

Consultation on the Assessment of Practical Work in GCSE Science

covering:

Biology

Chemistry

Physics

Combined science



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Foreword

We are pleased to present our second consultation on reforms to GCSE sciences¹ in England.

Last year we suggested that students' practical science work should be assessed by non-exam assessment, counting for ten per cent of the marks. People who responded to our consultation had mixed views about that, and we have been discussing fresh options with teachers, subject associations and others.

We want a good educational experience and good educational outcomes for students, as well as results we can all trust. Above all, we want science GCSEs that encourage a wide range of practical science teaching over the period of study, so that students' experience of practical science work is positive, and beneficial.

Scientists agree that practical work is central to good school science and that science GCSEs should require it. The problem is how to make sure students get sufficient and stimulating experience of it, and then how best to assess it when so much rides on results, for students and for schools.

It has long been recognised that assessment drives teaching and learning,² but assessment has led to a narrowing of the curriculum. It is important to have reliable assessment in a high-stakes environment. We do not have the evidence that practical science work can be assessed reliably enough by marked non-exam assessment, particularly if marks for direct assessment of practical skills³ are included in grades, given other pressures on schools.

We think the proposals we are making are more likely than any others to encourage breadth and variety in practical work, and enable teachers to integrate practical work into their teaching so as to deliver a good educational experience for students, as well as results we can all trust.

We are open to other suggestions, and to any ideas for trialling new ways to improve controls over teacher-assessed student work. This will be an open and fully consultative process. We welcome your views and suggestions, and look forward to hearing from you.

¹ GCSE sciences includes biology, chemistry, physics and combined science.

² J.F. Donnelly, A.S. Buchan, E.W. Jenkins, P.M. Laws and A.G. Welford (1996) *Investigations by Order: Policy, Curriculum and Science Teachers' work under the Education Reform Act*. Nafferton: Studies in Education. A. Pollard, P. Triggs, P. Broadfoot, E. McNess and M Osborn (2000): *What Pupils Say: Changing Policy and Practice in Primary Education*. London: Continuum.

³ Here, and throughout, we use the term 'practical work' to refer to such teaching in a broad sense and the term 'practical skills' to refer to the specific technical and manipulative abilities that it encompasses.



Chief Regulator

Glenys Stacey



Chair

Amanda Spielman

Executive summary

In summer 2018, students in England will take new GCSEs in biology, chemistry, physics and combined science (science GCSEs).⁴ These will be based on new subject content and requirements for 'working scientifically' that emphasise students' understanding of scientific experiments and their ability to conduct them.

We need to determine how students will be assessed. Our aim is to ensure the best educational outcomes, and valid, reliable assessments that must be manageable for schools. This consultation seeks views on our proposals for students' practical science experience to be assessed by exam and confirmed through a school and student record. In summary, our main proposals are as follows.

- Written exams would include questions that draw on students' practical science experience. At least 15 per cent of marks for each GCSE would be allocated to these. The questions would be designed to give students with practical experience a real advantage over those without.
- GCSE specifications would set out the apparatus students should use and the techniques they should develop, together with a minimum of eight practical activities (16 for combined science) they should do during the course using the specified apparatus and techniques.
- Students would each keep a record of their practical work, to be made available to their exam board on request. This student record could be a laboratory notebook (we welcome views and suggestions).
- Schools would then confirm to their exam board that each student has completed the practical activities and so has used the required apparatus and developed the required techniques. This submission of the school record would be a pre-requisite ahead of exams.

We believe this approach addresses many of the current problems. It should broaden the range of practical work in science GCSEs and enable students to develop good hands-on skills. There are implementation questions to consider with schools and exam boards – for example, what happens should students not complete the required practical work, and what monitoring should exam boards do? We will want fair and practical arrangements for such matters, but we are not dealing with that detail here. Instead, we set out the rationale for our main proposals and the alternatives we have considered.

We welcome views on our proposals. We also welcome suggestions for alternative proposals and how they can better address the aims, as set out in the consultation document, such as whether they will encourage a wide range of practical teaching.

⁴ The new GCSEs in biology, chemistry and physics will be single awards; GCSE in combined science will be a double award.

We look forward to receiving your views.

How to respond

The closing date for responses to this consultation is **4th February 2015**. You can respond to this consultation in one of the following ways:

- Complete the online response at:
<http://surveys.ofqual.gov.uk/s3/theassessment-of-practical-work-in-gcse-science>
- Email your response to consultations@ofqual.gov.uk
Please include the consultation title (GCSE practical science consultation) in the subject line of the email and make clear who you are and in what capacity you are responding.
- Post your response to: GCSE practical science consultation, Ofqual, Spring Place, Herald Avenue, Coventry, CV5 6UB.

Evaluating the responses

To evaluate responses properly, we need to know who is responding to the consultation and in what capacity. We will only consider your response if you complete the information page.

Any personal data (such as your name, address and any other identifying information) will be processed in accordance with the Data Protection Act 1998 and our standard terms and conditions.

We will publish the evaluation of responses. Please note that we may publish all or part of your response unless you tell us (in your answer to the confidentiality question) that you want us to treat your response as confidential. If you tell us you wish your response to be treated as confidential, we will not include your details in any published list of respondents, although we may quote from your response anonymously.

1. Background

Curriculum, assessment and accountability tensions

A recent review⁵ of some other countries'⁶ practical science assessments found that some countries that count as high-performing make use of a substantial proportion of

⁵ Ian Abrahams, Michael J. Reiss & Rachael M Sharpe (2013): The assessment of practical work in school science, *Studies in Science Education*, 49:2, 209-251, DOI:10.1080/03057267.2-13,858496

⁶ China, Finland, Singapore, New Zealand, Australia, France and Scotland

direct assessment of practical skills, compared to countries such as Australia, England and Scotland where we rely more on indirect assessment. It also noted that countries differ greatly, and vary over time, in the importance they attach to school accountability, teacher autonomy and the utility of regular summative assessment and reporting of student attainment (results).

There is an established expectation that GCSEs will provide remarkably reliable results, to inform selection decisions. For that, they must be resilient, able to withstand accountability pressures. Indeed, the newly stated purposes of GCSEs⁷ include that they provide a basis upon which schools will be held accountable for the performance of all their pupils. That heightens the natural tension between the curriculum aims, reliability expectations, and the need for resilient assessments – a tension noticeably more apparent here than in other countries with less demanding accountability arrangements.

There is a variety of practice around the world. For example, Singapore O levels use a teacher-marked practical exam. Cambridge International O levels use a board set and marked practical exam. In the Netherlands schools have much more freedom in the way that they test practical and investigative skills. So do teachers in Finland, but the Finnish Matriculation Examination includes no practical element. Good qualifications strike a sensible balance between curriculum aims, assessment and accountability, recognising that curriculum matters most, and that not everything that is taught in a good curriculum need be formally assessed. Some things of value are impossible to assess, or to assess validly given our accountability pressures. This is especially so for practical skills in any subject. They are the first to suffer when the tensions become too great.

For new high-stakes qualifications that include practical work, we have prioritised curriculum aims and then the need for reliable assessment, if necessary by protecting practical work from the pressures of accountability. So, for example, geographers agree that fieldwork is an essential part of GCSE geography,⁸ disagree about whether it can be assessed sufficiently reliably by non-exam assessment, but agree that some of the skills can be assessed by exam.⁹ The new GCSE includes fieldwork, with fieldwork-related knowledge and skills assessed by exam, rather than non-exam assessment. Schools will be required to include fieldwork as a compulsory part of their courses, to protect curriculum aims.

Our proposals for science GCSEs are similar, and seek to strike the same balance so as to increase the prospect of students studying the full curriculum and enjoying stimulating and varied practical skills work as they study.

The importance of practical science work

There is a unanimous view in the science community that practical work is a vital part of good science education. In 2011 the House of Commons Science and Technology

⁷ Letter from the Secretary of State to Ofqual, 6th February 2013

www.gov.uk/government/uploads/system/uploads/attachment_data/file/278308/sos_ofqual_letter_060213.pdf

Committee reported that in its view practical work, including fieldwork is a vital part of science education.¹⁰ The Gatsby Foundation and the Wellcome Trust (April 2013)¹¹ said that:

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.

The science teaching profession generally agrees that the main purpose of practical work is *formative*,¹² enabling students to learn to understand science, and how scientific ideas are developed. Teachers commonly state the purposes of practical work as including motivation for students, the excitement of discovery, consolidation of theory, development of manipulative skills, knowledge of standard techniques,

⁸ Review of Controlled Assessment in GCSEs, June 2013 Ofqual/13/5291
www.gov.uk/government/uploads/system/uploads/attachment_data/file/377903/2013-06-11-review-ofcontrolled-assessment-in-GCSEs.pdf

⁹ Responses to Ofqual consultation *GCSE Reform 2013* including the response from the Royal Geographical Society (with IBG) www.rgs.org/NR/rdonlyres/ED45F16A-85E0-4981-9322DD59CFB9646A/0/RGSIBGcgsereformconsultationsjune2013.pdf

¹⁰ www.publications.parliament.uk/pa/cm201012/cmselect/cmsctech/1060/106005.htm#a2

¹¹ Policy Note: Assessment of Practical Work in Science - April 2013
www.gatsby.org.uk/~media/Files/Education/Practical%20Science%20Policy%20Note.ashx

¹² Where assessment is formative the feedback students are given helps them to further their learning, as opposed to an assessment that is a formal judgement of their achievement which would be summative.
general understanding of data handling, development of other skills (e.g. analytic, evaluative, planning, applied, mathematical) and developing an understanding of how science works (e.g. concepts of scientific process, collaborative working, reproducible results, fair testing).⁸

Teachers also generally agree that isolated practical tasks of the type carried out for assessment purposes at GCSE do not enable students to find out how scientific enquiry really works. The *summative* non-exam assessment that is prevalent now (Controlled Assessment) does not support the aims of practical science. In short, practical work is essential but as summative assessment drives what is taught,⁹ the

⁸ (January 2013) *The Assessment of Practical Science: a literature review* Andrew Watt, Cambridge Assessment.

⁹ I. Abrahams, M.J. Reiss and R.M. Sharpe (2013) "The assessment of practical work in school science", *Studies in Science Education*, vol.49 no.2, pp.209–51.

way it is summatively assessed at the moment is reducing its formative impact significantly.

Practical science assessment now

There is a universal view that current practical assessments are not working. A joint policy note published by the Gatsby Foundation and the Wellcome Trust ¹⁰ included the following:

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.

Controlled assessment replaced coursework in recent years. Coursework suffered from the same problems as those identified in the quote above, and it was thought that controlled assessment would be more effective. It is not. In response to our last consultation, the Centre for Innovation and Research in Science Education at the University of York stated “there is not currently a satisfactory method for schoolbased assessment of practical work” and “the current Controlled Assessment tasks which replaced [the previous coursework model] have not improved matters, and in many respects have made them worse”.

The ‘59 club’¹¹ described the current arrangements as “time-consuming, prescriptive and repetitive... [and they] encourage ‘teaching to the test’”. The Wellcome Trust noted that the current system “consumes valuable teaching time and is vulnerable to widespread malpractice”.

Like coursework, controlled assessment arrangements do not promote an extensive and positive student experience of practical science, or produce sufficiently reliable results. Instead, students are frequently overfamiliar with just a few experiments, and their marks are skewed towards the top end of the mark range.

We do not believe that this situation can be resolved by making a few technical changes to present arrangements and expecting the exam boards to control more closely what happens in school classrooms and laboratories.

¹⁰ Policy Note: Assessment of Practical Work in Science - April 2013

www.gatsby.org.uk/~media/Files/Education/Practical%20Science%20Policy%20Note.ashx

¹¹ The ‘59 Club’ comprises the Heads of Science from 26 of the top independent schools in the UK.

Requirements for practical work in new science GCSEs

The new subject content¹² emphasises the practical aspects of science teaching (see the Working Scientifically section). There is no question that students must complete practical work. Students' understanding of scientific experiments and their ability to conduct them are emphasised throughout the requirements. Science GCSEs must give students opportunities to use relevant apparatus to develop and demonstrate a range of practical techniques.

The question, then, is how to design science GCSEs so that they meet their stated purposes, with assessment arrangements more likely to stimulate an extensive and positive student experience of practical science.

