

## **Challenge: Coping with Complexity**

### **Envisioning education in the context of social and technical change – what sorts of education systems, methods and institutions do we need to help people deal with complexity?**

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#### **Preamble**

A brief sketch of my research relevant to this topic will help contextualise what follows. I am interested in the processes of educational change (see Ridgway, 1998). Another interest is in the creation of new sorts of dynamic interface to support reasoning with multivariate evidence as part of the process of understanding complex phenomena. The latter work has involved the creation of new ways to engage users with data, and systematic work exploring the difficulty (in psychometric terms) of working with these displays. Interest in the use of these displays extends into adult statistical literacy (we are starting to work with major data providers such as the ONS and OECD), and into ways to reconceptualise the nature and teaching of statistics at school level, and in the social sciences in general. The Science Mathematics and Related Technologies group at Durham (see [www.dur.ac.uk/smart.centre/](http://www.dur.ac.uk/smart.centre/)) has created and trialled curriculum materials designed to present students at KS3 with rich data sets for use in mathematics and citizenship (on topics such as sexually transmitted diseases, poverty, obesity, alcohol and drug use), and has created simulations to help students in mathematics and geography learn about disease spread. Sample materials can be viewed on the SMART website. I am interested in developing ways to make mathematics relevant and useful to students; the SMART Centre has developed materials on 'plausible estimation' (not yet released) where students answer question such as 'is there enough 'set aside' land to grow 20% of the diesel we need for road transport in the UK?' I am also interested in new approaches to learning and teaching, and in e-assessment.

#### **Modelling Change**

In an earlier monograph (Ridgway, 1998), I describe 3 classes of models:

- Linear, additive models, of the sort that are often used in school physics;
- Systems models, characterised by feedback, of the sort often used in school biology;
- Macrosystemic models, where the focus is on systems undergoing change in terms of both basic elements and processes.

Linear additive models (LAM) are extremely powerful when applied to situations involving a number of variables with additive effects. Such situations can be understood by examining the relationships between pairs of variables, while holding everything else constant. The results of the small studies can be added together, to understand the functioning of the whole system. The combined gas laws provide a good example. LAM can be applied to situations where they may not be useful. One example might be human body temperature in a cold room. We simply do not cool down in the way that a hot cup of tea does. We don't violate fundamental principles of physics by not getting colder, but one does need a notion of homeostasis to explain the phenomenon.

Biological systems show an increase in order and form over time (violating the second law of thermodynamics, in the short term), and cannot be understood by simple LAM. Notions of multiple interacting factors, and feedback, are essential to understanding biological processes.

Macrosystemic models are useful when considering radical changes (usually over long periods of time). Powered flight provides a simple example. In 1900, there was no

powered flight; by 1914, airplanes were an important part of military strategy; today mass air travel has revolutionised society. The emergence of humans on a planet that started out as a gas cloud provides another example of macrosystemic change. Developments were not part of a predictable smooth sequence. Each transition (gas condensing to rock; surface water; the emergence of oxygen generating creatures followed by the evolution of oxygen using creatures) led to a new system with novel elements, novel affordances, and the potential for a new trajectory.

Why start here? A number of major ideas come from this analysis. First is the idea that there are lots of ways to describe and model phenomena. Second is the need to think of social and technological change as part of an evolving macrosystem (which has education as an element). Third is that macrosystemic change is inherently unpredictable – the problem is not that we are not smart enough, or that we do not have enough computational power – the phenomena are simply not knowable in the longer term.

Many formalisms have been developed to model complex situations. These include 'models for complexity' such as chaos theory, finite element analysis, and decision models in computer science (and statistics) using ideas from Artificial Intelligence. While there is a need in the long term to review these techniques, and their current and possible future uses, it is sufficient for the purposes of this document to acknowledge their existence, and their absence from much of formal education.

### **Uncomfortable 'Truths'**

It is easy to overstate our chances of predicting future events even a year ahead – Microsoft failed to anticipate the internet, the majority of multinational computer companies in the 1980s have disappeared (a notable exception is IBM – who have completely reinvented themselves). There are collections of predictions from people eminent in their field at the time of writing that are, with hindsight, a source of humour. As a note of caution about the likely success of the whole *Beyond Current Horizons* (BCH) initiative, some uncomfortable 'truths' are set out below. Their truth status is ambiguous.

