Policy Note: Assessment of Practical Work in Science April 2013

Purpose

This policy note has been written by the Gatsby Foundation and the Wellcome Trust to support decisions about the assessment of science practical work in English schools. It is particularly concerned with GCSE assessment, given the timescale for developments at that level. The proposals have been shaped by a study of practice in other subjects and in other countries and by consultation with subject and assessment experts in schools, universities and Awarding Organisations. Annex 1 has details of the evidence base.

Why is it so important to assess science practical work?

Experiments are the essence of science, and studying science without practical experimental work is like studying literature without reading books. Practical work develops technical and scientific skills, and improves scientific understanding. Yet, over the last 20 years, there has been a steady erosion of laboratory skills taught in school science and this is of significant concern to industry and universities.

It is vital that practical work is assessed as part of all science qualifications including at GCSE and A level. A qualification such as GCSE Physics or A level Chemistry needs to assure employers and universities that the holder has competence in technical and other investigative skills as well as theoretical knowledge and understanding.

No GCSE or A level science qualification should be awarded without evidence that students have developed hands-on practical scientific skills.

The problem with present arrangements for GCSE science

The current norm at GCSE is 'controlled assessment', whereby, in science, candidates have to carry out one or two investigations from a small number set by the Awarding Organisation under highly controlled conditions. There is universal agreement among those we consulted that this assessment method is deeply flawed. It makes teachers focus on a narrow range of externally-set practicals as they hone students to do well in what constitutes 25% of their final grade. Students are internally assessed on their planning and analytical abilities (not on their technical skills) by their teachers who, under our high stakes system, are under enormous pressure to give students maximum marks.

Our current system of controlled assessment in science has to go, but what should take its place?

Our study of practice in other countries and other subjects shows that direct assessment of practical work, involving the teacher in some way, is widely trusted. It is not seen as problematic in countries such as China, Singapore and Finland, and in our own country it is settled practice in modern languages and music – though usually involving some kind of moderation to secure standards. We believe that in the long term, this is the way to go.

We accept that a system relying mainly on teacher assessment has pragmatic and political implications difficult to resolve in the short term. We are however convinced that such a system would better recognise technical skills and improve teaching practice. We have considered several models (see Annex 2), including externally marked practical examinations, and we make the following recommendation for the shorter term.

Our recommendation for the shorter term

All GCSE science qualifications should include practical work assessed by a combination of:

A. **Questions in the written paper** which are designed to assess candidates' experimental and investigative skills developed through their familiarity with performing, and understanding of, certain experiments identified in the specification (for example, investigating the effect of temperature on enzyme action).
B. **Teachers' assessments** of certain technical and scientific skills identified in the specification (for example, using an ammeter to measure the current in a circuit). Evidence of participation in this work should be collected for every student and the headteacher of each school would be expected to certify the authenticity of each teacher's assessments. Teachers would give each student an overall mark across the full range of skills, thus allowing a deficit in one skill to be compensated for by proficiency in others.

The combination would be more heavily weighted towards component A: the purpose of B is to ensure that candidates have sufficient experience of a range of essential practical techniques to assure their competence. As a starting point, we suggest Component A should carry 15% of the overall marks, and Component B 10%. It must be stressed that component A can never be sufficient on its own, not least because it leaves open the likelihood of teachers coaching students to do the questions without having done any real practical work.

Awarding Organisations would be expected to publish in their specifications lists of (a) the specific experiments that candidates will be expected to have done and (b) the specific technical and scientific skills they will be expected to have acquired. Annex 3 has examples of such lists.

If for any reason this recommendation is unacceptable, our fall-back recommendation would be for an externally set and marked practical examination.

In the longer term

We believe that both components A and B can be optimised through research and development. For component A, Awarding Organisations should undertake work to improve questions and develop assessment techniques, perhaps involving computers, to minimise the potential for students to score well without having done the experiment.

For Component B, Awarding Organisations should pilot systems for quality assuring teachers' assessments, so that confidence in the reliability of these assessments grows over time. This might involve the accreditation of individual schools, or the use of local school cluster moderation whereby experienced teachers from nearby schools collectively help standardise each centre's assessment.

Finally, we are convinced by the evidence that open-ended project work, in which candidates are able to explore a practical project of their own devising, has great potential for developing a wide range of practical and enquiry skills. While we accept that this is not yet a pragmatic possibility at GCSE, we believe it should be explored further, especially at A level, where the Extended Project Qualification has great potential for practical projects.

Annexes

Annex 1 Sources of evidence

Due to the lack of relevant, published research on this issue, in June 2012 the Gatsby Charitable Foundation commissioned a review of assessment of practical skills in other countries, subjects and qualifications from senior researchers at the Institute of Education (University of London) and the University of York. The final report on 'Improving the assessment of practical work in school science' from Professor Michael Reiss, Dr Ian Abrahams and Ms Rachael Sharpe was published in October 2012 and is available to download from the Gatsby website: http://www.gatsby.org.uk/~/media/Files/Education/Improving%20the%20assessment%20of%20practical%20work%20in%20school%20science.ashx

The results of the report were discussed with representatives from the three main Awarding Organisations in England (AQA, OCR and Edexcel) in November 2012 who acknowledged that the current methods of assessing practical science were not optimal. These representatives claimed that greater clarity from the science community regarding the most important practical skills at GCSE level would help them to develop more suitable methods of assessment.

