'The Nature of Learning and Progression in Design and Technology' in J. S. Smith (Ed), *IDATER92*, Department of Design and Technology, Loughborough University: 9-14
- Pedgley, O. F. (1999) *Industrial Designers' Attention to Materials and Manufacturing Processes: Analyses at Macroscopic and Microscopic Levels*, PhD Thesis, Loughborough University
- Roberts, P. H. (1992) 'Of Models, Modelling and Design: An Applied Philosophical Enquiry', in *Modelling: the Language of Designing*, Design: Occasional Paper No.1, Department of Design and Technology, Loughborough University, 33-43
- Roberts, P. and Norman, E. (1999) 'Models of Design and Technology and their Significance for Research and Curriculum Development', *The Journal of Design and Technology Education*, 4 (2): 124-131
- Ryle, G. (1949) *The Concept of Mind*, first published by Hutchinson and reprinted by Penguin Books, 1990: 26-60
- Thistlewood, D. (1990) 'The Essential Disciplines of Design Education', *Issues in Design Education*, Harlow: Longman: 14-29
- Welch, M. and Lim, H. S. (1998) 'The Effect of Problem Type on the Strategies Used by Novice Designers', in J.S.Smith and E. W. L. Norman (Eds), *IDATER98*, Department of Design and Technology, Loughborough University: 75-82