- Our ability to predict the future is very poor (but amusing, with hindsight) in part because the course of macrosystemic change cannot be predicted;
- ICT has had very little impact on classroom practices – let alone on attainment;
- Optimistic claims for the likely effectiveness of ICT are rarely grounded in evidence;
- Change depends on coordinated action across lots of levels in the social system – from political will, through organisational structures, to the actions of individuals – this is very difficult to orchestrate.

### **Overarching Questions**

Assessment systems define what is worth knowing, exemplify constructs, and drive systems. A key message for all the work in the BCH programme is that ideas should be exemplified.

- How do we design an assessment system that provokes engagement with complexity?
- What is worth knowing, and how do we measure it?

How do we equip people for coping with complexity?

- How do we get people to engage in complex issues?
- How do we get people to think in sophisticated ways about complex problems?

How do we help people to adapt to fast changing environments?

In the next section, I identify some plausible dysfunctions, before going on to identify some major drivers of system change.

## **Dysfunctionality and Dystopia 2008**

### Dysfunctionality I: the fossilized curriculum

There is a major problem with the ways that students are taught to reason with evidence. This problem is particularly acute in the teaching of statistics at school and in some social sciences (it is taught essentially via pre-packaged 1920s techniques originally designed for an environment which lacked computational power).

### Dysfunctionality II: C.P. Snow's 'two cultures'

There are structural problems with A-level and university courses which allow students to specialize exclusively in Arts or Science courses. The 2007 New York Times' *100 Notable Books of the Year* includes no science books. Being weak in mathematics and science is socially acceptable.

### Dysfunctionality III: Academic versus practical knowledge

Academic knowledge often has a higher status than practical knowledge. Engineering and medicine provide better models for the design of education systems than do pure mathematics and the study of literature.

### Dysfunctionality IV: Popper constructed as nihilist

There is evidence that people go through a number of stages in their beliefs about knowledge. Perry (1970) studied the changing epistemologies of undergraduates at Harvard and Radcliffe College. He described the transitions from a belief in absolute knowledge, through nihilism to relativism. A much simplified account follows:

- the world can be understood in absolute terms (c.f. a semi-religious belief that science reveals 'truths');
- if absolute knowledge can't be obtained, then all stories have equal value;
- all accounts of the world are provisional, but accounts can be compared on the basis of their supporting evidence. Some current accounts summarise large bodies of empirical evidence very well, and don't have well grounded rival accounts.

These beliefs about the nature of knowledge are all alive and well, even in the academic community. Some scientists believe in 'truth'; postmodernism come close to nihilism, and true believers (like me) hold dear to relativism.

Too much education in school (especially in school science) has an absolutist epistemology; nihilism is alive and well in the media – exemplified by the recent anti-MMR debacle, and the journalistic tradition of granting equal status to a meta analysis of research findings and to one person who disagrees with its conclusions.

### Dystopia I: the individually disconnected world

*Play* is a magazine devoted to *PlayStation* games. The December edition of *Play* offers a review of the 'top 50 games for 2008'. 35 are shoot-em-ups. The advertising section contains 3.5 pages of advertisements for games and 4.5 pages of advertisements for (male oriented) pornography. ICT can facilitate disconnected narcissism.

### Dystopia II: the culturally disconnected world

In this dystopia, mass migration leads to cultural ghettos (c.f. the almost complete ethnic polarization in some Lancashire towns' schools) that are breeding grounds for alienation and disruption (c.f. riots in Paris suburbs, and the bombing of London tube trains by British Muslims).

## **Dystopias 2009**

### Dystopia III: the atomized over connected world

There are so many channels and *Facebook* groups that identities are defined in very parochial terms – people no longer have regional, national, European identities, or political affiliations, so 'there is no such thing as society'.

### Dystopia IV: the unified media saturated world

There are so many channels and *Facebook* groups, all controlled by the same agencies that identities are defined globally in terms of the property – people no longer have regional, national, European identities, so 'there is no such thing as society'.

### Dystopia V: the scrutinized world

Technology becomes so cheap that ICT modules are routinely put into food and clothing to provide full surveillance of citizens – diet, disease diagnosis, waste disposal, etc. All ICT activities (including everything relevant to education) are monitored via sophisticated AI systems (c.f. current AI analyses of loyalty card transactions to facilitate targeted marketing).

