DATA-RICH REPORTING AND STANDARDS SETTING FOLLOWING RULES-BASED MARKING

Mike Peppiatt

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Background

There has been a lot of movement in recent years towards computer-based assessment, or e-assessment. This has tended towards the conversion of paper test models for use on-screen, mimicking existing test construction and question writing processes and data collection models.

The questions assessment experts, psychometricians and statisticians have been asking are:

- Is the on-screen test comparable to the paper-based test?
- Are the results reliable?
- Do questions perform in the same way on-screen as on paper?
- Are pupils disadvantaged by their level of computer literacy?
- How do we make the tests secure?
- Does having different types of equipment affect the results?
- How do we present the questions in a different media?

Whereas the questions that should be asked are fundamentally different:

- What can we test using this medium?
- How do we deliver assessments that are fair to learners – both within and across subject domains?
- How can we utilise the opportunities and limitations the medium offers?
- How do we build a process model that provides all stakeholders with confidence that their needs are being met?
- What information can we elicit from an e-assessment?
- What data is required to support the information needs of all the stakeholders?

The driver for this paper is the need to answer the last question which, in turn, requires answers to all of the preceding questions.

Approach: Evolution or revolution?

A scientific analogy

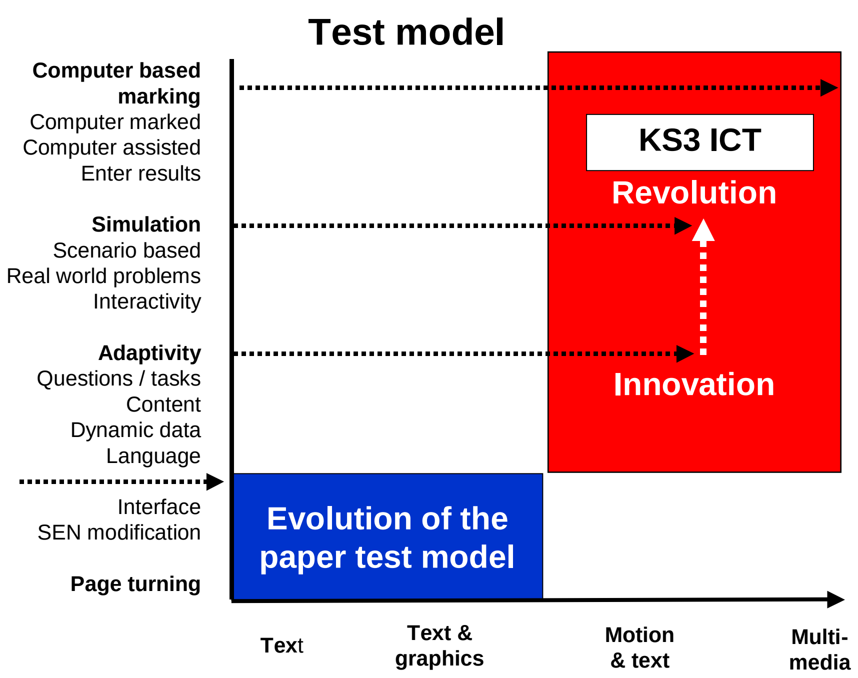
To date, there has been an evolutionary phase in the transition from paper-based assessment to e-assessment. It has fundamentally changed little. It has, by and large, only addressed the question “Can we do the same thing in a different way?” Through evolution we have “Neanderthal” assessment.

On the horizon is a revolutionary model, a forerunner of modern e-assessment for which there is a need to:

- Set the hypotheses;
- Test the hypotheses;
- Prove or disprove the hypotheses; and,
- Refine the thinking that underpins the hypotheses.

In one particular case, the Key Stage 3 ICT project, a series of feasibility studies have been used to set out and test out the bases of the hypotheses. The experience gained was used to inform the contingency plans, should the initial findings show that a revolutionary model was unsustainable. The real test of the model will come, as it is rolled out and used in the school environment. See Figure 1 below.

Figure 1. The evolution of the test model



The feasibility studies were used to look for series of observable phenomena that explain regularities, predict what might happen, and provide evidence to differentiate performance. Different models of test were used in a controlled environment to elicit these observable phenomena. The outcomes of these studies indicated that it would be possible to manage a revolutionary approach.

Over time the theories developed, explained more phenomena and make more accurate predictions – and become more elegant in the process. For example, we had to benchmark our understanding and be prepared to modify our thinking as test practice informed development.

Unfortunately, the outcomes of the tests do not come with convenient packages of data with attached metadata providing explanations. Going back to first principles there is a requirement to define the data that are required to support the information needs of stakeholders, then create a means of capturing it, and then look for it in the results files.

This is a complex, interconnected and disconnected world, where we have to determine the causes and the effects, thereby creating and refining predictions, and the very models themselves. Again, this should be benchmarked in the early iterations of the model and will be refined over time.