2. Possible approaches

There are two basic options for assessing practical work: direct assessment, or indirect assessment.¹³ They can be used together, with different options for different aspects of practical science work. Direct assessment refers to “any form of assessment that requires students, through the manipulation of tangible objects, to demonstrate a practical skill in a manner that can be used to determine their level of competence in that skill. In contrast, [indirect assessment] refers to any form of assessment in which a student's level of competency is inferred from the data they generate and/or reports of the practical work that they undertook.”¹⁴

Both have advantages and disadvantages. Abraham et al. recommend that if the intention is to determine competence, then direct assessment is best, whereas if the

¹²

www.gov.uk/government/uploads/system/uploads/attachment_data/file/307619/GCSE_combined_science_content.pdf

¹³ Either of these forms of assessment could be carried out by teachers or by exam boards. The difference is not in who conducts the assessment, but in the form of observation and judgement they make.

¹⁴ I. Abrahams, M.J. Reiss and R.M. Sharpe (2013) “The assessment of practical work in school science”, *Studies in Science Education*, vol.49 no.2, pp.209–51.

intention is to determine an understanding of a skill or process, then indirect assessment would be the preferred option.

Current controlled assessments assess science practical work indirectly. They mainly test how well students have planned a practical science investigation and analysed the results. They only infer students' practical skills through the results they produce. This is indirect assessment. Students' actual practical skills – their ability to manipulate scientific equipment and to conduct experiments – are not directly observed and assessed. They do not currently contribute to students' grades.

Stakeholders have suggested a range of possibilities for assessing practical science work, both directly and indirectly:

- questions in written exams that address specified practical work;
- a practical exam testing students' technical and manipulative skills;
- an extended investigation;
- a portfolio of experiments, detailing methodologies, results and conclusions.

We have considered each of these, looking for the approach that can best meet the aims to:

- deliver the curriculum aims and encourage a wide range of practical science teaching over the period of study;
- be manageable for schools – taking into account the numbers of students who take science GCSEs, the range of ability and the time typically allocated to each subject;
- provide valid and reliable assessments – test the right things and do this accurately and consistently, so as to differentiate effectively between students' performance;
- be able to withstand accountability pressures, that is, to avoid exerting unmanageable contradictions on teachers where they are acting as the assessor and being judged themselves through the outcomes of the assessments they make – the results of their students.

No one approach or combination of approaches is perfect. When it comes to the inevitable trade-offs between these aims, we have put the curriculum aims first – recognising and appreciating the formative value of practical science work in science education.

Below, we consider direct and indirect approaches to assessing practical skills, recognising that they inter-relate and can be used in combination.

Direct assessment of practical skills

Here the teacher (or an examiner) observes and marks the student doing practical science work, or views a recording of it. It has rarely been used in England, and tends to result in the use of laboratory activities that can be undertaken easily in a restricted time.¹⁵ Nevertheless, without the prospect of direct assessment it is argued that teachers are less inclined to devote time and effort to developing students' practical skills.¹⁶ Direct assessment is attractive because of its very nature.

China, Singapore, New Zealand and Finland – often described as high-performing countries – all make use of a substantial proportion of direct assessment of their students' practical science skills at some point in their schooling system. Arrangements differ in each country, depending no doubt on a range of factors, and direct assessment rarely stands alone.

There are a number of considerations for us in this country, in particular the manageability for schools, and then what would be the best monitoring and checking arrangements, given the exceptional accountability pressures here. We consider these below, and then go on to consider whether marks should count towards grades,²² and whether performance should be reported separately.

Manageability issues

We have thought about how direct assessment could be made appropriately manageable for schools, but we haven't found an answer. Arrangements must be manageable, and yet manageable arrangements inevitably mean that other aspirations for practical work would be severely compromised.

Sheer numbers are a particular consideration. Class sizes are typically much larger than for A levels, and the teaching time significantly less. Over half a million students take science GCSEs each year and there are over one million entries in all: 130,000 for each of biology, chemistry and physics; 310,000 for additional science; and 350,000 for science. A level entry figures are much lower, at 58,000 for biology, 49,000 for chemistry and 33,500 for physics.²³

Teachers would need to observe directly and carefully a sufficient amount of each student's practical work to judge whether or not that student had performed the wide range of specified skills to the required standard. If students' skills were to be

¹⁵ V.N. Lunetta, A. Hofstein, and M.P. Clough (2007) "Learning and teaching in the school science laboratory: an analysis of research, theory, and practice". In S.K. Abell, and N.G. Lederman (eds), *Handbook of Research on Science Education* (pp.393–441). Mahwah, NJ: Lawrence Erlbaum.

¹⁶ Donnelly et al. (1996), op. cit.

assessed in more than a few practical tasks, the assessments would become unmanageable, yet with too few tasks they would not be particularly valid.

One approach would be to notify schools of a limited set of assessment tasks a short time before assessment. That could encourage the teaching of a wider range of practical skills beforehand and so meet the curriculum aims. There would be some issues (equipment supply, for example) to consider that might themselves limit the choice of task. Moreover we fear that, given other pressures, some teachers would be tempted to limit students' experience to those tasks they think most likely to come up, or might practise with students the tasks once known, rather than undertaking stimulating practical work throughout the course. We are most struck by a comment made to us by a teacher about summative assessment in science:

My concerns over the use of teacher-assessed components are based on the changes to education and accountability that have happened over recent decades. Before the introduction of league tables, teachers could

²² Currently, teachers' marks for practical work contribute to grades through the controlled assessments.

²³ 2014 GCSE, AS and A level entry data for students in England only, Joint Council for Qualifications

be expected to reliably and honestly assess their own students. Since then, the intense pressure that schools are under to maximise students' results has increased dramatically, and this pressure is pushed down on to teachers by senior staff. Promotion opportunities often relate to student performance, and now the abolition of automatic progression up the Main Pay Scale will result in further increased pressure on teachers to inflate the grades of their own students. I have often used the analogy that asking teachers to assess their own students is like asking Premier League footballers to referee their own matches. The stakes are too high to expect them to do this honestly.

The use of visiting examiners would on the face of it reduce the loss of teaching time to assessment, and incidentally bring independence of judgement as well. However, millions of practical assessments would need to be conducted in a short period of time as each student would need to be assessed across a sufficiently wide range of practical skills and activities. Moreover, most visiting examiners would themselves be serving science teachers, unlikely to be freed up from their day jobs in schools. We do not think this option is deliverable.

Monitoring and checking arrangements

We can envisage the direct assessment of a limited range of practical tasks, albeit this would be a sizeable undertaking for schools and it would come with the drawbacks outlined above. However it does not seem to us to be a viable option

once we consider the monitoring and checking arrangements that would be necessary, so as to provide reliable assessments that withstand accountability pressures.

Cluster moderation

This involves teachers observing and marking across a cluster of schools and comparing them with each other, and with national standards, and adjusting marks accordingly. Cluster moderation featured in the past, notably in the Certificate of Secondary Education (CSE), when exam boards were numerous, and regional. All schools in a geographical area entered for the same exam board, making things easier. And at that time, accountability measures were much less pressing.

Cluster moderation could engage and develop teachers through the sharing of standards. It would be costly, however, in both time and money. It would make significant demands on teachers' time, since they would not only be required to assess their own students, but to engage in the moderation of assessment for students of the other schools within the cluster group.

We are also aware of concerns about practicalities in rural areas and for schools using a different exam board to others in their area, should we introduce it now.

Moreover, we question whether it is deliverable in the time available given the sheer size of the task, and the modern-day pressures on teachers and schools.

We have looked at where and how it is done elsewhere. Cluster moderation arrangements are used in some places including in Queensland, Australia. However, it is students' written work (indirect assessment) that is used for the moderation exercises rather than visiting centres where practical science skills are being demonstrated, in real-time, by students. The assessment seems based on the same kind of evidence as in current GCSEs, and given the high stakes nature of the assessment, Queensland uses an external test to support the moderation system.

Visiting moderation

An alternative approach would be for exam boards to visit schools to observe teachers' direct assessments. Once again, student and school numbers are the problem, exacerbated by other school pressures. Given that visiting observers are themselves teachers taking time away from their own schools and teaching, we don't see this as any more manageable, or actually deliverable. In reality, exam boards would only be able to sample a proportion of students and schools each year. Realistically, such an approach could only be used alongside another form of monitoring.

Statistical moderation

This would involve using students' exam marks to adjust, where necessary, their teacher's assessment of their practical skills. It takes some of the pressure off schools, and it can be seen as even-handed as well, treating practical skills in the same way as other achievement. We have thought about this option carefully, not

least because it is manageable for schools. However we think that on balance, the drawbacks outweigh the benefits.

Statistical moderation aims to match up performances from different sources or in different areas within a subject by statistically adjusting scores in an attempt to make them comparable. Using this method, the moderation involves adjusting the average and the spread of teacher assessment marks of students in a given school with reference to the exam scores of the same group of students. During the moderation process, teacher assessment marks may be adjusted, but the rank order determined by the school will remain unchanged. Generally speaking, the results obtained will become the final marks of individual students in that school.¹⁷

Statistical moderation can be used to calibrate or to monitor marking.¹⁸ Calibrating refers to the process, as described above, whereby statistical adjustments are universally applied to teacher assessments based on the exam results. Monitoring refers to a broader approach in the use of statistical comparisons, where statistical moderation is used to detect comparability issues by, for example, triggering an inspection. It may also be used for longer-term monitoring of schools or exam boards. It is used in some countries, typically in conjunction with other forms of moderation and generally to monitor performance rather than to calibrate it, owing to the limitations of the evidence it generates.

For statistical moderation to act as a calibration of performance and achievement in practical science skills it presumes that the ability being moderated is one that can be demonstrated at a range of levels, as the purpose of moderation is to adjust marks between and within these. It is questionable how far this would be achievable with the technical and manipulative skills that would be directly assessed here.

From a technical perspective, the specific properties of the statistical model used could present challenges. So for example, we know that small adjustments to the statistical model can lead to significant differences in outcomes, and its reliability will vary depending on the number of students in a group: the smaller the number of students, the less reliable the process.

For this approach to be seen as fair there would need to be a strong relationship between the assessment of practical skills and the exam. That may not always be the case. What is more, statistical moderation could have undesirable effects on teaching practice. There would be a clear incentive to focus on exams as the marks for these

¹⁷ See, for example, www.hkeaa.edu.hk/DocLibrary/Media/Leaflets/HKDSE-SBAModerationBooklet_r.pdf

¹⁸ Daley, Billington, Chamberlain, Meyer, Stringer, Taylor, Tremain: *Principles of Moderation of Internal Assessment*. AQA Centre for Research and Policy; https://cerp.aqa.org.uk/sites/default/files/pdf_upload/CERP-RP-AD-13102009_0.pdf

would, ultimately, determine students' adjusted performance in the practical assessment.

Recording

Any recording of a student doing practical science work would need to be audiovisual, using equipment able to capture performance accurately. This would have significant resource implications for schools, given student numbers. It does not seem to us to be a viable possibility.

Marks counting towards grades¹⁹

To be worthwhile, direct assessment needs to have sufficient weight, say at least 10 per cent of the available marks. If they are to count towards grades, then those marks must be accurately and consistently given, particularly as there is no lasting evidence to check unless the performance is recorded – otherwise the whole assessment is insufficiently valid and reliable.

One of the challenges of teachers directly assessing their students comes from the nature of what is being assessed. The main point of assessing practical science work directly is to assess students' technical and manipulative skills; their ability to use particular equipment and to perform particular techniques.

It is possible to determine whether a student has a given skill, but much harder to determine grades or levels of performance. These are often skills not possible to assess on a sufficiently wide spectrum, reflecting the range of ability of all science GCSE students. And this is what would need to be possible – on a reliable basis – to support their inclusion in grades. SCORE has noted previously the significant difficulties here, suggesting consideration should be given to a “model where direct assessment is not intended to provide differentiation, but rather to check whether or not a student is competent in a given practical skill”.

Separate reporting of directly assessed performance

If teachers' marks for practical skills are reported separately rather than contributing to grades, it might alleviate some of the pressures that distort assessments. It would also allow greater transparency – students' practical skills would be shown as separate to, rather than being subsumed within, their subject grades. There might be greater reliability too, depending on the grading scale used. The assessments would need to be valid, reliable and provide effective discrimination between levels of

¹⁹ Currently, teachers' marks for practical work contribute to grades through the controlled assessments.

performance. For example, a pass/fail decision would require a less granular judgement than the specific mark that would be needed if the skill were to contribute to the subject grade. It would also be more consistent with, for example, the competencies suggested by the Gatsby Foundation and the Wellcome Trust.²⁰

This would mean each student having to be directly assessed over a minimum of, perhaps, 45 minutes. Given the number of students who take science GCSEs, this would mean a considerable amount of assessment time. Safety considerations are also relevant: it would be difficult for a teacher to be simultaneously assessing each student, in turn, while the rest of the class were working in the laboratory.