## **Drivers and Trends - The UK in the World and in Europe**

### The UK in the connected world

The world is connected far more than it used to be. Major economies in China and India will increase their influence over world affairs as their economic power grows (c.f. China's reserves of \$1000bn+), and as they consume and pollute more. Citizens in fast developing countries will demand and seek out higher standards of living (motivated in part by exposure to world media) and better education. It is unlikely that mass education in higher education in fast developing countries can be provided by conventional models of attending physical universities, and so there will be pressure (and massive resources) available for distance education, with direct implications for competence-based assessment. There will also be a massive expansion in the number of highly qualified people world wide, most of them in India and China, with direct implications for science and industry in the UK.

Movement of capital has never been easier; it is very easy for multinational companies to export jobs; controls over the migration of labour will continue to be important, politically.

### The UK in Europe –economic imperatives

The Lisbon strategy for growth and jobs (European Commission, 2004) advocates a move towards an economy that is dynamic, competitive, and knowledge based. This requires a workforce that is highly skilled, and able to adapt to new jobs and situations (see Leitch, 2006). There is a perceived need to improve current levels of 'key skills', 'key competencies' (KC), and 'learning to learn' (L2L), and to develop a culture where Lifelong Learning (LLL) is widely accepted. All of these will be difficult to develop (and assess); more problematically, the definition of KC is a moving target. The world of employment is changing very fast, and so definitions of KC will change (as, probably, will notions of L2L). Working in fast changing environments, thinking systemically about changes (so the 'law of unexpected consequences' is invoked far less often by widespread adoption of 'what if' games at the times when plans are made), and acquiring new ways to represent and model situations, are all likely to be important KC.

### The UK in Europe – demographic disjunction

The European Union (EU) is currently the world's largest importer and exporter of goods, and needs to retain control over its own economic activities, and to continue to be active on the world political stage. The EU is at a critical juncture in its development. There are two key drivers of change: one is that the nature of the EU has been changed radically by recent enlargement; the other is that the very definitions of society and societal progress are undergoing reform.

The change in the composition of the EU can be characterized as the addition of relatively poor, but demographically younger countries to relatively rich but demographically older countries. There has been an impressive migration from east to west (in Ireland, the percentage of international migrants as a proportion of the total population has risen from about 2% to about 14% in the last decade [Putnam, 2007]), in some cases associated with a strain on social services such as education, health and policing. This very rapid migration may well cause problems for community well being. It well known (e.g. Putnam, 2007) that areas of high social mobility are associated with low cultural capital (as measured by indicators such as participation in voluntary work). It is an act of faith to believe that these problems will only be present in the short term, and that long term happiness and prosperity will increase.

Dramatic demographic change is a major driving force in society that has immediate implications for education. There are obvious practical and structural issues such as teaching in multilingual and multicultural contexts to people of all ages. There is an urgent need for fine grained measures of language competence, and for programmes for language instruction. At least as important, is the need for a consensus on new definitions of the success of the education system, which must include fostering 'intangibles' such as tolerance and cultural cohesion.

### The UK in Europe –changes in cultural values and implications for educational alignment

A second driving force is a major reconceptualisation of the ways in which the progress of societies should be measured. The current dominant measure is gross domestic product per capita (GDP). Two recent conferences have provided a platform for policy makers such as the president of the EU and the chief executive of OECD to argue for a much broader range of measures such as cultural capital, happiness of citizens, natural resources, renewable resources, and infrastructure to become key measures of success. Why is this important? The change itself shows a good awareness of 'systems thinking' at a high level. Essentially, the structures of rewards for key individual players should be aligned with the overall ambitions for the system. In this particular case, the target behaviour is the short-termism that politicians are driven to, by the current structures of rewards. Politicians must be seen to be effective over their term of office, and so are driven by short term pressures to make changes (so that they are seen to be active) and to improve scores on key indicators (e.g. waiting times in the health service, or GCSE results in education). Consider the dilemma of allowing fishing at unsustainable levels. If GDP is the only measure of progress, then, in the short term, over fishing is likely to be allowed. If a broader measure is used that includes renewable resources, then the decision to allow over fishing might lead to a drop in overall societal wealth, and so would be less likely to be taken by politicians seeking re-election.

