20 AUGUST 2013

REFORMED GCSE SUBJECT CONTENT FOR SCIENCE

RESPONSE TO THE
DEPARTMENT FOR EDUCATION CONSULTATION

GATSBY

KEY MESSAGES

1 Practical skills, including technical and investigative, must be made more explicit within the GCSE science subject criteria. We recommend a more detailed set of skills and associated learning outcomes in the 'Working Scientifically' section and embedding these skills through the subject content, as is currently done for skills in the 'Uses of mathematics'.

2 The new GCSE science criteria must at the very least maintain the current weighting of 25% for the assessment of practical skills. We therefore recommend that 'indirect assessment' of 'Experimental skills and methods' is increased to 15%.

3 We welcome the requirement in the GCSE science criteria that practical skills need to be directly assessed, and the proposal in Ofqual's GSCE reform consultation that 10% of the marks in each science qualification comes from an alternative to a written exam. In the long term, a way needs to be found to restore professional integrity to teachers' assessments but in the short-term we recommend a terminal practical examination for the 10% direct assessment of technical and manipulative skills in science GCSEs. We develop this further in our response to the Ofqual consultation on GCSE reform.

INTRODUCTION

1 Gatsby is a foundation set up in 1967 by David Sainsbury (now Lord Sainsbury of Turville) to realise his charitable objectives. We focus our support on the following areas:

- Plant science research
- Neuroscience research
- Science and engineering education
- Economic development in Africa
- Public policy research and advice
- The Arts

2 Practical work is an essential part of school science education. Good quality practical science develops important skills, deepens knowledge, enhances engagement among students, and challenges them to apply both knowledge and skills in purposeful contexts. 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.

3 Evidence shows that practical science needs support in UK schools and colleges and Gatsby is currently engaged in a programme focused on better assessment, improved access to teaching resources, and strengthened roles for technicians and senior leaders[1]. This response is based on work conducted in partnership with the Wellcome Trust.

SUBJECT CONTENT AND ASSESSMENT OBJECTIVES – PRACTICAL SKILLS

4 The 'Working Scientifically' section of the draft GCSE science subject content needs work to remove duplication, clarify skills requirements, and align the content with the Assessment Objectives and learning outcomes. This will ensure that Awarding Organisations each develop their GCSEs in science to equal levels of demand when it comes to practical skills. We set out below our thinking on what 'Working Scientifically' might comprise. In Appendix 1 we give explanations of some of the terms used. We would be pleased to work with DfE to help redraft this section of the GCSE science subject content.

5 'Working Scientifically' requires a range of practical skills which we divide into two sets: technical and manipulative; and investigative and experimental. These equate to AO4 and AO3 respectively in the Assessment Objectives. We believe that the latter set of skills can be assessed by questions in a written paper which are designed to assess candidates' skills developed through their familiarity with performing, and understanding of, certain experiments identified in the specification.

6 However technical and manipulative skills are not best assessed through a written exam. Our study of practice in other countries[2] 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, direct teacher assessment of practical skills is the way to go, but in the short term we recommend the introduction of a terminal practical exam.

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[1] Further information about this programme of work and the evidence collected is on the Gatsby website: http://www.gatsby.org.uk/Education/Projects/Review-of-Practical-Science-in-Schools.aspx.

[2] Reiss, M., Abrahams, I., and Sharpe, R. (2012) Improving the assessment of practical work in school science. A report for the Gatsby Foundation.

Together with the Wellcome Trust we have produced a policy note and a more detailed addendum to give further information on our position on GSCE science assessment[3,4].

7 Technical and manipulative skills are needed for all practical work from following instructions given in protocols and standard procedures to investigations and experiments. Broadly these are:

- using laboratory and fieldwork techniques
- making and recording observations and measurements
- processing data

8 Further practical skills (investigative and experimental skills) are needed to carry out investigations and experiments. Broadly these are:

- analysing a problem
- planning an investigation or experiment
- analysing and evaluating data
- drawing conclusions

9 The 'Working Scientifically' section currently includes 'Examples' of activities across each of Biology, Chemistry and Physics. We welcome this attempt to show that some practical skills can be usefully associated with core content, but suggest that this would be clearer for Awarding Organisations if those skills appeared within the content, in the same way as for skills in the 'Uses of mathematics'. Appendix 2 indicates how the range of technical and manipulative skills, expressed as learning outcomes, might be associated with a scope of subject content in GCSE sciences. Practical skills can be taught, and assessed, through a range of different contexts in the same way as mathematical skills[5].