There is a completely new set of opportunities to explore causal links and define differentiating clusters of information. For example, there may be a direct correlation between speed of decision making when choosing an appropriate action and level of cognitive process. This information could be used in conjunction with the test and/ or task outcome to differentiate between students at the same broad level. Equally, the teacher and/ or mentor could make use of this information to assess potential and speed of advancement for individuals. For example, students at the peak of their current cognitive ability might find it more difficult to progress rapidly, whereas students with higher cognitive processing skills might be able to progress faster, given the right motivation.

As with all revolutionary science, pioneering work seeks to determine the fundamental principles and establish the foundations of the domain. It sets out the paradigm, defining the structure of the work and creates the conceptual framework. The feasibility studies provided the information that allowed the defining of the process-based e-assessment model.

In the process of establishing the first principles the more difficult issues are parked for future investigation. For example, one cannot establish the validity of the model until it has been built and trialled. A limited scale pilot test can be used to validate the model. As these outliers are researched, the original assumptions are challenged and new theories are often hypothesised, fundamentally changing the thinking and can even lead to a revolutionary shift in the domain itself. Therefore, in the passage of time we will have to be prepared to alter or give up some of our original proofs.

Revolutionary science also needs to be cognisant of the social aspects it affects in its wake. These are determined by the goals and aspirations of the people that are working in and are affected by the domain. For example, in UK educational assessment the Department for Education and Skills requirement, for a measure of progress against business case targets, has significant implications for teachers and students.

Therefore, in a revolutionary model we should not view the current hypotheses of e-assessment and their manifestation in test models, its data and our notions of validity as the final solution, but as a necessary stepping stone in the evolution of the paradigm. Rather, we are going to have to determine how we might handle challenges, new ideas and approaches that develop our understanding of what is happening inside any of the test models developed.

Key stage 3 and ICT: What are they?

First, the English education system currently demands that all pupils aged 7, 11 and 14 be tested in three core subjects - English, mathematics and science1. These are known as key stages 1,2 and 3. There is no requirement to test information and communication technology (ICT) but there is a requirement for teachers to report an attainment level for pupils at Key Stage 3. The project, which informs this paper, may lead to a statutory assessment in ICT at Key Stage 3.

De facto ICT

ICT is part of a language metaphor and is defined by what people do rather than by a prescriptive set of pre-determined rules. It changes over time, rapidly in some cases, as shifts in performance and take up of current technologies occur and as new technologies come into play. Therefore, it is the role of the subject domain to establish, through the interpretation of performance data, the current status and to monitor shifts over time in order to understand fully the true nature of the subject and the associated pedagogical and assessment models that necessarily follow.

If this constant monitoring and adapting is not done then, the teaching and assessment of the subject domain will fail to reflect reality and would not be a “fair” test, because it would not have face validity. In turn, this would lead - very rapidly - to a “Neanderthal” state. An historical analogy can be drawn from medical science, where if this constant reviewing and updating process had not have been carried out we might not have the surgical advances we have access to today; we may even still be using leaches to draw blood. (Come to think of it, it’s interesting how things turn full circle. Modern medical science now uses leaches to clean wounds - de facto practice in action.)

[1] The Key Stage 1 assessment for 7 year old pupils is restricted to English and mathematics

The problem is to characterise the grammar of ICT, the tacit knowledge whereby a user displays such grammar. We must postulate explicitly the mental structures and processes. Since there are no technologies for observing and measuring what is going on in the mind of the user, at best we have the outcomes of what is going on expressed as the ICT-based processes deployed to arrive at any given final outcome.