Educational goals need to be adjusted to reflect ongoing changes in definitions of social progress. One positive aspect of this is that if a broad raft of measures of success is adopted, teachers and schools will be less likely to teach to very narrow tests.

## ICT as a driver

Information and knowledge is rapidly changing. Rapid increases in knowledge will continue to be a fact of life (a list of discoveries in the last 50 years would include the structure of DNA, and the acceptance of the idea of tectonic plates – both now 'basic' school science), and the rate of change continues to increase. There has been massive progress in ICT technology, with associated social implications. ICT is a major driver of change. The existence of the web has extended our ideas about the nature of knowledge, and has shifted our ideas on what is worth knowing. Skills in finding information, and critiquing the quality of that information have become more important (for example, the CIA and the Vatican have both been identified by *Wikipedia Scanner* as editors of some of the changes made to *Wikipedia* – see <http://news.bbc.co.uk/1/hi/technology/6947532.stm>).

ICT provides a range of modeling tools that support dynamic modeling that can be used to explore complex processes. (Our collaborative work with the Geographical Association at KS3 - see [www.durham.ac.uk/smart CENTRE](http://www.durham.ac.uk/smart CENTRE) - provides examples in the context of disease spread).

New representations will emerge that will have widespread application. The work of the SMART Centre provides some examples.

AI techniques based on pattern recognition are far harder to understand, but are important ways of modeling and handling situations.

Recent software developments such as wikis, forums, *Facebook*, and *Many Eyes*, are characterised by the construction of knowledge by a community of people rather than by a few individuals. This is sometimes (confusingly) referred to as 'Web 2.0' software. Here, I use the term 'People Net' (PN) software. Much conventional work in education (and assessment) is individualistic and competitive – collaboration is discouraged. PN software has important implications for new educational targets (and for e-assessment, especially in the context of the definitions of L2L, and LLL). PN software may well become an important source of curriculum activities.

## On educators and educated

The target population to be educated is changing very quickly. A number of dimensions can be identified. The population in formal education is becoming more diverse, very quickly. Another challenge is the extension from formal education to LLL – mature students present different skills, dispositions and problems. Another is a polarization in the motivation of the population to be educated. In formal education across the EU there are very serious problems of alienation. One in 6 students in Europe leaves the education system with no qualification (COM 2007, p8). This poses a major challenge for education systems. A more positive message might come from the Massachusetts Institute of Technology (MIT). MIT presents almost all of its courses free, online. These courses get about 1.5 million hits a month; a course on linear algebra receives about 200,000 hits a month, with a large proportion from the developing world (<http://www.cbc.ca/technology/story/2007/12/31/mit.html>). This is not such a positive message if it actually reflects an underlying problem that very large numbers of people in fast developing countries are enthusiastic learners, and that a large proportion of people in the more slowly developing world have disengaged from education.

A further challenge is the skills base of the communities who educate – professors in higher education, teachers of teachers, and classroom teachers. These groups are not easy to monitor or to influence. Their personal skills, and their ability to foster learning in others of new KC and L2L will be critical to skill and knowledge development, and so must be monitored.

## **Profound discontinuities and breaks with existing trends that might emerge**

World culture shifts from Anglo-Saxon capitalism to Chinese/Indian/Russian capitalism.

Global conflict over natural resources (the Chinese buy controlling shares in international oil companies, then only sell oil in China) or pollution.

Mass migration triggered by very fast ecological change (flood, famine...).

Terrorist nuclear attack leads to...

## **What will stay the same, and why?**

Working practices are still largely dominated by people attending places of work. Education has an important role in child minding for the working population. It is likely that current systems of education with pupils attending physical school buildings, at set times for attendance, and 'industrial production' models of teaching will be with us for a long time.

External assessment of qualifications will continue to be important (even if teachers are given more responsibilities, and the quality of their decisions is moderated). Globalisation will increase the perceived need for world wide competence-based assessment.

## **Forces acting against radical change**

Printed media have both direct influences on policy, and indirect influences, when policy makers suppress initiatives because they believe they will be unpopular with national newspapers such as the Daily Mail.

People who teach.