In December 2012 Gatsby invited a panel of 18 science education experts from across Chemistry, Physics and Biology to suggest the most important technical and investigative skills they felt should be learned by the end of Key Stage 4 science, and the results of this consultation have informed this paper.

Annex 2 Summary of the models of assessment considered

The research by Reiss, Abrahams and Sharpe identified a range of different forms of assessment of practical work (across a number of subjects) currently in use:

1. Report on an investigation – students write their report on an investigation using their own data OR data with which they have been provided. In neither case are their practical skills are observed or assessed directly.
2. Written examination – students complete a test paper under examination conditions, some questions in which will relate to practicals undertaken during their course.
3. Viva – students are given an oral examination in which they are asked questions about a project they have undertaken.
4. Practical examination by means of a report – students conduct a practical and write up their apparatus, methods, results and evaluations.
5. Practical examination – teacher (or other examiner) observes students undertaking practical work.
6. Practical examination by means of recording – examiner listens to an audio- or video-recording of a performed task.
7. Practical examination by means of observation of an artefact – examiner views a painting made in Art or a product made in Design and Technology.

Only methods 5 – 7 employ *direct* assessment of practical skills.

The view from the experts we consulted in February was that while assessment was a complex area, it was clear that in science we are talking about a range of different skills which logically require a range of different assessment methods. Those methods with most support were:

1. A written exam (which would assess parts of scientific enquiry such as planning an investigation, identifying dependent and independent variables, data analysis).

2. A practical exam OR series of 5-10 practical tasks (which would assess the ability to manipulate apparatus, take accurate readings, and work safely and logically).

3. A project report (which could assess the ability to apply knowledge, record and communicate findings, work in a group and present results).

There was no support among educationalists for the continued use of investigations as instruments for assessment under controlled conditions. It should also be noted that a minority felt that the problems of assessment in science were insurmountable under our high stakes system and that there were risks in the premature introduction of any new method.

Subsequent discussions with Awarding Organisations established that they do not want to continue with the current model of controlled assessment in GCSE science either. However they are mindful that whatever they do, their ‘product’ needs to be acceptable to schools in terms of costs and complexity. They also argue that any method needs to allow them to ‘differentiate’ among the ability range. With relatively little time to develop and test new methods of assessment, our impression is that the written examination would be their preferred option of assessing practical skills, despite the fact that this would inevitably involve a trade-off with the time and space available to assess core knowledge.

Annex 3 Examples of the skills experts suggested that GCSE science students should have acquired by the end of Key Stage 4, and experiments they should have experienced in order to gain and practice these skills.

*Most important **technical skills***	*Experiments through which that skill may be gained*
Assemble simple apparatus from instructions	– Use an ammeter to measure the current in a circuit – Use a respirometer to measure fermentation rates in yeast – Use volumetric apparatus to undertake titrations
Reliably demonstrate or test a scientific phenomenon using specialist equipment	– Use quadrats to investigate the effect on plant diversity of trampling on a playing field – Use a balance to determine yield when making ammonium sulfate
Make accurate and precise measurements of quantities with appropriate equipment	– Measurement of volume of liquids using measuring cylinders, syringes, burettes, pipettes, as appropriate – Measure the speed of an object with a light gate or ticker tape
Use glassware with safety and precision in laboratory-based investigations	– Collect samples of gases from chemical reactions – Measure the effect of temperature on an enzyme reaction using a water bath
Follow and safely use basic protocols and procedures	– Make up solutions using volumetric flasks – Prepare temporary mounts for microscope examination

*Most important **investigative and experimental skills***	*Experiments through which that skill may be gained*
Able to identify an appropriate question for investigation	– Devise a way of investigating the relationship between two variables e.g. height of drop and size of impact crater
Decide how many samples to measure and at what intervals	– Investigate the effect of temperature on enzyme action – Measure current in a circuit for changing potential difference
Able to carry out basic calculations using real data	– Calculate average speed from measurements of distance and time – Measure voltage and current and calculate resistance
Able to record and manipulate data in SI units	– Convert from cm to m and ms to s and similar
Able to present results in appropriate form	– Present patterns in observations related to reactivity series – Plot a graph of rate of reaction data (e.g. volume of gas against time)
Use conceptual models to provide explanations of their experimental results	– Use a lock and key model of enzyme action to explain the effect of temperature on enzyme action – Explain why two masses fall at the same rate
Relate observed patterns in data to emerging scientific explanations	– Explain the diffusion rate of beetroot pigment at different temperatures – Interpret observations of displacement reactions of metals
Able to draw the most reliable conclusions from available data and defend decisions	– Explain the extent of correlation shown in a scattergram – Draw conclusions about patterns in thermochemistry from tables of data