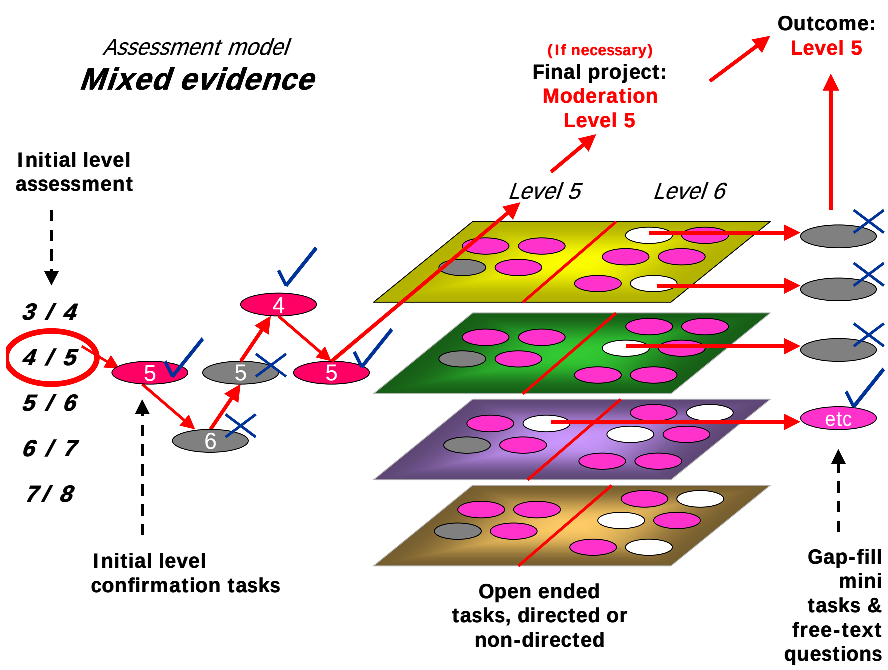
The test model

The revolution is driven by the need for a valid assessment of process and outcomes, including subordinate outcomes, rather than outcome alone, and a need to provide a secure on-screen assessment in a "when ready" environment through a non multiple-choice assessment. Processes are in themselves strings of subordinate outcomes and there will be many different strands to the same process

The model, as illustrated in Figure 2, uses a mixture of methods to gain as much performance data as possible in order to facilitate a decision on the level outcome. All possible data sources are mined, including an initial level assessment (IAL) by the teacher. There are a number of tasks and sub-tasks that through adaptation and guidance points take the pupil through a unique test instance. This is coupled with randomised data sets to ensure that test sessions are bespoke and locally unique.

The data captured have associated metadata, which is used to assess esoteric or holistic performance traits such as appropriateness. The higher level thinking skills may be determined through the appearance of complex recurring clusters. This will only be seen in non-directed assessments.

Figure 2. Derivation of a national curriculum level



As the pupil progresses through the task, all of the keystroke actions are recorded and clustered into “atomic indicators” (AIs), these are clustered into opportunities – unique clusters which demonstrate evidences of elaborations. This progresses up through the logical structure of the rules base to determine, through the implementation of threshold-based algorithms, to determine the level of the performance. Carrying the scientific analogy forward this is similar to the outcome of a chemical formula. Chemical elements are the AIs, compounds are the opportunities to evidence and the formulae are the algorithms that describe different mixtures of compounds

The model has the capability to “interrupt” the flow of the test and to ask direct questions, or to set mini tasks, to back up the inferences the marking engine is making.

Having utilised scientific and linguistic analogies it is time to introduce a mathematical one, to temper the linguistic, employing Chomsky’s notion of performance versus competence, an abstract concept related to mathematical proof.

Mathematics is a language of notations and formulae that can be used to represent true propositions, given a set of axioms and rules of inference – in this case the rules base. Contrary to the linguistic model the mathematical model does not look to study the underlying thought processes of the user, rather it sets out to determine a set of rules and formal mechanisms that precisely determine which ones are true – this is the function of the Key Stage 3 ICT rules base and associated algorithms.

The test model marking and reporting engine employed, therefore, adopts for its view of the ICT domain both of the preceding propositions, looking at the underlying thought process through the ICT-based process deployed and looking at the known “truths” established through the self fulfilling prophecies of the rules base. As long as the rules base is continuously monitored and modified to reflect actual performance behaviour – real life – there is no contradiction, just a lot of data and subsequent information derived from the analysis of the data.

Drivers

Why do we need data? There are many drivers for this:

- To deliver value to learners;
- To inform:
  - The development of the tests and test construction;
  - Marking and reporting, both formatively and summatively;
  - The proving of validity in all of its manifestations;
- To report to stakeholders – e.g. on the business case;
- For accountability.

One of the most important elements of this and one that is often overlooked is that of multiple stakeholder expectations. In a traditional low stakes test model the drivers can very easily end up being the economics of the publisher and not the needs of the tester, the pupil or management. In high stakes test model the drivers can end up being the government remit, for example, a test to prove a school's improvement target thereby having little benefit to teachers or learners.

Test developers, having a theoretical and purist view of the test being a pure psychometric instrument, writing to an ill-defined business case with no knowledge of the end users' application of the test and their information requirements cannot construct a test to elicit the data to meet those requirements. This leads to users believing the tests to be of little practical value in the development of pupils' learning in the classroom. Teachers and school management get little valuable information beyond a standardised score or a percentile ranking.

There are a number tests which are diagnostic in approach and, therefore, provide a deeper layer of information. This information is usually generated from the scoring performance data, for example how many questions of a specific area of the subject domain the pupil got right, or sometimes combinations of sub-domain scores.

> Having established that there is a wider audience for information than is usually considered, there is a need to develop the outcomes of any test that they supply the required information.

What are we measuring and why?

Given the background as outlined, the domain and the test model as described we have to establish what are we measuring, why and how we are going to measure it?

In this assessment model there is the opportunity to extend the range of things that can be measured analysed and reported on. These things have to be determined prior to test and software construction in order to elicit the data required and to be able to capture and store it in a database for further analysis.

The process by which this is achieved is through the establishment of the business case, the specification of stakeholder data requirements, the development of the data schema, test development to allow the elicitation of the required data, the gathering and subsequent analysis of the data, and reporting the outcomes to the various stakeholders to inform their information needs. The final part of the process is to produce a “lessons learnt” report to inform subsequent test development cycles, should the business case be sustainable.