General system stasis – the universal system change problem of aligning the drivers at all system levels with the overall ambitions of the new system.

## **Major Uncertainties**

Just about everything. The future, in principle, isn't predictable (it says here).

## **Implications for social mobility and social justice**

Mass migration from the East to the West will accelerate, bringing new definitions of social justice that have a pan-European (and probably a global) dimension.

The old-young dimension will become more important. There are no obvious ways to diffuse the pensions time bomb, where an aging population seeks to retire and live for 30 years, supported by the rest of the population. Young migrants will be active politically about the inequality of treatment of old people in the UK, and their country of origin.

The lack of social mobility from the low attaining native population will contrast sharply with the higher social mobility of migrants – perhaps with negative social and political consequences.

## **Some Research Activities**

### Learning from on-going attempts to introduce large-scale educational change

There are a number of natural experiments going on, world wide. Singapore provides an example of extensive innovation with ICT; the USA provides a plethora of educational experiments such as the '*No Child Left Behind*' initiative; etc. International studies provide both a source of evidence, and examples of the challenges of dealing with complexity.

### Consensus building and validation

Educational goals are in a state of flux, and will be for the foreseeable future. A key starting point when developing a new measure of any goal is to explore different conceptions of the measure, and to think about how any measure might be validated against external criteria. It is sensible to look at existing measures, invent plausible measures, and to explore the psychometric properties of items and subtests.

In language testing, it is clear how one might proceed. It is sensible to review existing tests, and the existing literature on language learning. Tests have blueprints and evidence supporting their factor structure than can be compared, and perhaps synthesized. It is clear how one might validate measures against external criteria – ability to work in the target language in a variety of ways (understanding TV news, ratings of colleagues at work who are native speakers, and the like).

In contrast, L2L, KC, Lifelong Learning and Civics skills all pose big conceptual challenges. The constructs are not clear, nor are the external criteria for validating measures. One might begin with meta-analyses of literature reviews, and content analyses of key policy documents. Focus group discussions conducted on the nature of the concept, the identification of behaviours that do and do not characterise the concept, and the identification of people who exhibit and do not exhibit the construct will show the extent to which the same words have the same meaning in different communities, and about the possibility of operationalising the construct (Sternberg (2004) has examples of quite different interpretations of 'intelligence' in different countries). Repertory grid techniques are probably appropriate, here (Kelly, 1955).

It may be appropriate to develop core measures that can be applied nationally, complemented by measures local to regions, that are aligned closely with local goals (the educational challenges in Inner City London are different from those in rural Cumbria).

### Understanding the behaviours of low attaining groups

A group of particular importance is those people with very low educational attainment. Across Europe, about 1 in 6 students leave formal education with no qualification. Perhaps more significantly, research on the performance of low attaining students (see Harlen and Deakin Crick, 2002) shows that as a result of repeated testing, such students actually disengage from the educational process, and will not attempt to solve problems that they were able to solve earlier in their educational careers. This provides a real challenge for the measurement of KC and L2L. A disengagement from the educational process may well be a sign of cultural alienation, and evidence of poor civic awareness or engagement. If this conjecture is correct, then these students (as students and later as citizens) are unlikely to take up any form of direct assessment, such as e-assessment, with the result that population estimates of competence and civic engagement will be artificially high, and outbreaks of social unrest will come as a surprise to policy makers.

### Exploring the ethnography of educational innovation

There is an urgent need for an ethnographic approach to study the effects of policy changes that are introduced – in particular, an on-going programme studying the activity patterns of

different stakeholders, from students to policy makers, in terms of their actions, and the implications of their actions, for the education of individuals and the redesign of large-scale education systems.

#### Automated processing of free text input

Research on the automated processing of free text input ranges from genuine semantic analysis of short paragraphs (notably in science (e.g. Sukkarieh *et al.*, 2003) and medicine (e.g. Mitchell *et al.*, 2003), through latent semantic analysis (e.g. Landauer, 2002 – implemented by Pearson Learning as the Intelligent Essay Assessor™) to essay marking on the basis of surface features of text such as the number of keystrokes. All of these approaches can have positive educational benefits; these need to be explored in detail in terms of increasing user autonomy. Deducing models of complex situations from free text (and oral) input will be possible in the future. AI based tutor packages that support modelling will be developed.