10 However we do not think that the GSCE science criteria should specify the practical activities which should be undertaken during Key Stage 4 science. Instead we recommend that Awarding Organisations indicate in each GCSE science specification the range of practicals which could support the relevant assessment objectives. In Appendix 3 we give an example of how this might be achieved for the technical and manipulative skills outlined in the Appendix 2.

RELATIVE WEIGHTING OF ASSESSMENT OBJECTIVES

11 It is vital that practical work is assessed as part of all science qualifications at GCSE level. These qualifications need to ensure progression in STEM education and employment, where competence in technical and investigative skills is as important as theoretical knowledge and understanding.

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[3] Policy note: Assessment of school practical science, Gatsby Foundation and Wellcome Trust, April 2013: http://www.gatsby.org.uk/~/media/Files/Education/Practical%20Science%20Policy%20Note.ashx

[4] Policy note addendum: Assessment of school practical science, Gatsby Foundation and Wellcome Trust, August 2013: http://www.gatsby.org.uk/~/media/Files/Education/Practical%20Science%20Policy%20Note%20Addendum.ashx

[5] While fieldwork techniques are best taught outdoors, assessing them in the field the same way laboratory techniques are assessed in the lab is inherently problematic due to environmental unpredictability. Further work is needed across the science and geography communities to agree the best approach regarding assessment and fieldwork.

12 Current GCSE specifications in Science allocate a weighting of 75 per cent to external assessment and a weighting of 25 per cent to controlled assessment in the overall scheme of assessment. While this mode of controlled assessment is deeply flawed, it does represent 25% of the total marks being awarded to experimental skills and methods. Under DfE's proposals for reformed GCSE science, this weighting would be reduced to 20%: 10% for skills being 'amenable to indirect assessment' and 10% for skills 'requiring direct assessment'. We therefore recommend that weighting of the former set of skills be increased to at least 15% to make clear that practical science has not been diminished in the new science GCSEs.

13 Questions regarding this response should be directed to:

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APPENDIX 1 – EXPLANATION OF TERMS USED

There do not appear to be agreed definitions for some of the key terms used when discussing practical science but we suggest those below as good working explanations.

Laboratory and fieldwork techniques enable the correct handling and use of materials and scientific equipment when following a protocol or standard procedure or when carrying out an investigation or experiment. They include sampling, sample preparation, transferring materials, measuring quantities, assembling apparatus, mixing and heating and separating materials.

The term *'technique'* is also used for generic methods to investigate, identify, analyse and characterise, such as imaging (e.g. light microscopy), chromatography (e.g. paper, thin layer and GLC), aseptic technique (e.g. culturing) and spectroscopy (e.g. visible and infrared).

Protocols and standard procedures are used routinely to produce a required piece of information. Required materials, apparatus and equipment are specified and full instructions for gathering and processing data are given. They usually require the application of a number of laboratory and fieldwork techniques.

An *investigation* involves observing and measuring the natural world with minimal interference or manipulation. Ecological studies are an example.

An *experiment* involves controlling variables to establish cause-and-effect relationships. Finding out what factors affect the rate of photosynthesis is an example.