The requirements for assessment time would have a noticeable impact on teaching time. Because much less time is allocated to teaching GCSEs than to teaching A levels, the proportion of time diverted from teaching to assessment would be much more for GCSEs than for A levels if the assessment requirements were consistent across the two qualifications.

Indirect assessment of practical skills

Questions in the written exams

This has been a feature of qualifications in England and internationally for some time. Good questions blend the theoretical and practical aspects of experimentation. So for example, they may relate to solving a problem or be set in a context that is linked appropriately to each part of the question. They may apply knowledge of familiar practical techniques to unfamiliar contexts. And for this approach to work well, exam questions must be well-designed, and not be too formulaic or predictable.

Well-designed questions are known to produce valid and reliable results. As the ground they cover is not known beforehand, those students with sufficient breadth of practical experience are most likely to be well prepared and to do well. This approach could provide a strong incentive for schools and teachers to provide a breadth of practical activities, because this would best prepare students, and performance in the exams would determine students' grades.

To answer such questions, students would be expected to draw on their experience of practical work, applying what they learn from it as well as recalling the various activities. For example, students may be asked to identify steps or to plan to identify an unknown compound or separate a mixture; they may be called on to comment on experimental results and design in order to evaluate the scientific methods and measurements required to obtain reliable data. Contributing directly to students' grades, exam questions are an attractive option supported by the science community. Using them has been a recurring and unanimous suggestion from stakeholders:

²⁰ *Policy Note: Assessment of Practical Work in Science April 2013*; available at: www.gatsby.org.uk/~media/Files/Education/Practical%20Science%20Policy%20Note.ashx.

- The Centre for Innovation and Research in Science Education at the University of York indicated these questions would “encourage teachers to carry out a wide range of practical tasks throughout the GCSE course”. They also suggested that exam boards should agree a list of practical tasks to act as a basis for these questions to promote comparability.
- The Gatsby Foundation and the Wellcome Trust emphasised that such questions could be “designed to assess candidates’ experimental and investigative skills developed through their familiarity with performing, and understanding of, certain experiments identified in the specification”. These groups also recommended they should be weighted more heavily than the direct assessment of practical skills that they also proposed.
- SCORE suggested that questions in written exams could assess “procedural understanding of how to plan, carry out and evaluate aspects of practical work and analyse results ... in such a way that students are likely to perform better if they have acquired that procedural knowledge through doing practicals”.

There are some drawbacks. The vast majority, but not all, of the specified requirements for ‘working scientifically’ in the new science GCSEs could be assessed validly by good exam questions. The exceptions are those to:

- carry out experiments appropriately having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations;
- make and record observations and measurements using a range of apparatus and methods.

Exam questions do not directly assess students’ ability to use scientific equipment. Only direct assessment can do that.

A practical exam

Individual responses to our A level consultation, mainly from teachers, proposed a practical science exam as a way of testing students’ technical and manipulative skills. This would most likely be set by exam boards. Each student could be required, for example, to follow instructions, manipulate equipment, perform procedures and make observations. A student’s ability at, say, performing a procedure would be inferred from the observations they recorded about it. The main benefit of the approach is that it would enable students to be tested on specific, relevant practical activities, but there are curriculum, manageability and validity issues.

The options would be restricted by necessary health and safety considerations and also by the need to cater for schools with varying amounts of equipment. In any event, a practical exam would only be able to sample a relatively small proportion of the subject content. Just as controlled assessment can narrow the curriculum now, so could this.

The resource requirements would be high, and it would be likely to have a significant impact on the availability of laboratory space for teaching – given the need for exams to be delivered across all science subjects in each school. The students in a given school would not usually be able to take the exam at the same time, since most schools do not have sufficient teaching laboratory space, and that leads to another problem: students taking the exam first would be able to spread word to other students in their school or others, compromising the validity of results. Different tasks could be used at different times but this brings its own manageability challenges.

Finally, mark distributions could be skewed by the nature of the tasks: students who were not able to complete a given part of the test would automatically be unable to access the marks for any following parts that were dependent on it. We don't think this option will provide sufficiently valid and reliable assessments.

On balance, then, we do not favour a practical exam.

An extended investigation

The Gatsby Foundation and the Wellcome Trust have suggested 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 [but] is not yet a pragmatic possibility”. We agree.

It is an attractive option at first sight because of its formative value, assisting students to understand the science they are studying, and how scientific ideas are developed. Equally, though, we see significant challenges were it to be used in large-scale summative assessment – in terms of manageability, and validity of assessment. The manageability issues are clear, given student numbers, and the ability range.

The extended investigation is not a direct assessment of practical skills although it may appear so at first sight. Rather it is an indirect assessment, as students' accounts of the investigation are assessed. Investigations involve the exercise of practical skills, but as they cover the continuum of designing, experimenting, evaluating and refining, the range of practical skills involved can be limited, and that would bring into question the validity of the assessment. Moreover, there are significant design challenges in developing, delivering and awarding assessment models that are likely to produce nationwide results that are sufficiently comparable and reliable.

In response to our A level consultation SCORE and the Council of Science and Technology proposed that an extended investigation should be an *additional* requirement to the direct assessment of practical skills. That's the case in the highly respected International Baccalaureate qualification where students' practical skills are assessed by questions in exams. In addition, students submit an individual investigation report, an indirect assessment for which students can use evidence collected through experimentation *or* use data from other sources. There is no reward for the exercise of practical skills, and that is what we are trying to assess in the new science GCSEs.

Portfolio of practical skills

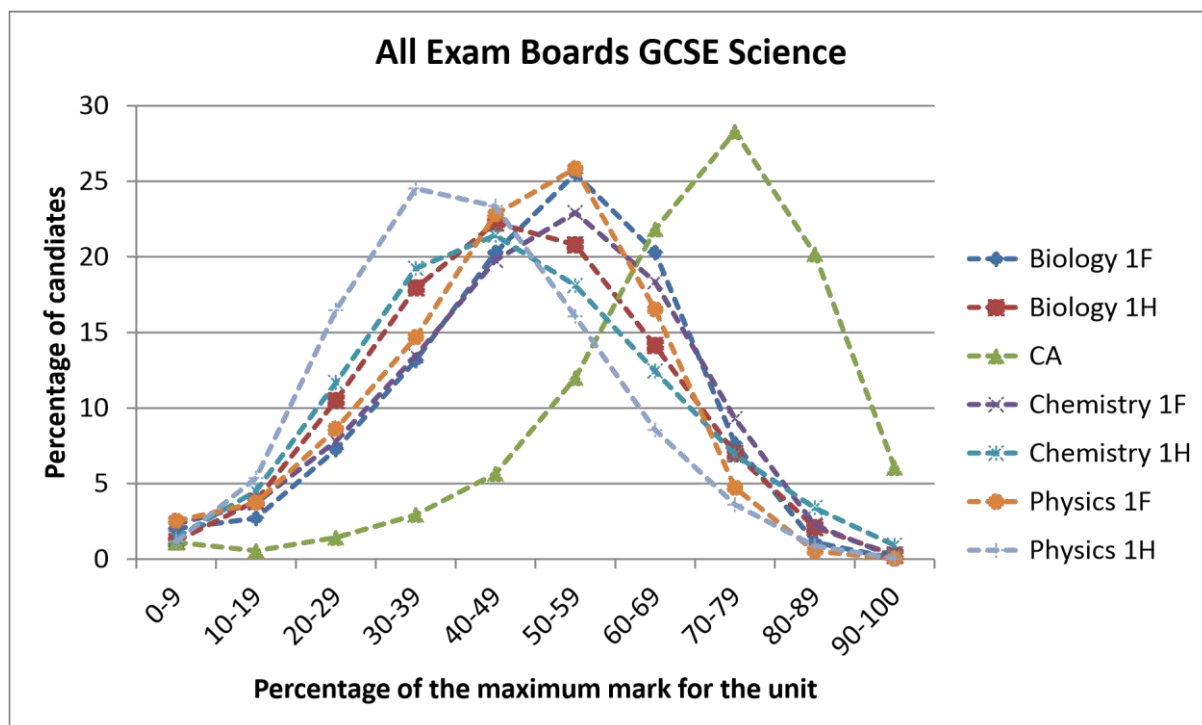
Some responses to our A level consultation suggested the use of a portfolio of evidence to assess the practical skills. This could be a collection of accounts of the work that has taken place or photographic evidence of practical work being completed. Both are examples of indirect assessment with all the attendant issues identified above. On the other hand it could be an expanded record or log book of practical work. We are proposing that there must be a student record of practical work completed. How this should be compiled and presented is part of the discussion about implementation which, as noted at the beginning of this consultation, is a discussion of details and for another day.

Other considerations

The assessment of practical work in GCSEs through coursework or, more recently, controlled assessment has ended up narrowing the curriculum. Students do tasks set by exam boards. Teachers must have prior knowledge of them, to be ready to deliver them, and they must be manageable and deliverable on a suitably large scale, nationwide. So the range of likely controlled assessment tasks is narrower than the curriculum, and fairly predictable. For some specifications, teachers set the tasks themselves to guidelines from the exam board. That brings similar problems, because it can lead to a focus on those tasks at a cost to wider work. The science GCSE findings from our review of controlled assessment last year²¹ show the shortcomings of the existing arrangements, much as described above.

There are other drawbacks. Students typically receive higher marks for controlled assessments marked by their teachers than for the written exams. Controlled assessment marks also tend to be skewed towards the maximum mark. This is illustrated in the graph below which combines the 2014 results from all the exam boards for the GCSE science qualifications. Units assessed by exam are indicated by for example, 'Biology 1F', where 'F' and 'H' indicate performance in the separate tiers of assessment, foundation and higher tier. Controlled assessment units are labelled 'CA' and, as they are not tiered, indicate performance for all candidates. Individual graphs showing the 2014 results for each of the GCSE specifications for each of the sciences from each of the exam boards together with the entry information for each unit are attached at Appendices 2 and 3 and show a similar picture.

²¹ *Review of Controlled Assessment in GCSEs* (June 2013) Ofqual/13/5291; available at: www.gov.uk/government/uploads/system/uploads/attachment_data/file/377903/2013-06-11-review-of-controlled-assessment-inGCSEs.pdf.



The peak or *modal* mark for controlled assessments (the green line) is much higher than those for the written exams. So the mark achieved by most students in controlled assessment was a higher proportion of the total marks available. The shape of the curves is also rather different. Those for the exams have a fairly normal distribution, while that for the controlled assessment is shifted towards the upper end of the mark range. This shows that, on the whole, students achieved higher marks in the controlled assessments than in the written exams. The distribution curve between the peak and the maximum mark for the controlled assessment is also steep, suggesting a significant proportion of students have achieved marks in a fairly compressed section of the upper end of the mark range.

The controlled assessments, then, do not discriminate effectively between students' performances, one of the things we are looking for. To some extent the differences between them and the written exams may reflect differences in what each assessment is assessing – between the knowledge and understanding of content generally assessed by exams and the broader practical skills that are the focus of controlled assessments. However, school accountability is likely to have had a significant effect here.

The Gatsby Foundation and the Wellcome Trust have noted previously that “a system relying mainly on teacher assessment has pragmatic and political implications difficult to resolve in the short term”. We agree.

Teachers are put in a difficult position when their assessments are used to judge their performance and that of their school and students. It can also create unfairness between schools, because of different interpretations of the amount of assistance teachers can provide to students, different degrees to which teaching focuses on specific assessments and different marking expectations being applied to students' work. Arrangements whereby teachers mark other students' work, rather than their

own, could modify these effects. However, they would not deal with the narrowing of the curriculum.

Options

Each approach has its benefits and drawbacks, with no one perfect solution.

To sum up, there are numerous direct assessment permutations. Students' practical science work could be assessed by teachers, or visiting examiners, and could be monitored and moderated in different ways. Results could be included in subject grades or reported separately.

In terms of indirect assessment, using questions in exams has substantial support from stakeholders. It is an approach used currently both in England and internationally. We favour it because it would encourage the teaching of a wide and varied range of practical work, it is manageable for schools and students, and done well it is likely to produce valid and reliable results. It is a strong option.

Students' practical skills could be assessed indirectly by a practical exam, with inferences about practical skills being made on the basis of how students record their work. Alternatively they could be assessed by an extended investigation, or a portfolio approach, where similar inferences would be made.