#### More use of conventional web applications

A number of uses of conventional web applications are set out below. These will all need extensive development and research before they are viable approaches in formal educational settings.

'Open web' activities seem eminently sensible (especially with older students) – many problems faced by professional people are approached via collaboration based on extensive use of the web, untrammelled by physical proximity. The ability to use the web effectively is an important KC, and learning how to use new tools is an important L2L skill. AI analyses of search strategies during open web activities may well provide useful summative information on current skill levels, and formative information to guide future learning.

#### Use of 'People Net' web resources

A number of web resources are being created that facilitate collaboration between people, where users can upload content, collaborate actively, and where the expertise derives from the whole community, rather than from a few experts. Here we will call these resources 'People Net' (PN) resources (rather than 'Web 2.0' resources). PN resources, potentially, are important for education. PN resources allow different sorts of performance - notably more authentic performance - to be promoted and assessed. Facility with PN tools is an emerging KC. Some possible uses are set out below. In this section, we focus on using PN resources with the full knowledge and consent of participants. The nature of the activities are clear, and target behaviours could be described in such a way that participants could judge (and improve) their performance. I discuss covert monitoring in the next section.

**Mashups** such as *popfly*, *netvibes* and *pipes* allow users to combine data from multiple sources into a single tool, so survey data can be overlaid onto *Google* maps, for example. Mashup editors can accommodate RSS feeds. Mashups could be submitted as evidence of KC, or as evidence of substantive domain knowledge in a particular area. In the context of handling complexity, mashups provide a good resource for students to display their prowess. A mashup skeleton could be specified that required a summary of key phenomena, some historical account, evidence of the use of different representations and modeling techniques, or perhaps the presentation of the same evidence from a number of different perspectives.

**Wikis** such as *wikipedia* can provide evidence on skills in finding information, as well as about procedural skills associated with collaborative writing and organizing information. Student contributions to wikis and forums could be assessed using tools such as *wiki scanner*; their ability to contribute, and to learn from such resources could be a component of any attempt to assess their L2L capability.

**Wiki 'skeletons'** (e.g. <http://www.wiki.com/>) could be used with individuals or small groups to support the creation of knowledge in a complex domain. These creations could then be assessed in terms of dimensions such as semantic structure, completeness, and sense of audience (judged in terms of ease of navigation and use of language, for example).

**Folksonomies** (or collaborative tagging or social bookmarking) such as *del.icio.us* and *Furl* are methods of describing content in terms of user-defined tags, in ways that can be shared. The ways in which sources are tagged, and the sources that are identified, provide insights into the user's semantic constructions. Folksonomies could be used as objects for study to develop sophisticated ideas about modelling – *what is this person's world view? What sources of evidence would you use to help them change their minds?* Use of others' tagging to identify resources quickly is an indicator of KC. Taxonomic tasks could be devised to make such assessments more formal.

**Communication tools** such as Discussion Forums, *Skype* and *MSN*, facilitate interviews and information exchange, and provide evidence for authentication. *Youtube* offers the facility to upload video, and can show evidence of the ability to create and share information (for example, by uploading a series of web pages assembled via *clipmarks*). Again, these are vehicles to support discussions on the modeling of complex situations.

**Search engines** such as *Google* can provide information on user skills in finding information.

There are interesting developments on workplace uses of PN for professional development (e.g. Brown *et al.*, 2007). These activities include the use of e-portfolios to support reflection, and the use of PN to build a workplace community that innovates, that supports professional development, and that supports organisational change. These ideas could be applied to communities of modelers at different stages of development.

Predicting future uses of the web is impossible – patterns of use have changed radically in recent history, and these sea changes are likely to continue.

#### Artificial Intelligence approaches

Artificial Intelligence (AI) approaches have been used to address a wide range of problems where sophisticated pattern recognition is likely to be useful. Here, some applications to system monitoring are set out. In particular, we identify ways in which estimates might be made about ICT competence, KC, L2L and about a number of aspects of citizenship, alienation, social and cultural capital, and the like, in ways that are unobtrusive. Unobtrusive measures have a number of potential benefits. There are few problems with scale – larger numbers of participants do not necessarily require much more processing – indeed, large numbers of participants are needed to develop appropriate categorisations. Biases associated with verbal self reports will be avoided – as will the problems of differential drop out by members of different ethnic (or alienated) groups. AI systems are easily extensible – new items do not have to be written and piloted, as would be the case with measures of new educational goals developed via conventional psychometric methods.