Establishment of the business case

This is the where the sponsor of a test details their main purposes for its creation. There may well be, in a benefits capture plan, the sponsor's view of the benefits to other stakeholders. This forms the baseline for the data requirements.

Specification of stakeholder data requirements

An accurate picture of all stakeholder expectations needs to be established through stakeholder forums, either individually face to face, through the use of questionnaires or user groups. The stakeholders themselves should prioritise these needs, as not all will be met.

Indicative examples of these needs can include:

a) Marking rules refinement, through updating a rules base or marking scheme;

b) Government or management performance statistics;

c) Contract performance information – hardware/ software interaction, screen refresh time, speed of data processing, support etc;

d) Formative and summative report statement development;

e) Marking algorithm, including sufficiency threshold, performance;

f) Software security performance measures, such as number of hacking attempts;

g) Teaching strategy management – wash back;

h) Business case metrics;

i) Ongoing user acceptance testing, including regression testing of software developments;

j) The pedagogic need for the test, e.g. a diagnostic mathematics test for 11 year olds from which can be reported a standardised score, a strengths and weaknesses profile of performance, and a percentile ranking;

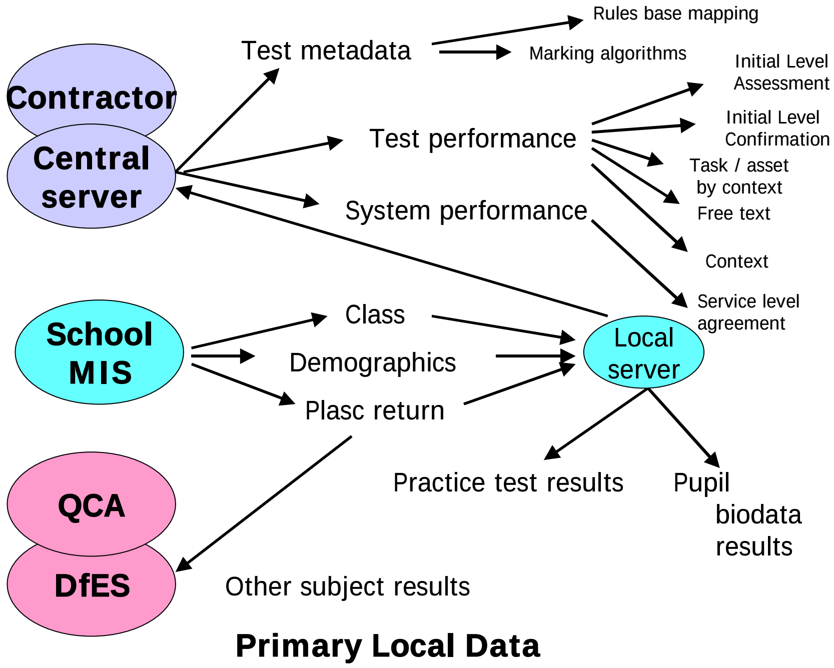
k) Proof of validity; and,

l) Test security.

The development of the data schema

From the prioritised information needs a data schema can be used to determine the data sets that are required to support them (see Figure 3). Data is either gathered directly from the test or is derived through the analysis of that and associated ambient metadata, such as time logs.

Figure 3: The data schema



The schema identifies the reporting outcomes and may also include a data flow chart to establish the points of creation and ownership, imperative for software developers to build the data collection, storage and analysis routines. (See Figure 4.)

Figure 4: The data flow model

				Source		= automatically available			1 = Primary data source
						= automatically transferred			SMS= Schppl Management System
						= by data file transfer			CPS= Central Point Server
						= exception report			APS= Administration Point Server
				Available to:					
Data				*SMS*	*APS*	*CPS*	*QCA*	*DfES*	Data source or outcome
	Administration								***Pupil biodata and test history***
		Local data		1	2	3			School management systems
				to SMS	2a				Input by school at admin set up
				to SMS	2b				Input by pupil on registering for a test.
		National data						1	DC1 / DC2 School level data
			SMS	1				2	PLASC data set
	Performance								
		within a test	Practice test only		1	2			Initial teacher assessment range data
					1	2			Confirmation question data
					1	2			Pupil log data files
					1	2			Free text response data files

The pedagogical, psychometric and statistical requirements are all articulated in this process, to a sufficient level to allow test developers to write and compile tests which will provide the opportunity to gather the data

Test development - to allow the elicitation of the required data

With the pedagogic information needs and the stakeholder requirements test writers then develop the required assessment instrument. In the Key Stage 3 ICT test model this included the development of processed-based assessment, which is not often possible in a paper-based test model.

It is incumbent on the test developers to ensure that all relevant psychometric validity measures are met. It is, therefore, a different combination of skills that are required of a writer, indeed a writing team, as there are issues to do with:

a) The use of the media in the assessment itself;
b) Technical issues;
c) Health and safety;
d) The marking/ decision algorithms to be employed in the test engine;
e) Metadata and ambient data requirements;
f) Time at a screen;
g) Test security both in terms of items and cheating;
h) Adaptability of the test items or tasks;
i) Accessibility of language, for dyslexics for example;
j) Special educational needs accessibility tools and software.