3. Our proposals

There is no single approach that is strongest in all respects – promoting a wide range of practical work; being manageable for schools; ensuring valid and reliable assessments; and withstanding accountability pressures. Our preferred option best squares, though not perfectly, these competing tensions and puts the curriculum aims first.

Questions in the written exams will draw on students' knowledge and understanding of a common, specified range of practical equipment and techniques and will count for at least 15 per cent of the overall marks. We have seen good examples of such questions in other qualifications here, in other countries, and in the sample assessment materials produced by exam boards for new science A levels.

Exam boards will write these questions with the expectation that students have completed the specified practical work. And although the specific practical activities required by the exam boards would have to be completed, there would be no limit to the number of activities a school could make available to their students. This flexibility would enable schools to offer their students wide and varied experience of practical work.

Schools will be required to confirm to their exam boards that their students have completed the required practical work prior to the exams. Students each keep a record of their practical work, to be made available to their exam board on request. This student record could be a laboratory notebook, a formal written account to a given template, a portfolio or take some other physical or virtual form (we welcome

views and suggestions). It will provide further, more detailed, information about the practical work completed, as well as helping prepare students for further study.

We think these arrangements will be manageable for schools and students. They are realistic. Teachers' time will not be diverted from teaching to assessing (beyond the formative assessment that characterises all good teaching, and confirming the school record) because the practical work will be an integral part of the course of study. Students will experience practical work as part of a coherent whole rather than as a one-off, high-stake assessment. Above all we think these arrangements are more likely than others to provide a stimulating and enjoyable practical work experience for students, best suited to the curriculum aims.

The detail of our proposal is as follows:

- Exam boards will be required to include questions in the written exams that draw on the knowledge and understanding students have gained from their practical science experience. These questions will have to account for at least 15 per cent of the marks for each qualification.
- A list of the apparatus and techniques that students must be able to use and demonstrate will be included in each specification. These lists will be common across the exam boards and are provided below.
- Exam boards will be required to include in their specification for each subject at least eight practical activities (16 for combined science) that students will be expected to complete during their course of study. This requirement balances promoting a wide range of activities while ensuring manageability for schools and mitigating predictability when the written exams target the activities. It also emphasises how the subject should be taught and is in line with the approach for reformed A level science subjects. The practical activities the exam boards include will have to reflect the common lists of apparatus and techniques.
- Schools will be required to confirm to their exam board that their students have completed the required practical science work – the school record. Schools will have to do this before their students take their exams.
- Students will be required to keep records of the practical work they have done – the student record. This will have to be made available to their exam board on request.
- The draft assessment objectives for science GCSEs will be amended to reflect the revised assessment arrangements.

Assessment objectives

The assessment objectives we propose make clear the abilities that will be the focus of the exams. They emphasise that practical work and theoretical understanding are both integral to science qualifications. Their requirements are also consistent with those for the reformed A level science subjects.

	Assessment objectives	Weighting
AO1	Demonstrate knowledge and understanding of: <ul style="list-style-type: none"> ■ scientific ideas and processes ■ scientific techniques and procedures 	35%
AO2	Apply knowledge and understanding of: <ul style="list-style-type: none"> ■ scientific ideas and processes ■ scientific techniques and procedures 	40%
AO3	Analyse, interpret and evaluate scientific ideas, information and evidence to make judgements and reach conclusions	25%
<ul style="list-style-type: none"> ■ Learners' knowledge and understanding of practical activities must be tested across the assessment objectives. The total mark used to credit the demonstration of such knowledge and understanding must be no less than 15 per cent of the sum of all marks for the assessment objectives AO1 to AO3. ■ Learners' ability to use mathematical skills at a level appropriate for GCSE science subjects must be tested across the assessment objectives. The total mark used to credit the demonstration of mathematical skills must be no less than 15 per cent of the sum of all marks for the assessment objectives AO1 to AO3. ■ Learners' ability in terms of the requirements for Working Scientifically must be tested across the assessment objectives. ■ Learners' knowledge and understanding of practical and theoretical contexts must be tested across the assessment objectives. ■ Learners' ability to organise and communicate information and ideas coherently must be tested across the assessment objectives. 		

We have previously consulted²² on our proposal that new science GCSEs will be tiered, reflecting current practice. We propose that the weightings outlined above for the assessment objectives for science GCSEs should be the same at each tier. Our proposals are based on those for mathematics, where the foundation tier is designed for Learners likely to achieve grades 1 to 5 and the higher tier for Learners likely to achieve grades 4 to 9.

Use of apparatus and techniques

The proposed requirements in relation to apparatus and techniques³⁰ have been drawn from proposals produced by the Gatsby Foundation and the Wellcome Trust.³¹ They are designed to promote progression to the equivalent requirements for the A level science subjects.³²

Biology

²² <http://webarchive.nationalarchives.gov.uk/20141110161323/http://www.ofqual.gov.uk/files/2013-06-11gcse-reform-consultation-june-2013.pdf>

Specifications for biology and the biology elements of combined science must give students opportunities to use relevant apparatus to develop and demonstrate the techniques listed below.

Practical techniques to be demonstrated by Learners:

- use of appropriate apparatus to make and record a range of measurements (to include mass, time, temperature, volume of gas produced, distribution of organisms);
- use of a Bunsen burner and a water bath or electric heater for heating;
- measurement of pH and oxygen levels using a variety of techniques such as indicators, a pH/oxygen meter or a pH/oxygen probe and data logger;
- use of qualitative reagents to identify biological molecules;
- measurement of rates of reaction by a variety of methods such as production of gas, loss of mass, uptake of water, colour change of indicator;
- choice and use of appropriate laboratory and field apparatus for a variety of experimental investigations;

³⁰ This proposed list of apparatus and techniques has been compiled by the DfE and reflects the content requirements for these subjects.

³¹ *Policy Note: Assessment of Practical Work in Science April 2013*, op. cit.

³² www.gov.uk/government/uploads/system/uploads/attachment_data/file/371197/2014-04-09-gce-subjectlevel-conditions-and-requirements-for-biology.pdf

www.gov.uk/government/uploads/system/uploads/attachment_data/file/371201/2014-04-09-gce-subjectlevel-conditions-and-requirements-for-chemistry.pdf

www.gov.uk/government/uploads/system/uploads/attachment_data/file/371203/2014-04-09-gce-subjectlevel-conditions-and-requirements-for-physics.pdf

- use of sampling techniques in fieldwork to investigate the distribution and abundance of organisms in an ecosystem;
- safe and ethical use of living organisms to measure physiological functions and responses to the environment;
- use of the light microscope at low and medium power;
- production of labelled scientific drawings from direct observation of biological specimens.

Chemistry

Specifications for chemistry and the chemistry elements of combined science must give students opportunities to use relevant apparatus to develop and demonstrate the techniques listed below.

Practical techniques to be demonstrated by Learners:

- use of appropriate apparatus to record a range of measurements (to include mass, time, volume of liquids and gases, and temperature);
- use of a Bunsen burner and a water bath or electric heater for heating;
- measurement of pH using pH charts and digitally;
- collection and identification of products of reaction and measurement of rates of production;
- safe and careful handling of gases, liquids and solids;
- careful mixing of reagents under controlled conditions using appropriate apparatus to prepare substances;
- use of a range of equipment to separate chemical mixtures: to include evaporation, filtration, distillation, crystallisation, chromatography, electrolysis;
- collection and analysis of products from a simple electrochemical cell;
- use of appropriate apparatus to determine relative concentrations of strong acids and strong alkalis.

Physics

Specifications for physics and the physics elements of combined science must give students opportunities to use relevant apparatus to develop and demonstrate the techniques listed below.

Practical techniques to be demonstrated by Learners:

- use of thermometers and electrical measuring instruments, with heating and cooling devices, to explore energy transfers as temperatures change and to explore phase changes;
- use of measures of weight and direct and displacement methods for measuring volumes to determine densities of solid and liquid objects;
- use of instruments to measure distances and times: to determine speeds and accelerations both in laboratories (for example, motion of a mass down a slope, or of a mass projected by a compressed spring) and in everyday motions (for example, walking, running and cycling); to explore transmission and reflection of sound waves;

- measure speeds of both sound and of waves on water, and the wavelengths and frequencies of waves on water;
- use of low-voltage power supplies, ammeters and voltmeters to explore the characteristics of a variety of circuit elements;
- construction of both series and parallel circuits from circuit diagrams using DC power supplies, cells and a range of circuit components, including those where polarity is important; representation of the circuits used with conventional symbols;
- connection, or checking, of the three wires for an AC mains plug and checking of the way these wires are connected to a domestic device;
- safe and careful handling of electrical power supplies, experiments involving accelerated and uniform movement of objects, and effects of steady or oscillating light sources;
- use of springs and strings with weights to explore linear, non-linear, elastic and inelastic stretching;
- use of iron filings and magnetic compass to explore fields of magnets and of electric wires and solenoids.

Combined science

Specifications for combined science must give students opportunities to use relevant apparatus to develop and demonstrate the use of apparatus and techniques for all the separate sciences (biology, chemistry and physics). However there should be no requirement for the same technique to be exercised in all three of the disciplines.

4. Equality analysis

We are subject to the public sector equality duty. We have set out in Appendix 1 how this duty interacts with our statutory objectives and other duties.

We have considered the potential impact on students who share protected characteristics²³ of our preferred approach and the alternative options for assessing practical work in science GCSEs.

We have not identified that any of the options would have an impact, positive or negative, on students because of their age, racial group, their religion or belief, their sex or their sexual orientation.

Arrangements will have to be made for students who are absent when the practical activities take place to do them at another time. Such absence may occur because of a disability, pregnancy and maternity or gender reassignment. However, exams may

²³ Disability, racial group, age, religion or belief, pregnancy or maternity, sex, sexual orientation, gender reassignment.

also be missed for the same reasons. As the practical activities are not, in themselves, assessed it may be more straightforward for schools and colleges to reschedule any missed opportunities.

Some disabled students will not be able to use scientific equipment owing to the nature of their disability. If students' abilities to use scientific equipment were to be directly assessed, rather than (as now) their ability to write about practical methods, some disabled students would not be able to access the assessment. Currently some disabled students use a practical assistant to support their learning and they complete their controlled assessment by using a practical assistant. As students' practical skills are not being directly assessed, this can be permissible as a reasonable adjustment.

If the outcome of an assessment of students' ability to use scientific equipment contributed to one overall grade for the qualification, disabled students unable to access the assessment could be disadvantaged. They could be granted an exemption from the practical assessment, assuming that this assessment did not contribute more than 40 per cent of the marks for the qualification, in which case their performance in the written exams would be 'scaled up'. However, they would have lost an opportunity available to other students to perform well in the practical assessment, and to have that performance reflected in their overall grade. The fact that a student has been granted an exemption is currently reported on the student's certificate.

If the practical assessment outcome was reported separately, disabled students exempted from the practical assessment would have their exam grade reported on their certificate, together with an indication of the exemption from the practical assessment. They would still have to answer written exam questions drawing on their experience of practical work, whether done directly or with the help of a practical assistant.

Our preferred option, whereby students would not be directly assessed on the use of scientific equipment, would allow disabled students to access all of the assessments, so they would not need to be granted an exemption. They would have to undertake practically based learning, however, or they would be disadvantaged when answering written questions designed to draw on such learning. As at present, they could work with a practical assistant.

5. Responding to the consultation

Your details

To evaluate responses properly, we need to know who is responding to the consultation and in what capacity. We will therefore only consider your response if you complete the following information section.

We will publish our evaluation of responses. Please note that we may publish all or part of your response unless you tell us (in your answer to the confidentiality question) that you want us to treat your response as confidential. If you tell us you wish your response to be treated as confidential, we will not include your details in any published list of respondents, although we may quote from your response anonymously.

Please answer all questions marked with a star*

Name*

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Would you like us to treat your response as confidential?*

If you answer yes, we will not include your details in any list of people or organisations that responded to the consultation.

Yes No

Is this a personal response or an official response on behalf of your organisation?*

Personal response (Please answer the question 'If you ticked 'personal views'...')

(x) Official response (Please answer the question 'Type of responding organisation')

If you ticked 'Personal views' which of the following are you?