#### Embedded assessment

Embedded assessment has many advocates (e.g. Birenbaum *et al.*, 2006). One conception of embedded assessment is that students engage in learning activities and in performative tasks as part of the normal pattern of learning and instruction, and that an assessment system draws conclusions about their competencies based on what they actually do. For example, recognising competencies in ICT would be relatively easy to do, given access to all the keystrokes on someone's personal computer. A large number of approaches can be taken to the description of performances and to the recognition of performances (including

Bayesian models, simple pattern recognition systems and AI connectionist networks). This approach could be used to assess competence in modelling.

#### Survey data – engagement with PN

Some PN sites (e.g. *Facebook*) provide information on users, categorized in a variety of ways. These data could be useful in identifying overall levels of engagement in PN activities, and (more interestingly) in identifying the patterns of activity in vulnerable subgroups. AI approaches could be used to categorise individuals in terms of their likely sex, ethnicity and social group.

AI analyses of traffic on data nodes could provide valuable information about patterns of ICT use, broken down by region, ethnicity and sex, and social background. Essentially, the software could be based on software designed to detect terrorist activities, or on the data mining techniques used for focused marketing by supermarkets, applied to 'loyalty card' transactions.

#### Process skills assessed via e.g. Google desktop and spyware

This is an extension of the concept of embedded assessment. Spyware would be loaded (with user knowledge) onto users' computers, and would track the patterns of activity. Here the topic under investigation is the way that the student searches for information, the sources used, and the like. Given an appropriate research design (c.f. PISA sampling of respondents) such a system could be used to collect large scale survey data on a wide range of competencies.

This data analysis could be used at the individual level to provide feedback to the user to improve their search strategies, and to identify areas for their future development.

### **What are the new educational goals?**

Understanding factors that influence culture, and media processes (accidental and intended).

Skills in the critique of discourses in science and humanities.

Understanding the philosophy underpinning modelling.

Metamodelling – understanding the strengths and weaknesses of different approaches to modelling, and the likely range of application of different sorts of models.

Modelling:

- Discovery skills (including evaluating the quality of different sources);
- Reasoning with evidence;
- Handling new representations;
- Being able to model unfamiliar situations in a variety of ways;
- Being able to critique and improve others' models;
- Being able to play 'what if' games;

Competence that spans the gap from strategy to delivery (planning a system to doing the wiring).

Knowledge of other cultures, tolerance for many aspects of other cultures.

High-level language skills in English and at least one other language.

Understanding political processes at local, national, EU and global levels.

Skills in working with others face to face and remotely.

L2L skills – including metacognitive skills such as reflection, and the ability to learn from web-based sources.

ICT skills – L2L new software packages.

Motivation for LLL.

### **What are the new educational processes?**

Problematizing 'knowledge'.

Discourse analysis in the media, science and humanities (the discourses surrounding climate change are riven with contradictory views about models and possible solutions to environmental management).

Modelling – playing with models and building models. Exploring famous modelling failures, such as the Club of Rome doom scenarios in the 1970s (Meadows *et al*, 1972).

Metamodelling – exploring the strengths and weaknesses of different approaches to modelling, and the likely range of application of different sorts of models.

Reasoning with evidence.

Discussing the philosophy underpinning modelling.

Some problem based learning, taken through to an implemented solution.

Some immersion in other cultures.

Language use for some important functional outcome.

Analyses of political processes at local, national, EU and global levels; media analyses, tracing decision making processes.

Exposure to ICT challenges.

Collaborative work with others face to face and remotely.

Engagement with leading edge thinking (e.g. the *edge* group, *many eyes*, *gap minder*)

Bleeding edge topics injected regularly into all levels of the curriculum, using resources such as *Hot Topics* on the BBC website, *edge*, or *ted*.

Analysing complex situations, such as:

- playing and analysing team games in sport;
- playing and analysing team games in design, such as the Great Egg Race, Scrap Heap Challenge etc.;
- studying biographies of people who have solved massive logistical challenges via multimethod approaches (Florence Nightingale, Alexander, Julius Caesar, Gandhi, Nelson Mandela).