One of the main differences in test construction requirements of an e-assessment and a paper test is the development of algorithms. Dependent on the test model, algorithms are required for:

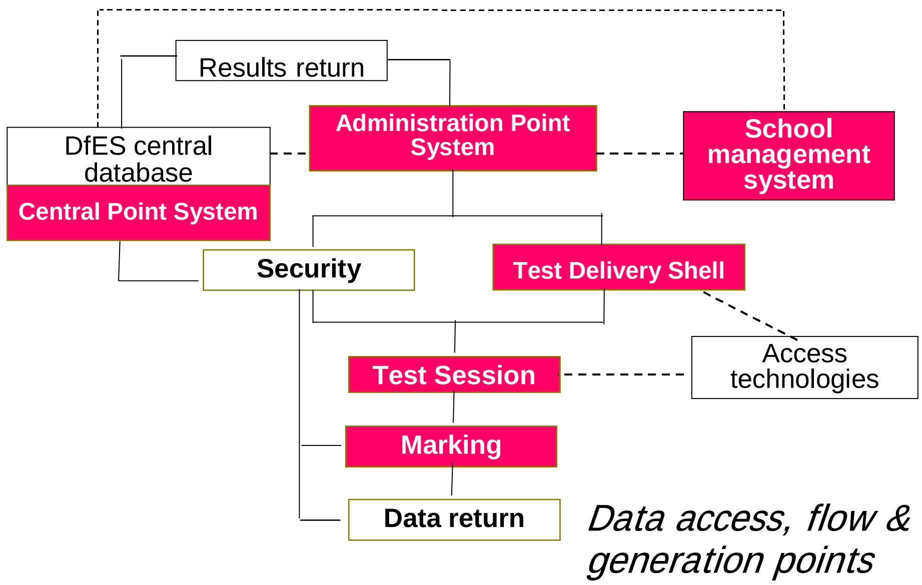
a) Adaptability;
b) Guidance triggers;
c) Evidence sufficiency's and thresholds;
d) Determination of grade/ level;
e) Performance analysis, including longitudinal analysis;
f) Prediction;
g) Diagnostics;
h) Reporting statement invocation.

Gathering and subsequent analysis of the data

Having established the data requirements and the database schema the test engine itself must be built to gather the data from a test instance and securely store and return the data. Data can be primary or secondary – derived, the secondary data may be generated at a central or local server. At this point it is merely data. Referring back to the data schema one can determine exactly what analysis is required to translate this data into meaningful information. Figure 5 provides an example of the data collection and storage points within the overall systems architecture.

Locally, the test engine itself may require branching decisions to be made, in an adaptive test, based on timed performance data – either dependent upon individual or clusters of questions' answers, or upon processes employed, or outcomes of processes. These require algorithms to be defined by the test writers, building into the test engine and the storage and manipulation of data on the fly. The results of these decisions are captured as the pathway is taken through the test. This leads to a more complex analysis of test validity. See Figure 5 below.

Figure 5.



Algorithms for this need to be written and encoded into the central analysis software or into the local test software, as appropriate, in order to satisfy the various stakeholder needs. An example of local information requirements would be informing the student of their grade, level or pass/ fail. In a high stakes test it may not be deemed appropriate at this stage to award a grade, as the result would be unmoderated.

An appropriate step in the process to achieve moderated results would be to return all data to a central server and to analyse in real time the cohorts' performance and results. These can then be automatically interrogated for, say, grade boundary issues, within pre-defined parameters, and a list of students with their performance and results files automatically passed to moderators for review.

In this way real time adjustments can be made to the overall marking routine to allow for the re-parsing of students' performance and results files. In a process-based model, such as that employed by the Key Stage 3 ICT test, this will also allow for the inclusion of unexpected – but correct – or "left field" solutions to be properly assessed and for the modification of the process rules base.

In the Key Stage 3 ICT test model, data gathering is not confined to the test instance itself. Data at student and school level are gathered from the schools' information management system through the use of a data extraction routine already used by all schools for the return of data to the Department for Education and Skills. This allows for performance analysis of the test and elements within the test by, for example, special educational needs, ethnicity, geographical location, socio-economic status, type of local area – e.g. rural, 2-year infants, etc. It is with this level of detail of information that the tests become much more than a mechanism for reporting a grade.

In a closed environment where the data and analysis requirements have been pre-defined, processing is of little consequence in terms of computer effort or time. It is imperative that thorough consideration is given to this part of the process up front. Trying to meet information and, therefore, data requirements post hoc may lead to expensive and time consuming work.