- () Student
- () Parent or carer
- () Teacher (but responding in a personal capacity)
- () Other, including general public (Please state below)

If you ticked "Official response from an organisation/group", please respond accordingly:

Type of responding organisation*

- () Awarding organisation
- () Local authority
- () School or college (please answer the question below)
- () Academy chain
- () Private training provider
- () University or other higher education institution
- () Employer
- (x) Other representative or interest group (please answer the question below)

School or college type

- () Comprehensive or non-selective academy
- () State selective or selective academy
- () Independent
- () Special school
- () Further education college
- () Sixth form college
- () Other (please state below)

Type of representative group or interest group

- Group of awarding organisations
- Union
- Employer or business representative group
- Subject association or learned society
- Equality organisation or group
- School, college or teacher representative group
- Other (please state below)

Charitable foundation working to support science and engineering education.

Nation*

- England
- Wales
- Northern Ireland
- Scotland
- Other EU country: _____
- Non-EU country: _____

How did you find out about this consultation?

- Our newsletter or another one of our communications
 - Our website
 - Internet search
 - Other
-

May we contact you for further information?

- Yes No

Questions

Question 1: In relation to our proposed model (page 5 and pages 23 to 29 of the consultation) how far do you agree with each of the following statements?

Please give reasons for your answers.

1a: GCSE science students will be given appropriate opportunities to complete a range of practical work if exam questions reward those who can draw on their practical experiences.

Strongly agree

Agree

Neither agree nor disagree

Disagree

Strongly disagree

Please give reasons for your answer

This will depend on:

- whether exam questions can indeed distinguish those who have undertaken the practical work from those who have not;
- the extent to which higher marks are accessed according to the level of skill the student gained in that practical work;
- whether all teachers are equally convinced that there is no alternative teaching method other than undertaking the practical work;
- whether in any single exam series it is possible to assess the full range of practical skills developed during the preceding years of learning.

If these conditions are not fulfilled, and the exam questions do not properly assess the range of practical work, then there is a significant risk that some schools will reduce their funding for practical science and fewer practical experiences will be on offer.

1b: At least 15 per cent of the marks in science GCSE exams should be allocated to questions drawing on students' practical science experiences.

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Please give reasons for your answer

The current weighting given to assessment based on students' practical experiences in science GCSEs is at least 25%. By reducing this to 15% Ofqual is giving a clear and strong message that practical work will be less important in the new GCSEs than in the current ones, and introduces the possibility that students could achieve a high grade (in the remaining 85%) without doing any practical work at all. This is counter to what scientists, DfE, Awarding Bodies and Ofqual themselves have said about their priorities for practical science. Indeed when Ofqual consulted on GCSE science assessment in 2013, most respondents who expressed a view suggested the % allocated to science practicals "should be between 20-30%"²⁴. We therefore recommend that the current weighting of 25% is retained as a minimum.

1c: Science GCSE students will be more likely to be given opportunities to undertake a wide and varied range of practical work if such work is focused on teaching and learning and is not itself assessed.

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree

²⁴ Ofqual GCSE Reform Consultation Analysis, November 2013.
Ofqual 2014

Strongly disagree

Please give reasons for your answer

We have seen no good evidence to answer this question either way, but what we do know from our research undertaken with teachers in 2012 is that 40% of those who had increased their practical work over the preceding 5 years did so because of changes in assessment²⁵. Our concern is that for as many teachers who are able to do more and better practicals if the skills involved are not assessed, there are others less confident or less well-resourced for whom it may become a struggle to maintain the staffing and budget needed for good quality practical work if a link to assessment is not clear to senior management. We trust that this consultation will elicit the views of a wide range of teachers and not just those who already have the wherewithal to offer their students rich practical experiences.

We also point out that while ideally assessment does facilitate better teaching and learning, it must also give evidence as to skills gained. Practical skills should be assessed at GCSE is to show that students can work safely and accurately when conducting practical work. Students must be able to undertake core practical work competently, as well as have the opportunity to develop their knowledge and ideas through a wide range of practical experiences.

1d: Science GCSE students will be more likely to be given opportunities to complete the practical work included in an exam specification if schools are required to confirm this in writing to their exam board.

Strongly agree

Agree

Neither agree nor disagree

²⁵

<http://www.gatsby.org.uk/~media/Files/Education/Practical%20work%20research%20summary%20%20Teacher%20views%20of%20practical%20work%20181012.ashx>

Disagree

Strongly disagree

Please give reasons for your answer

It somewhat more likely, but this will only be true across all schools if there is a system in place to check that the confirmation is valid, and that there are repercussions if the exam board does not receive such confirmation.

1e: Science GCSE students will be more likely to be given opportunities to undertake a wide and varied range of practical work if they are required to keep a record of such work (a student record).

Strongly agree

Agree

Neither agree nor disagree

Disagree

Strongly disagree

Please give reasons for your answer

While keeping records of lab work can be valuable for many reasons (it is a skill in itself, it enables teacher-student discussion about practical work, it is revision material for the student) it only works as an incentive for teachers to offer a wide and varied range of practical work if the requirement is checked and there are repercussions if it is missing. There is also the possibility that using student records for monitoring/moderation purposes may undermine the other benefits such record-keeping can bring, and focus teaching time on producing high-quality records rather than doing practical work. The student record (coupled with the teacher record) must also indicate where students lack competence, otherwise it cannot report a 'fail'

1f: It would be unmanageable, in terms of time and cost, for teachers to assess directly each of their science GCSE students manipulating a range of equipment and conducting a range of experiments to confirm their competency in practical skills.

Strongly agree

- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Please give reasons for your answer

In response to the previous Ofqual consultation on GCSE science assessment we reported our preliminary work among teachers who indicated that direct assessment of a carousel of tasks performed under exam conditions could be manageable. This would be a significant change from the current focus on assessing whole investigations. The current consultation makes many claims about what is not manageable in schools but the given evidence behind these claims is weak. It would be particularly helpful to make this evidence public given that in response to the previous 2013 consultation Ofqual received a positive response regarding the 10% direct assessment of practical skills and the need for alternatives to written exams.

1g: The revised assessment objectives for science GCSEs are appropriate.

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Please give reasons for your answer

We are disappointed that AO4 with its 10% direct assessment of practical skills has been removed since the last consultation, meaning that the following set of important skills will no longer be assessed:

The ability to:

- follow instructions accurately
- use scientific instrumentation, apparatus and materials appropriately

- work with due regard for safety, managing risks
- observe, measure and record accurately and systematically
- carry out and report on investigations or parts of investigations.

These skills are relevant for all young people, but are particularly important for the many who are going to progress into a range of scientific and technical jobs and further study. There is nothing in these proposals to prevent a GCSE science student who consistently breaks equipment, is always inaccurate in their measurements and cannot maintain a safe laboratory environment for themselves and others, from receiving the highest grade in their exams. We consider this to be unacceptable.

1h: The weightings proposed for the revised assessment objectives for science GCSEs are appropriate.

- () Strongly agree
- () Agree
- () Neither agree nor disagree
- () Disagree
- (x) Strongly disagree

Please give reasons for your answer

...See above.

1i: The weightings proposed for the assessment objectives for science GCSEs should be the same at each tier.

- () Strongly agree
- () Agree
- (x) Neither agree nor disagree
- () Disagree
- () Strongly disagree

Please give reasons for your answer

.....

.....

.....

1j: The proposal that no less than 15 per cent of the total marks available in a science GCSE must be used to credit the demonstration of mathematical skills is appropriate.

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Please give reasons for your answer

No evidence is provided to justify this weighting. We only note that data analysis might also be considered a practical skill, in which case there is the potential for a lack of clarity about the weightings associated with practical and mathematical skills.

1k: The proposal that no less than 15 per cent of the total marks available in a science GCSE must be used to credit the demonstration of mathematical skills should apply to each of the science GCSE subjects.

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Please give reasons for your answer

.....

.....

.....

1l: The lists of apparatus and techniques that all students taking science GCSEs will be expected to be able to use are appropriate.

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree

Strongly disagree

Please give reasons for your answer

In our response to the DfE consultation on GCSE science in August 2013 we gave our recommendations as to the practical skills we believe appropriate for GCSE sciences²⁶, and additional recommendations were given in our policy note on assessment of practical work in science in April 2013²⁷. We would like to clarify that we did not dictate apparatus in either of these documents, instead we suggested the sorts of experiments (and hence the range of equipment) through which students might gain the recommended skills. This was intended to give Exam Boards and teachers the flexibility to choose a range of practicals in order to achieve their learning outcomes. The list of apparatus being proposed by Ofqual should be subjected to significant professional scrutiny before being confirmed, and the intended activities and learning outcomes from their use made clear.

1m: The proposal that exam boards must require each student taking science GCSEs to undertake at least eight practical activities (16 for combined science) is appropriate.

Strongly agree

Agree

Neither agree nor disagree

Disagree

Strongly disagree

Please give reasons for your answer

Ofqual's rationale behind the choice of 8 (or 16) is not given. We would only note that if schools choose to deliver GCSE science over 3 years that could equate to only 5-6 practicals per year. In specifying practical activities (as opposed to practical skills)

²⁶

<http://www.gatsby.org.uk/~media/Files/Education/GCSE%20Science%20Content%20Reform%20Response.ashx>

²⁷ <http://www.gatsby.org.uk/~media/Files/Education/Practical%20Science%20Policy%20Note.ashx>

Ofqual and the Awarding Bodies must take care to ensure a spread of activities

across the full range of GCSE content.

Question 2

Do you have any views about what form the student record should take and the types of information it should contain? If 'yes', please give suggestions below.

Yes

No

Suggestions

.....

.....

.....

.....

.....

Question 3

We are looking for the approach to the assessment of students' practical science experience that can achieve the best balance between the aims of:

- delivering the curriculum aims and encourage a wide range of practical science teaching over the period of study
- being manageable for schools – taking into account the numbers of students who take science GCSEs, the range of ability and the time typically allocated to each subject
- providing valid and reliable assessments – test the right things and do this accurately and consistently, so as to differentiate effectively between students' performance
- being able to withstand accountability pressures, that is, to avoid exerting unmanageable contradictions on teachers where they are acting as the

assessor and being judged themselves through the outcomes of the assessments they make – the results of their students.

How far do you agree that our proposed model (page 5 and pages 23 to 29 of the consultation) provides the best balance between these aims? Please give reasons for your answers.

- Strongly agree
- Agree
- Neither agree nor disagree
- Disagree
- Strongly disagree

Please give reasons for your answer

We consider that the main aim for Ofqual should be providing valid and reliable assessments for the full range of important content in GCSE science, including practical skills. We do not agree that the proposed model fulfils this aim. We acknowledge the perverse pressure of accountability and the need for manageability, but we do not feel sufficient time and efforts have been taken to research alternatives to the proposed model.

Question 4

Do you believe that there is an alternative option that can provide a better balance between these aims?

- Yes
- No

Question 5

If you responded 'yes' to question 4, which of the options below do you believe provides a better balance between these aims when used in addition to some science GCSE exam questions drawing on students' practical science experience? Please give reasons for your answer.

[x] **Option (i)** science GCSE students' practical skills are directly assessed and marked and that mark contributes to the overall grade.

The practical skills are assessed by:

- teachers observing students during the course
- a practical exam testing students' technical and manipulative skills

() an extended investigation including direct assessment of practical skills

() a portfolio of experiments, detailing methodologies, results and conclusions and including direct assessment of practical skills.

[] **Option (ii)** science GCSE students' practical skills are assessed on a pass/fail basis related to competency with that outcome reported alongside the grade derived from their performance in the exams.

[] **A different option** that has not been covered in our consultation (please give full details of your proposed option).

We recommend a terminal practical exam for the assessment of technical and manipulative skills across science GCSEs.

The examination would comprise a series of short experimental tasks, each focussed on a specific practical skill. It would be set up as a carousel of stations, performed under exam conditions, with individuals moving between stations after a set period of time. Groups of candidates would take the examination sequentially; stations would be refreshed and tasks changed between groups.

The examination could take place over several days using a number of different tasks, drawn from a bank provided by the exam boards to prevent candidates from sharing the contents. The examination would be independently invigilated, perhaps by a teacher from a neighbouring cluster school. Tasks could have simple and advanced versions, providing differentiation. Evidence of performance would combine results recorded by the student and witness statements from the teacher.

Written or photographic evidence could be taken and samples sent for moderation by the exam board. The examinations would be monitored by the exam board through visits to schools, with serious consequences where malpractice is discovered.

We outlined this model in our response to Ofqual's 2013 consultation on GCSE reform and indicated our willingness to work with Ofqual and the exam boards to further develop the model.

Question 6

We have identified some ways in which our proposals for science GCSEs would impact (positively or negatively) on persons who share a protected characteristic. Are there any potential impacts we have not identified? If so, what are they?