Analysing the science and politics of key issues facing the world - in all cases, the key activities are to explore current models, and to trace the history of the ideas (especially acceptance and rejection), and the contributing factors. Sample topics are:

- global warming;
- the use of biofuels (and knock on effects for third world poverty);
- AIDS in South Africa;

Role shifts: creating manuals for others to use on 'how to find out', or 'how to solve this class of problems', 'how to use this package [how to find out how to use the next new package]'.  
Role shifts: creating manuals for others to use on 'how to find out', or 'how to solve this class of problems', 'how to use this package [how to find out how to use the next new package]'.

### **Future Education Systems?**

More mass distance HE.

Education geared to a far more diverse group.

Systems designed to support collaborative learning on specific topics, over a short timescale.

More AI hidden surveillance of the knowledge available in the whole community.

AI identification of excellent learners, and a concentration of educational resources on such people.

AI diagnosis available for individual learners.

### **Future Institutions?**

Compulsory education will still be based on physical schools.

Universities will be conceived of very broadly.

International certification of competence by global agencies such as the EU and Microsoft.

Industry as a major source of 'academic' research.

### **What disciplines can help?**

Anyone who actually creates uses new models can help. Core disciplines include computer science (for different approaches to AI); any science that concerns itself with complexity.

Psychology, for exploration of mental models, and world views.  
People who study change processes in organisations (Engstrom, on activity theory).

### **Whom to involve?**

The Santa Fe Institute takes a multidisciplinary approach to natural, artificial and social systems <http://www.santafe.edu/>

Interesting and interested social scientists include:

David Byrne, SASS, University of Durham;

Nigel Gilbert, Centre For Research In Social Simulation, University of Surrey;

Peter Allen, Complex Systems Management Centre, Cranfield University.

For expertise in modelling complex systems:

Neil Johnson, Physics, Cambridge;

Jim Doran, Dept. of Computer Science, University of Essex.

For Activity Theory:

Y. Engstrom at Stanford.

Other relevant communities:

People with a background in ethnography and anthropology would be extremely useful in describing social structures, and in describing social changes (and perhaps in tracking the impact of innovations).

Philosophers, especially philosophers with a focus on uses of knowledge, and on epistemologies.

### **Methods for desk work to develop robust evidence and fresh challenging thinking**

The order of the activities set out below is not important.

Identifying centres developing new models, and working on 'bleeding edge' topics; building a spatial and conceptual map of the domain. An analysis could be offered on the varieties of ways to model systems.

Developing a taxonomy of models, their current applications, and likely extensions.

Mining current sites where change is the focus of discussion (e.g. the current Edge Annual Question for 2008 'What have you changed your mind about? Why?

(<http://www.edge.org/>).

Posing a new 'Edge' challenge to highly successful people (HSP) – *what experiences have been most useful and important for your current work?*

Ask HSP for a career time line that includes their 'hinge' or 'cusp' moments.

Looking for, and evaluating, examples of educational practice designed to present students with complex problems. Work on Problem Based Learning is relevant here.

Reviewing evidence on traditional teaching approaches that have a focus on analysing complex situations, such as:

- playing and analysing team games in sport;
- playing and analysing team games in design;
- studying biographies of people who have solved massive logistical challenges.

Explore the learning gains from engagement in complex simulations of artificial worlds, including multiuser games.

## **How to focus work on areas of greatest potential interest and added value**

Monitor key sites where leading thinkers exchange ideas – such as The Edge.  
Check key 'general interest' journals, such as Nature and Scientific American  
Track academic citation counts, looking for fast rising people and subdisciplines.  
Monitor Yellow Pages to track the explosion of new sorts of services (and fast decline of old ones).

## **Ensuring credibility with key stakeholders**

Politicians are likely to be influenced by EU policies, and demographic trends described by OECD, Eurostat, and similar agencies. Citizen engagement in the political process is a serious concern for them, so anything that might help will be viewed positively.  
Emphasise links with past educational activities (associated with public schools) – notably reflective activities in the humanities based on analyses of biography. Point to state of the art approaches to improving performance in business and sport, and the use of technology.  
Ensure that KC are assessed as part of the high stakes assessment -engage examination boards in the whole process of reform.

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