Reporting the outcomes to the various stakeholders to inform their information needs

The generation of reports for the various stakeholders, generated at the central server, can be automatically distributed as a softcopy or hardcopy, and can have further interpretation added by, say, a chief examiner. Reports to students can contain both formative and summative information as well as a grade or level. These statements are automatically invoked by algorithms within the test engine and are based on the performance profile of each student.

Reporting can be made more informative by the creation of HTML pages with drill down, this way teachers can look at performance in a manner relevant to them, in essence a web-based interrogative database.

Reports are limited in their nature by their design, those of the test, and the information needs specification.

Lessons learnt report

The final part of this process is the production of the lessons learnt report. This report serves to inform the business case and the future development of tests themselves.

Performance data is interpreted to provide information on all of the issues raised by the project team, this includes test question or task performance and outcome(s) validity. Validity in this environment is the subject of another paper.

The measuring of what we are measuring

The first question is do we know what we are measuring? Having described the subject domain said to be assessed, the question to be asked is, is this not enough? I put it to you that it is not.

We have a number of influencing factors outside of the subject domain that are being assessed by the very nature of the test itself. An example, from an ICT test we can measure the speed of decision making when a student chooses an application or function to use for a particular task.

There may prove to be a direct correlation between the speed and accuracy of the input of a complex test password and final outcomes. Short term memory may be assessed by capturing how long or how many times a student revisits task instructions, parallel processing, eye to hand co-ordination, keyboard skills, confidence are all examples of factors outside the subject domain which could affect a student's outcome, the effect of which could be measured within an e-assessment. All of which, and more besides, could provide useful information to test constructors and to educationalists alike. Once specified and built into the system this is at no economic or time cost.

More direct pedagogical factors may be the influence on a 2 year curriculum or the teaching method employed, the influence of the latter at present would have to be carried out at the local level as the system does not currently capture this level of data.

In terms of the ICT test there is an inherent assumption of knowledge of the world or context in which communication takes place. These assumptions are being made by the communicator and the recipient, and this poses questions about the audience. How do we deal with this when these two people have experiences and views of the world or context environment that differ? For example, a paraplegic's understanding and experience of a supermarket is very different from that of an able bodied person. If a task is set in this context the test constructors cannot make outcome assumptions based on their own experience.

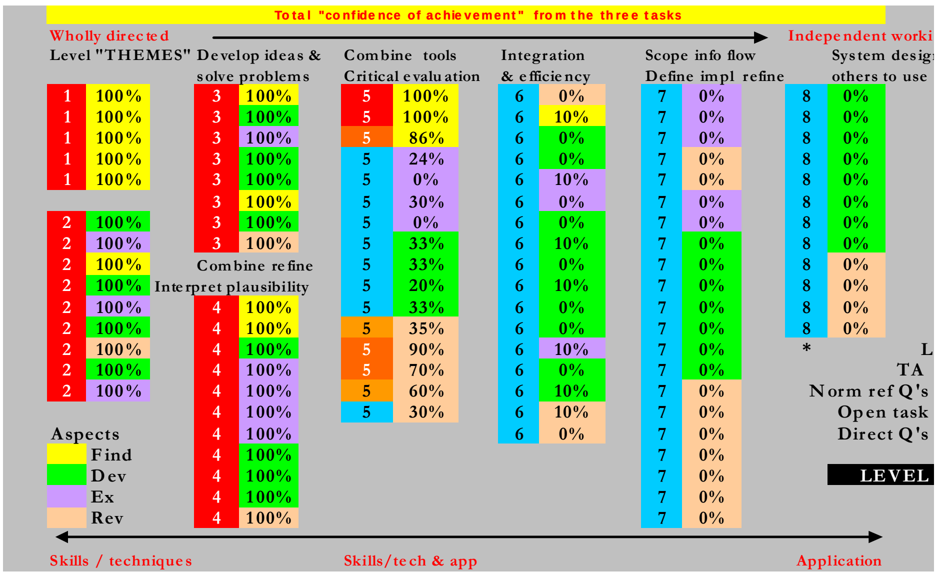
In the Key Stage 3 ICT test model we have to be aware of this and measure its effect on the test. The problem is the range of contexts in which to cite the tasks that have been created. In this virtual world a pool of general assets relating to a virtual environment persists from year to year. Specific assets and tasks are written for the individual tasks to be performed, for example, a cinema has been created in the virtual town of Pepford, used in the KS3 ICT tests.

This provides a choice of contexts for the student, where knowledge of the context domain is not required to complete the tasks but where working with the information and “assets” provided will allow the demonstration of ICT ability. “Assets” are defined as graphics, sound, word processing, video and data files, spreadsheets, emails and web pages. The student log file gathers the use of these assets and the content therein by attaching ambient data or metadata to specific actions.

The computational model employed breaks down the complex array of processes into a number of smaller independent processes. The marking algorithms start with these smaller processes and then rebuild the complex through grouping of performances that have met sufficiency thresholds. This is totally dependent on the routes the student has taken through the tasks and the opportunities offered to them. At the higher levels of cognitive processing, one has to determine the clusters in more and more complex arrays in a many-to-many set of mappings.

