Teaching Measurement and Control with Pi – Another Note 2 Gordon Taylor 2012-09-10

In an email to me, Graham wrote: 'In answer to your earlier question about control and the National Curriculum it was a very good question because since the ICT Programme of Study has been disapplied that is now no requirement for schools to teach any control technology. The DfE line is 'schools will be required to teach ICT to pupils at all Key Stages but teachers will have the flexibility to decide what is best for their pupils without Government prescription". This note responds with four examples.

1) I have been logging data from my house heating system for nearly 12 years. This includes 8 pulses (flowrates of gas, condensate, electricity, heat and water) and 14 thermocouples (temperatures). Scanned at 1 minute intervals, this has produced nearly 12 x 365 x 24 x 60 = 6,307,200 scans of 22 parameters = 138,758,400 readings. Last year I presented a paper based on the data for three years: 'Measuring the Heat Losses and Solar Gains of Buildings via a Novel Analysis of the Data'. Slide 11 in the Presentation shows that increasing the thickness of the insulation in the loft between Year 6 (before) and Years 9 and 10 (after) reduced the House Heat Loss by some 12%. Also the House Heat Loss values for Years 9 and 10 were within 0.5%. The house was occupied all the time and the weather differed from year to year, yet these effects were determined accurately by logging and analysing a sufficiently large dataset. (http://www.energypolicy.co.uk/Heat_Losses_and_Solar_Gains_11-2.pdf). Such data logging equipment is affordable by private individuals and schools, yet the tasks can be comparable in importance and scale with any in industry, commerce and the public services.

2) Another example is temperature control in humans and other animals – an instance of homeostasis. (http://en.wikipedia.org/wiki/Homeostasis). After the minor illnesses of childhood, every schoolchild knows that their normal, healthy, deep-body temperature is 37 C. Enquiring children may wonder how this is maintained regardless of their 'work rate' or how extreme is the outside temperature. If they had studied measurement and control, they would understand the concept of 'feedback' and that it is found in every field of science and technology. (http://en.wikipedia.org/wiki/Feedback) They would also learn that it is a vital function of all human, animal and plant life, even though it is not done with electronics.

For temperature control, two requirements are a 'source' and a 'sink' of heat – a form of energy. For all plants and animals, the source is ultimately the sun, but usually more immediately 'food', and the sink is the environment, often the atmospheric air. In addition, a 'control mechanism' is necessary - preferably one that operates without conscious effort. In all warm-blooded animals, the normal mechanism is the variation of blood flow between the body surface (to lose heat) and the depths of the body (to conserve heat). Another mechanism is 'sweating', which becomes necessary at high work rates or in high outside air temperatures. Biology teachers could ask children to consider elephants, which have a much greater body volume than humans but comparatively less surface area – an effect of the 'square-cube law'. Yet they usually live in high outside air temperatures and often perform hard physical work. The solution that they evolved is ears acting as 'coolers', to which the blood can be directed, and the cooling effect increased by flapping. As in humans, this control mechanism depends on feedback.

3) This example is inspired by Myra VanInwegen's results 'Watching Ice Melt or Fun with Thermistors'. (http://www.myra-simon.com/myra/scratch/index.shtml). She obtained these with a thermistor connected to a PicoBoard, itself connected to a computer running a program she wrote in Scratch. Enquiring children would notice the flat part of the curve at 0 C, and would learn that this is due to the 'latent heat of fusion' of water substance. Teachers of science or geography could relate this to 'the problem of the age' – that of global climate change – as shown by the melting of the ice caps in the Arctic and Antarctica. All children today will have to live with the consequences of their parents and previous generations having caused this.

If they are lucky, they may be shown the use of a light level sensor such as http://www.dataharvest.co.uk/products.php?g=sci&ppg=sci&a=sec&ppa=sec&t=sen&code=3124 By comparing the 'albedo' of snow and ice (about 0.85) with that of land and water (about 0.2), they will understand how the melting of the ice caps affects the global heat balance. With more luck, their studies may include Control and 'feedback', both positive and negative. (http://en.wikipedia.org/wiki/Feedback). Combining the ice melting with de-stabilising positive feedback from the lower albedo leads to 'climate change feedback'. (http://en.wikipedia.org/wiki/Ice-albedo_feedback and http://en.wikipedia.org/wiki/Climate_change_feedback). It is vitally important that we all understand this and act now to stop further melting, since it is impossible to reverse.

4) This example is about 'system dynamics', as set out in the seminal 1972 book 'Limits to Growth', by Donella H. Meadows and others, based at MIT. (http://en.wikipedia.org/wiki/The_Limits_to_Growth). Figs 23, 24 and 25 show multiple feedback loops like that in our 'schematic diagram': '1- Physical_Computing_6.pdf'. When all put together, they make up Fig. 26, The World Model. However, while the examples 2) and 3) above show successful control, resulting in stability, the World Model – like the real world – is usually unstable. Even with the population and non-renewable resources of 1970, the authors found that very few cases gave smooth transitions to stability, while most cases resulted in collapse. This has been confirmed many times in human history, with the collapse of empires - usually due to shortages of water and land for growing food. Yet politicians continue to talk of 'sustainable growth'. The present UK government should know better, since in response to 'Limits to Growth', the Conservative Government set up the 'Systems Analysis and Research Unit', responsible to the Prime Minister. (http://www.hawaii.edu/intlrel/pols635f/gmintro/SARUM.html). As Gail Tverberg has pointed out, recent events suggest that we may be approaching the Limits to Growth. (http://ourfiniteworld.com/2011/10/24/2012-reaching-limits-to-growth/).

These examples of measurement and control help us to understand ourselves and the real world. So the failure to teach every school pupil these concepts – especially for ideological reasons – is a betrayal of trust. Moreover those who end up in government are ignoring the very mechanisms that could improve the future of their electorates. This is inexcusable.