Yes

No

If yes, please provide them here:

.....

.....

.....

.....

.....

.....

Question 7

Are there any additional steps we could take to mitigate any negative impact from resulting from these proposals on persons who share a protected characteristic? If so, please comment on the additional steps we could take to mitigate negative impacts.

Yes

No

If yes, please provide them here:

.....

.....

.....

.....
.....
.....

Question 8

Have you any other comments on the impacts of the proposals on persons who share a protected characteristic?

Yes

No

If yes, please provide them here:

Ofqual make clear that systems are already in place to ensure that disabled students are not unfairly disadvantaged by requirements to undertake practical science at GCSE level. In addition, we note that even if practical skills are not directly assessed, these systems will need to continue under these proposals as Ofqual state that practical work will need to be done in order to answer the exam questions. It is not clear why Ofqual feel these systems will not be sufficient for any of the alternative models proposed, particularly as they must be robust enough to be implemented in other practical subjects.

.....

Accessibility of our consultations

We are looking at how we provide accessible versions of our consultations and would appreciate it if you could spare a few moments to answer the following questions.

Your answers to these questions will not be considered as part of the consultation and will not be released to any third-parties.

We want to write clearly, directly and put the reader first. Overall, do you think we have got this right in this consultation?

Yes No

Do you have any comments or suggestions about the style of writing?

.....
.....

Do you have any special requirements to enable you to read our consultations? (For example screen reader, large text, and so on)*

Yes No

Which of the following do you currently use to access our consultation documents? (Select all that apply)*

- Screen reader / text-to-speech software
- Braille reader
- Screen magnifier
- Speech to text software
- Motor assistance (blow-suck tube, mouth stick, etc.)
- Other:

Which of the following document formats would meet your needs for accessing our consultations? (Select all that apply)*

- A standard PDF
- Accessible web pages
- Large type PDF (16 point text)
- Large-type word document (16 point text)
- eBook (Kindle, iBooks or similar format)
- Braille document (
- Spoken document
- Other:

How many of our consultations have you read in the last 12 months?*

1

2

3

4

5

More than 5

Appendix 1: Ofqual's role, objectives and duties

Our statutory objectives include the qualifications standards objective, which is to secure that the qualifications we regulate:

- (a) give a reliable indication of knowledge, skills and understanding; and
- (b) indicate
 - i. a consistent level of attainment (including over time) between comparable regulated qualifications; and
 - ii. a consistent level of attainment (but not over time) between qualifications we regulate and comparable qualifications (including those awarded outside of the UK) which we do not regulate.

We must therefore regulate so that qualifications properly differentiate between students who have demonstrated they have the knowledge, skills and understanding required to attain the qualification and those who have not.

We also have duties under the Apprenticeship, Skills, Children and Learning Act 2009 to have regard to the reasonable requirements of relevant students, including those with special educational needs and disabilities, of employers and of the higher education sector, and to aspects of government policy when so directed by the Secretary of State.

As a public body we are subject to the public sector equality duty (PSED). This duty requires us to have due regard to the need to:

- (a) eliminate discrimination, harassment, victimisation and any other conduct which is prohibited under the Equality Act 2010;
- (b) advance equality of opportunity between persons who share a relevant protected characteristic and persons who do not share it;
- (c) foster good relations between persons who share a relevant protected characteristic and persons who do not share it.

The exam boards that design, deliver and award GCSE, A level and AS qualifications are required by the Equality Act, among other things, to make reasonable adjustments for disabled people taking their qualifications, except where we have specified that such adjustments should not be made.

When we decide whether such adjustments should not be made, we must have regard to:

- (a) the need to minimise the extent to which disabled persons are disadvantaged in attaining the qualification because of their disabilities;
- (b) the need to secure that the qualification gives a reliable indication of the knowledge, skills and understanding of a person upon whom it is conferred;
- (c) the need to maintain public confidence in the qualification.

Legislation therefore sets out a framework within which we must operate. We are subject to a number of duties and we must aim to achieve a number of objectives. These different duties and objectives can, from time to time, conflict with each other. For example, if we regulate to secure that a qualification gives a reliable indication of a student's knowledge, skills and understanding, a student who has not been able to demonstrate the required knowledge, skills and/or understanding will not be awarded the qualification. A person may find it more difficult, or impossible, to demonstrate the required knowledge, skills and/or understanding because they have a protected characteristic. This could put them at a disadvantage relative to others who have been awarded the qualification. It is not always possible for us to regulate so that we can both secure that qualifications give a reliable indication of knowledge, skills and understanding and advance equality between people who share a protected characteristic and those who do not. We must review all the available evidence and actively consider all the available options before coming to a final, rational decision.

Qualifications cannot be used to mitigate inequalities or unfairness in the education system or in society more widely that might affect, for example, students' preparedness to take the qualification and the assessments within it. Whilst a wide range of factors can have an impact on a student's ability to achieve a particular mark in an assessment, our influence is limited to the way the qualification is designed and assessed.

We require the exam boards to design qualifications to give a reliable indication of the knowledge, skills and understanding of those on whom they are conferred. We also require the exam boards to avoid, where possible, features of a qualification that could, without justification, make a qualification more difficult for a student to achieve because they have a particular protected characteristic. We require exam boards to monitor whether any features of their qualifications have this effect.

In setting the overall framework within which exam boards will design, assess and award the reformed A level and AS qualifications we want to understand the possible impacts of the proposals on persons who share a protected characteristic.

The protected characteristics under the Equality Act 2010 are:

- age;
- disability;

- gender reassignment;
- marriage and civil partnerships;
- pregnancy and maternity;
- race;
- religion or belief;
- sex;
- sexual orientation.

It should be noted that under section 149 of the 2010 Act, we are not required to have due regard to impacts on those who are married or in a civil partnership.

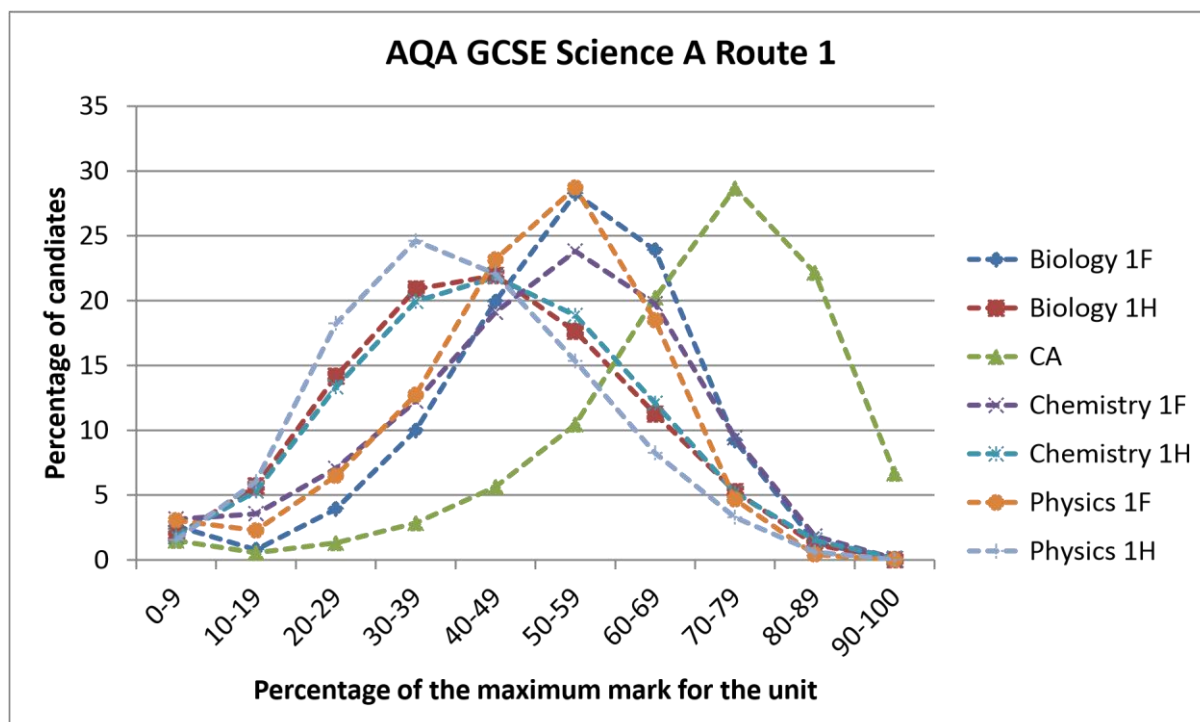
Appendix 2: GCSE Science, Additional Science and Single Sciences mark distributions s2014

The graphs below show the distribution of raw marks for the units that make up the current GCSE science, additional science, further additional science, biology, chemistry and physics qualifications for AQA, OCR, Pearson and WJEC.²⁸

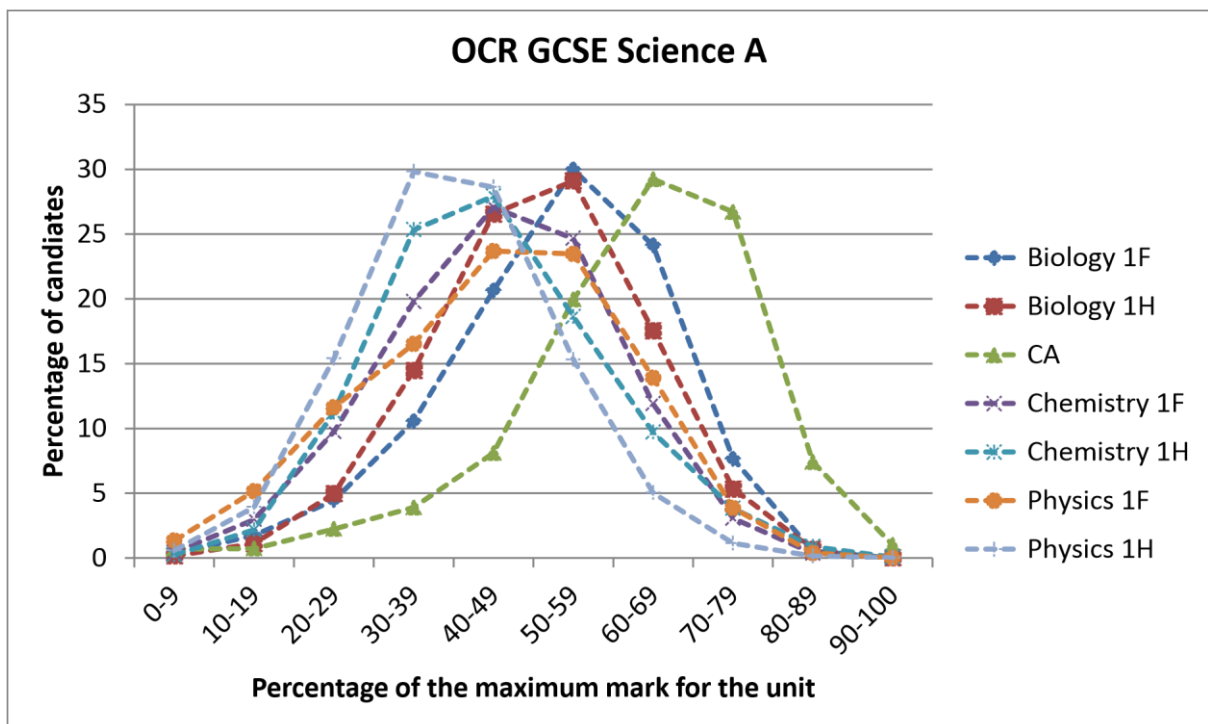
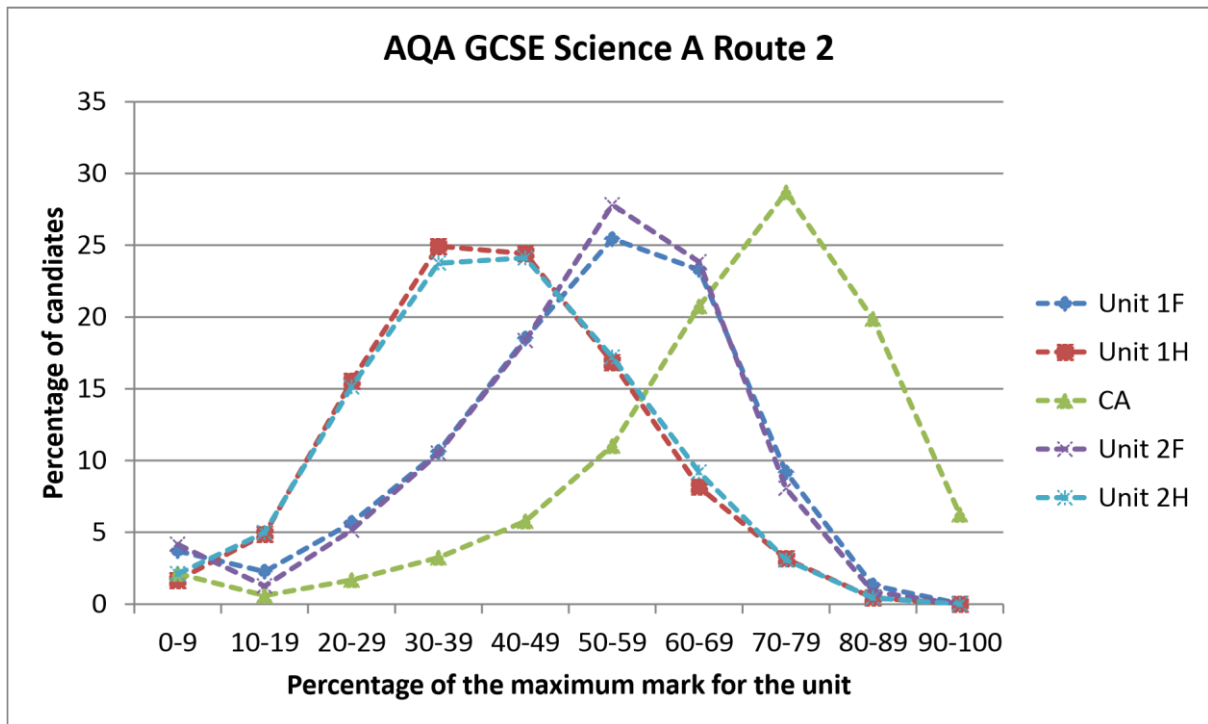
Units assessed by exam are indicated by, for example, 'Unit 1F' or by 'Biology 1F', where 'F' and 'H' indicate performance in the separate tiers of assessment, which are foundation and higher tier. Controlled assessment units are labelled 'CA' and, as they are not tiered, indicate performance for all candidates.