The sufficiency thresholds have to be established in fact from the data received to “prove” the hypotheses put forward in the conceptualisation of the model by the test constructor. These proofs form the basis on which the tests are written, algorithms defined and marking regimes created. Once established these thresholds need to be refined, under a metamorphic structure – the evolutionary model - by monitoring actual user performance. This can be done by creating statistical modelling tools and embedding them in the data repository at the central server. Marking, moderating and awarding can therefore be corrected by actual pupil performance. (See Figure 6 below.)

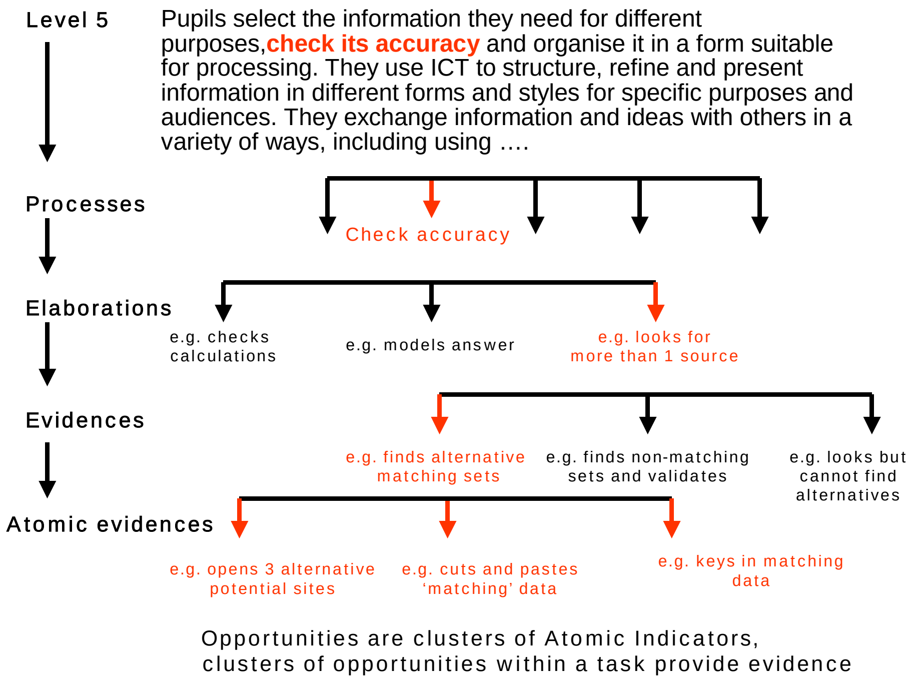
Figure 6.



In the longer term it should be possible to establish a model where only the subject domain rules change. As it stands the simple sequential model, Key Stage 3 ICT Levels 1-3, are prescriptive in expected outcome, employing lower cognitive process in indicative performances. This is inappropriate to the higher cognitive processes such as hypothesising, evaluation, creativity where more complex arrays have to first be identified and continuously refined.

Inevitable shifts in technology means that new methods of achieving successful task resolution will demand an updating of the models assumptions.

Figure 7:



In the current model the hypotheses have been set in a rules base. This rules base starts with high level descriptions of expected performance at each level, these are progressively expanded on through process, sub-process and evidence of sub-process by a process of examining students performance at each of these levels and analysing how they arrived at their outcomes.

Clusters of behaviours – opportunities to evidence – are observed and declared as indicative of particular evidence. The behaviours themselves are clusters of keystrokes around ambient data showing meaningful activity. These clusters are described as AIs.

In creating the rules base – setting the hypotheses – we have to gather data and analyse them to establish proof, validity or otherwise. If proof is not established then other proofs can be determined, which in turn inform the rules base development.

Student log files are interrogated by algorithms, that search for clusters of AIs, opportunities to evidence, and in doing so re-construct the complex system. The various sufficiency thresholds at each level of the logic tree, or matrix, provide data to inform a level outcome and aid the decision process.