APPENDIX 2 – TABLE TO SHOW SUGGESTED ASSESSMENT OBJECTIVES FOR TECHNICAL AND MANIPULATIVE SKILLS IN GCSE SCIENCE

Assessment objective	Learning outcomes	Scope
To be able to work safely and confidently when handling and manipulating materials and basic equipment in laboratory and in the field	1. collect and store materials and samples	living specimens and non-living materials (chemical substances, mixtures and materials) sampling techniques, e.g. quadrats and transects, kick sampling, representative, random
	2. prepare reagents, solutions and samples	standard solutions and serial dilutions agar plates temporary microscope mounts (including staining) dissection, e.g. organisms or parts of an organism
	3. assemble and use apparatus and glassware	transferring materials (solid, liquid and gaseous) separating mixtures (e.g. precipitation, crystallisation, filtration, drying, distillation, chromatography, decantation and centrifugation) titrations, simple (using dropping pipettes) and advanced (using burettes and pipettes) aseptic technique, e.g. inoculating loops, flaming , autoclave/pressure cooker
	4. assemble and use electrical and mechanical equipment	heating (including water bath) mixing materials electrical circuits from circuit diagrams and components mechanical devices
To be able to observe, measure and record accurately, either unaided or using instruments	5. make accurate and objective observations, unaided or using instruments	senses: sight, smell, sound appearance (static and changing situations) magnifying glass, optical microscope, telescope
	6. make accurate, precise and reliable measurements using analogue and digital equipment	basic: measuring tape, ruler; balance; stopwatch; thermometer, measuring cylinder, pipette, burette, syringe, force meter, ammeter, voltmeter specialised: micrometer, graticule, multimeter, ticker-timer, cathode ray oscilloscope sensors, e.g. pH probe, thermistor, colorimeter, motion sensor

	7. record qualitative and quantitative data	qualitative: written descriptions, annotated drawings and photographs quantitative: counting, measurement, standard form, appropriate number of significant figures data loggers, computers, digital camera, digital microscope with visualise/flexi-camera correct use of units, symbols and nomenclature
To be able to process data to identify and classify materials and to calculate quantities	8. describe and classify materials and change	states of matter and changes of state organisms (use of keys), elements (periodic table), chemical substances and reactions materials (metals, polymers, ceramics)
	9. calculate values from primary data	basic mathematical operations and mathematical formulae surface areas, volumes, ratios, direct proportions, percentiles arithmetic means, probability
	10. use graphs to present data and to calculate quantities	line graphs (including straight line) and tangents to curved graphs rate of change

APPENDIX 3 – TABLE TO SHOW THE RELATIONSHIP BETWEEN THESE ASSESSMENT OBJECTIVES AND A NUMBER OF ESTABLISHED PRACTICAL ACTIVITIES

Practical activity	Assessment outcomes									
	1	2	3	4	5	6	7	8	9	10
Biology										
Observing earthworm locomotion	✓	✓	✓		✓		✓			
Biodiversity in your backyard	✓				✓			✓		
Seed germination (including extensions ideas; also quantitative measurements and germination %)	✓	✓	✓		✓	✓	✓		✓	
Investigating factors affecting the rate of photosynthesis (including extension ideas)			✓	✓		✓	✓			✓
Looking at xylem and specialised cells (could also use digital microscope with camera)	✓	✓			✓		✓	✓		
Effect of size on uptake by diffusion		✓			✓	✓	✓		✓	
Chemistry										
Decolourising and deodorising (could be extended into a longer investigation)	✓		✓		✓		✓			
Preparing an insoluble salt (several alternative salts could be made; yield could be measured)		✓	✓		✓	✓	✓		✓	
The change in mass when magnesium burns (could be extended to finding the formula of MgO)		✓	✓			✓	✓		✓	✓
Exothermic or endothermic		✓	✓			✓	✓	✓	✓	
Identifying the products of electrolysis		✓	✓	✓	✓		✓			
Rate of reaction of magnesium with hydrochloric acid			✓			✓	✓		✓	✓
Physics										
Measuring the thickness of a coin						✓	✓		✓	✓
Trolley and falling mass (including series of readings for different loads and different distances of fall)				✓		✓	✓		✓	✓
Stress and strain (including extensions)		✓		✓		✓	✓		✓	✓
Watching crystal growth under a micropscope (could be extended to include measurement)		✓	✓	✓		✓	✓		✓	
Measuring the efficiency of a small electrical immersion heater			✓	✓		✓	✓		✓	
Measuring resistance with a voltmeter and an ammeter				✓		✓	✓		✓	

A green tick (✓) indicates that the assessment objective could be met with some small modifications to the procedure.