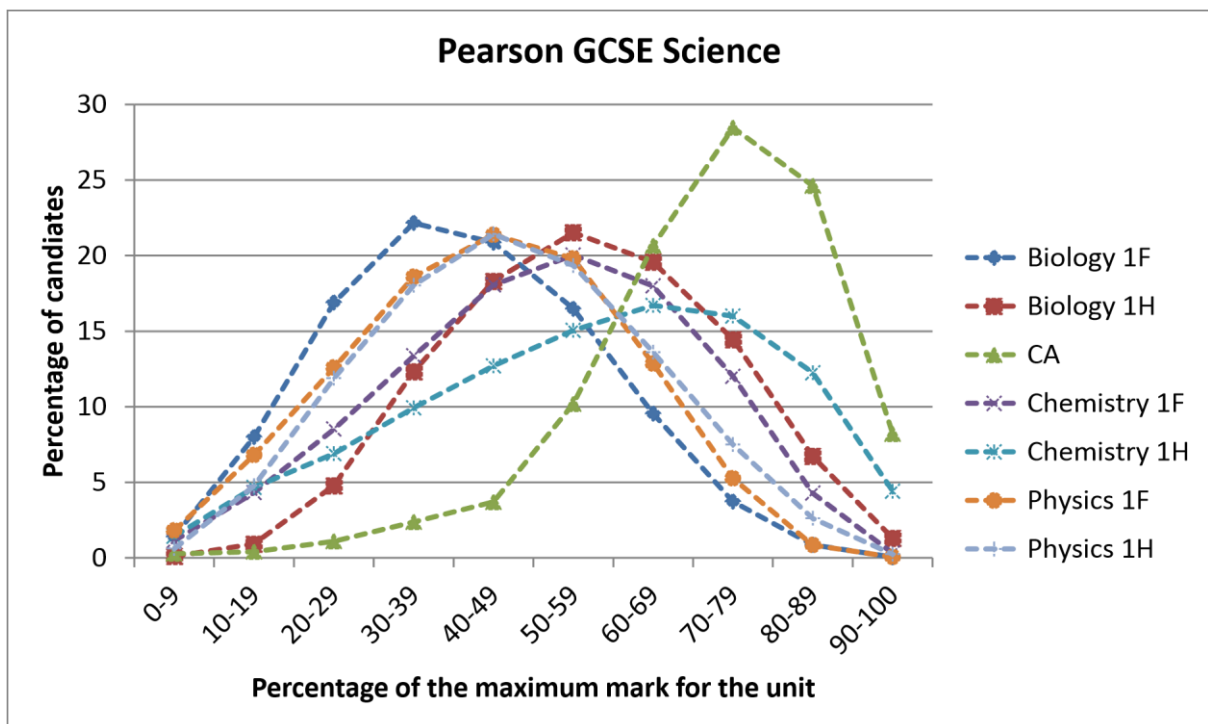
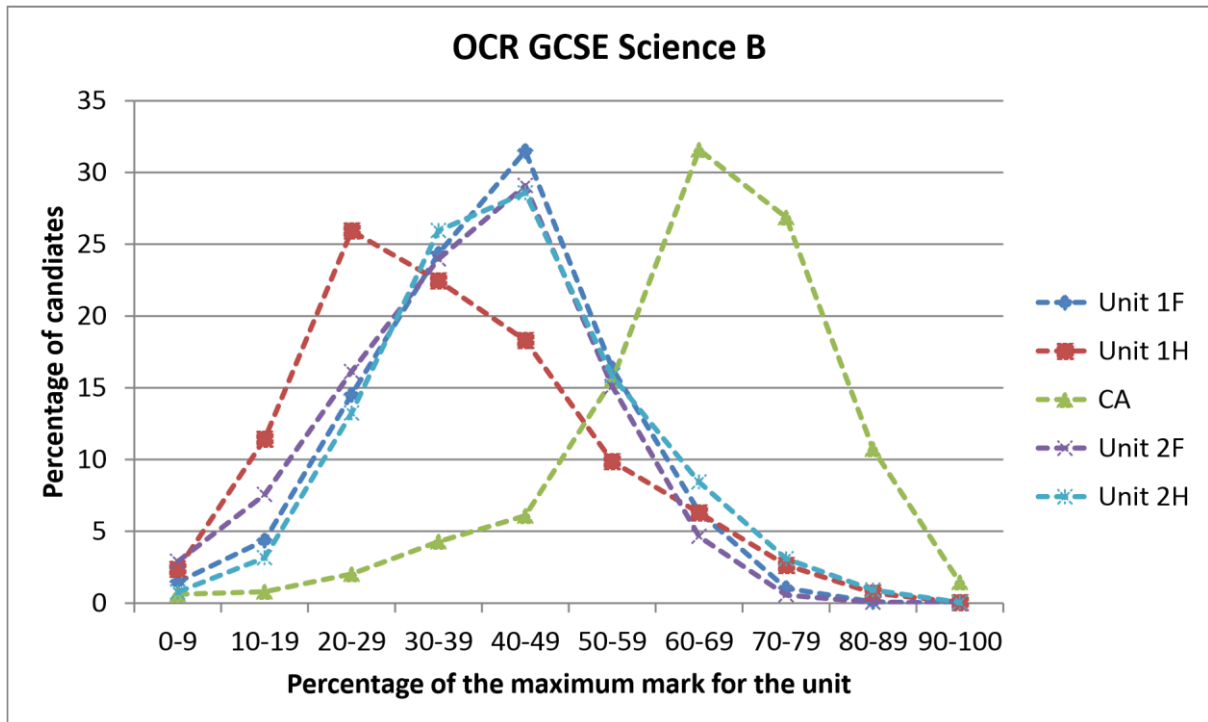
Since the different units have different maximum marks, each mark distribution is shown as a percentage of the total mark for that unit. After scaling them in this way, each unit had a different number of mark points, so ten groups of marks were created for each unit to allow a better comparison between them. For each unit, these ten data points were linked by a dashed line to show the overall distribution of the data.

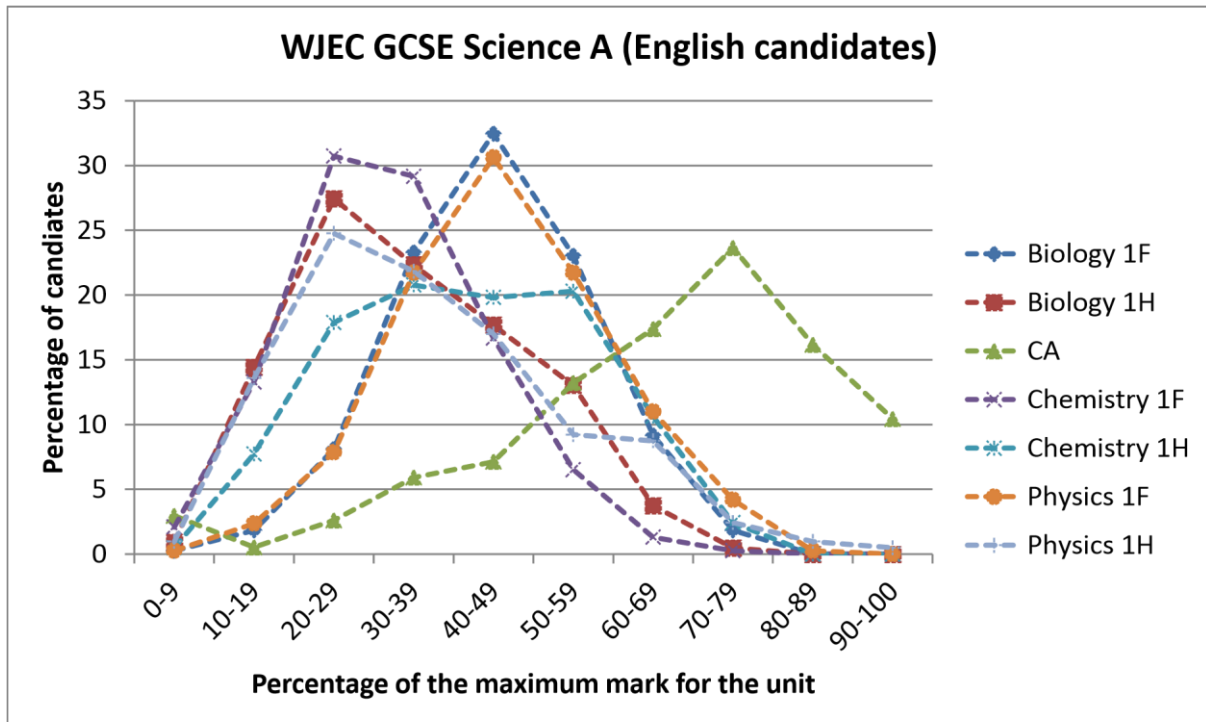
Science



²⁸ Only data for English candidates is shown for WJEC.