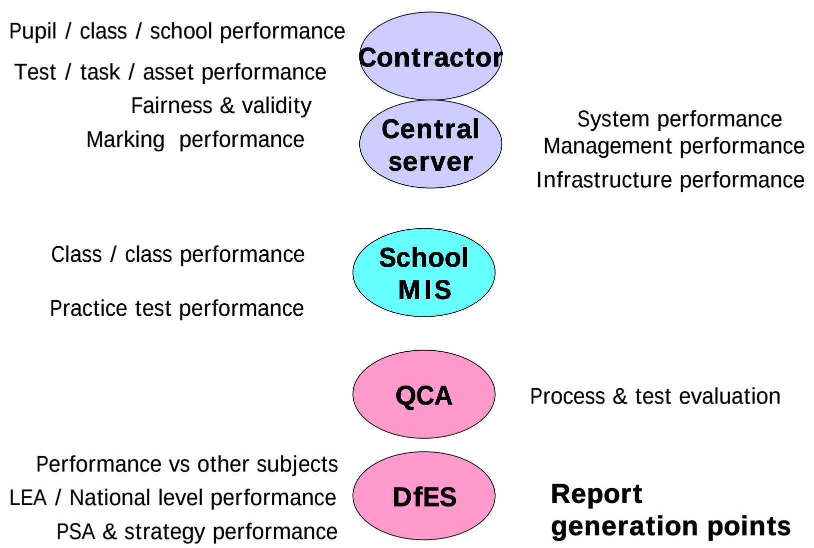
In the process of performing a task a student will deploy a range of methods within applications, although not a skills test, the Key Stage 3 ICT test will detect this and use the data to establish concepts of appropriateness. An example is to use a link to dynamic web-based data to ensure currency of the data where it is used in a spreadsheet. Another example is the use of the “paste special” function to preserve formatting as one indicator of efficiency, where it is appropriate. Tracking this inside the software requires each activity to have its own thread so that if something is copied into a piece of work appropriately a later deletion of that same something would lead to the previous action being negated.

Each student may well have been presented with different opportunities to evidence by the adaptive algorithms inside the test engine. Although the pathways may be different each will have its own sufficiency level. Test writers have the task of ensuring sufficient opportunities are available to students no matter what pathway they take. Add into the mix the adaptive nature of the ambient data and there is an increasing level of complexity when it comes to demonstrating, say, appropriateness of outcomes.

Examples of reporting outcomes and associated data sets for the Key Stage 3 ICT project

Reporting is the physical manifestation of the data/ information in a form appropriate for each stakeholder audience. In achieving this, it is necessary to determine, through the methods described earlier in the paper, not only what the data and information requirements are, but also the manner in which they should be presented.

Figure 8.



E-assessment systems allow for the generation of reports on the fly as well as at fixed points, they also allow for reports to be generated simultaneously in different locations at the same time whilst being tailored, in style, language, detail and media, for each stakeholder.

Figure 8 presents an example, from the Key Stage 3 ICT project, of multiple report generation at different locations.

With this data rich test model both summative and formative reporting for both pupil and teacher audiences, complete with next step guidance can be generated. The difference being that the summative report details the performance indicators that lead to the award of the specific grade or level alongside the award itself, whereas the formative report details the profile of the processes and outcomes generated by the pupil and where they map to the progression strands of the curriculum. In this way next steps guidance can be generated, but only guidance relevant to the parts of the curriculum covered by the tasks or by a pupil's performance. (See Figure 9.) Formative reporting cannot draw negative inferences about areas not covered, except where there is dependence through conceptual links.

Figure 9: An example of a draft – work in progress - formative pupil report, detailing current strengths

QCA TeLogo	**Name: Joe Bloggs**	**Class: 9A**

In the Tourist Information Centre, you were asked to:

- **Make a presentation for use in the Pepford Tourist Information Centre.**
- **Work out how much it will cost to stay in a hotel.**
- **Send an email with an attachment.**

	When working in Pepford Tourist Information Centre, you showed that you could:
Using data and information sources	decide which sources of information were most accurate and relevant, e.g. you compared data from two websites decide which data is most suitable for the job you are doing, e.g. you put the address of the tourist information centre in your poster
Searching and selecting	search data to help you prepare your presentation, e.g. you used efficient searches in the web browser experiment with rules of a model to see what happens, e.g. you changed the hotel pricing model
Organising and investigating	work out a new cost when your customer asked you to e.g. you entered customer information into the model to find out the price of the hotel. make changes to your presentation to make it better e.g. you used autorun for the presentation
Analysing and automating processes	create a model for a system e.g. you created an efficient model to calculate the cost of a hotel booking automate simple processes e.g. you used a master slide for your presentation
Models and modelling	use a spreadsheet or model e.g. you used a spreadsheet to create a model to work out hotel costs change a spreadsheet model, e.g. you changed the hotel cost model to make it easier to use
Control and monitoring	N/A
Fitness for purpose	change your work to make it suitable an audience e.g. you changed your presentation to make it suitable for younger people present your ideas in a way which suited the audience e.g. you used a large font to make it suitable for young people
Refining and presenting information	combine information from a wide variety of sources to solve a problem choose the most suitable data from the sources available and combine them in your presentation e.g. you choose an appropriate logo for the Tourist Information Centre
Communicating	use email and other tools to share ideas with groups of people e.g. you sent your presentation to Mr. Jones, the manager. use ICT in a businesslike way e.g. you used the letter template to write a letter to Mr. Harris.

The final analysis

There is a lot of work to be done post gathering of data in terms of validity, process evaluation and feedback. This could well be the subject of a follow up paper. Here the hypotheses have been comprehensively laid down in project documentation and the returning test data from the live pilot and beyond, in the Key Stage 3 ICT model, will help to ascertain their validity, or identify their weaknesses. The statistical mechanics of validity, in this process-based model, will also be closely followed.