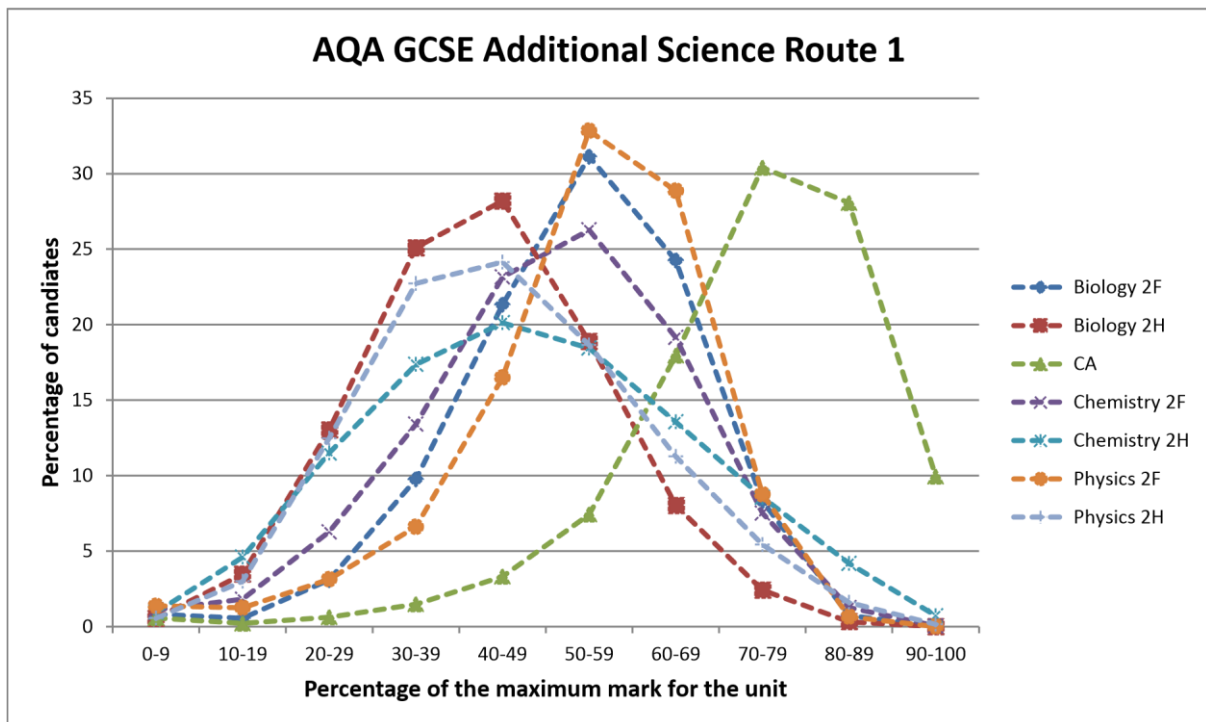




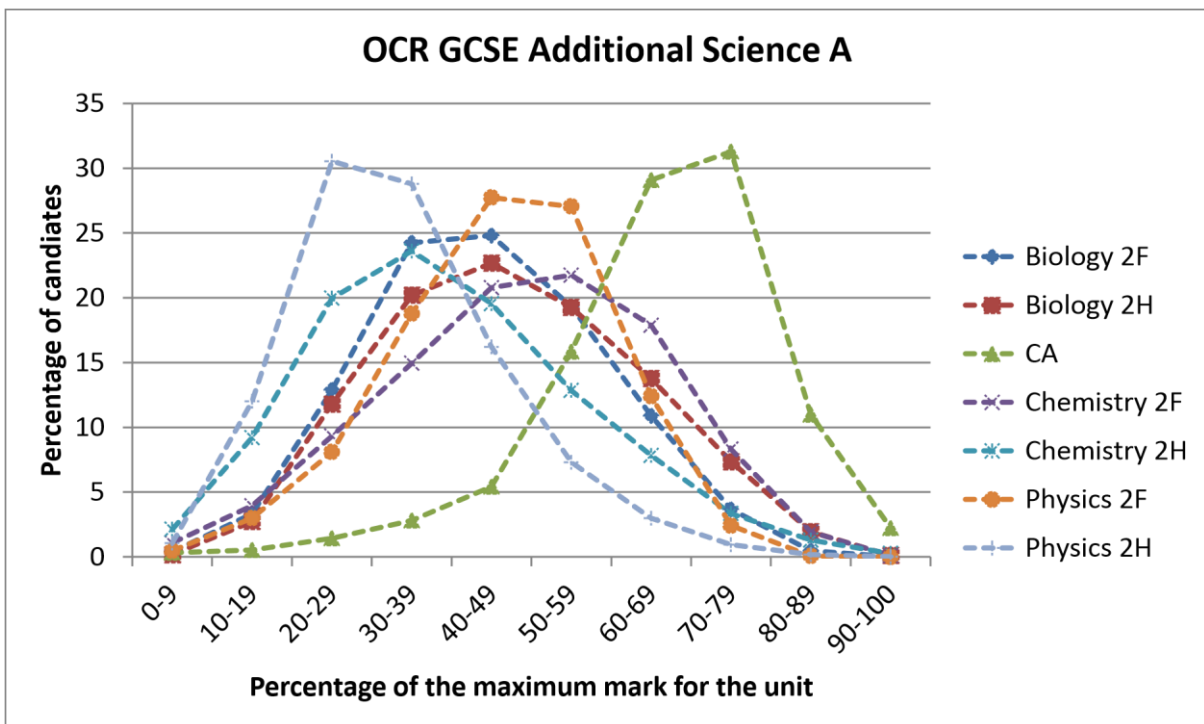
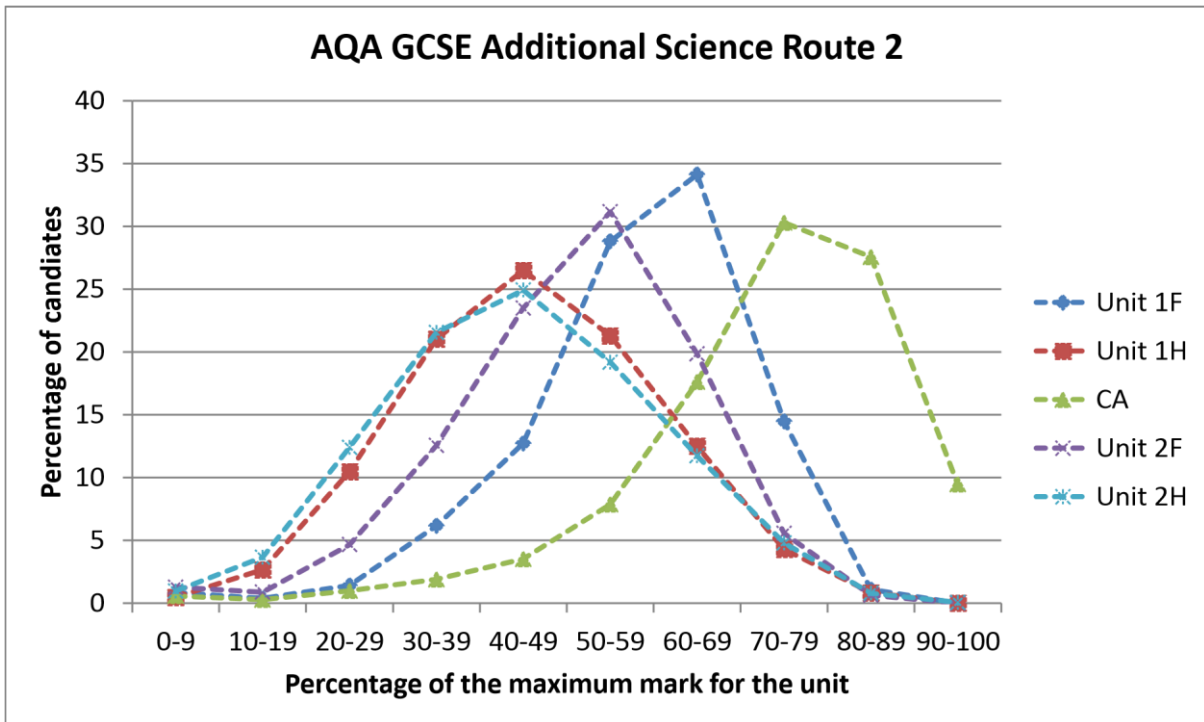


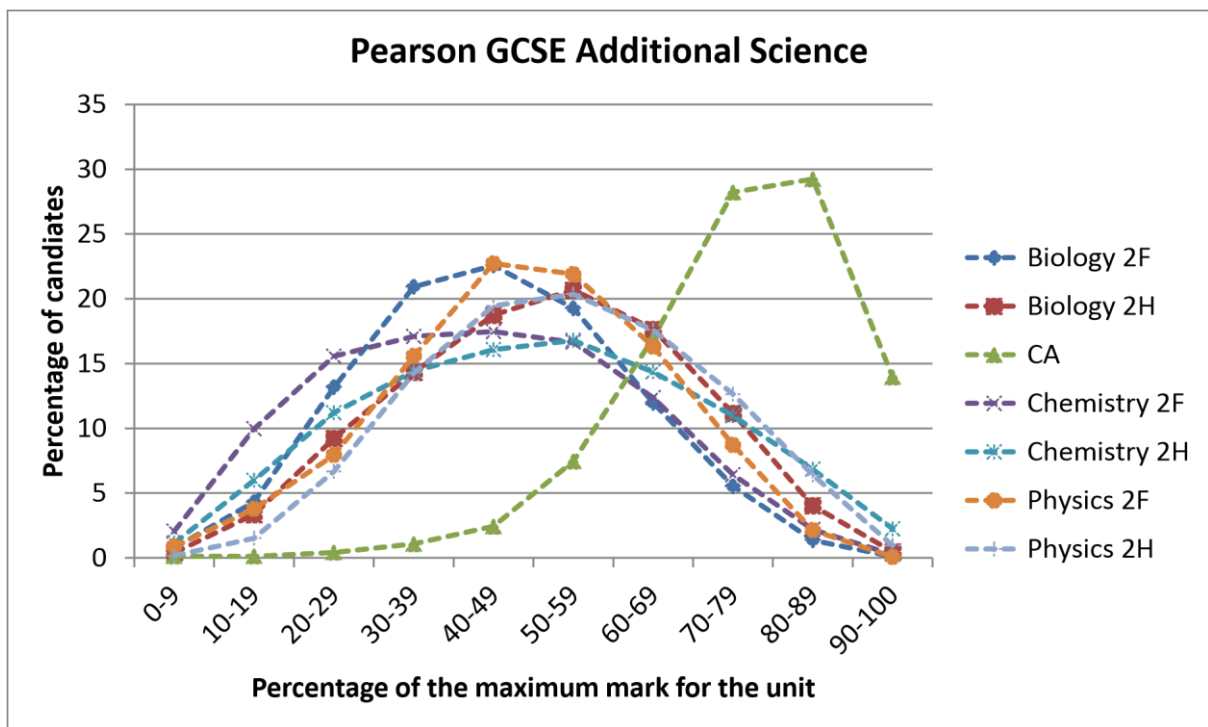
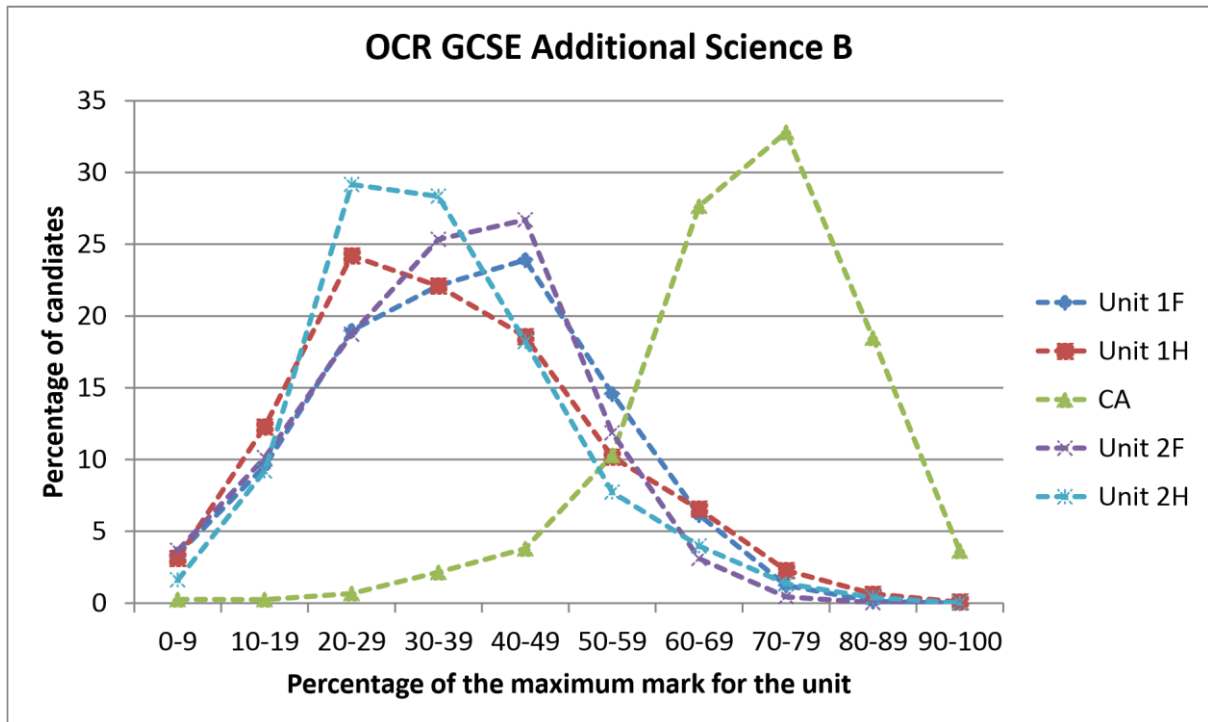
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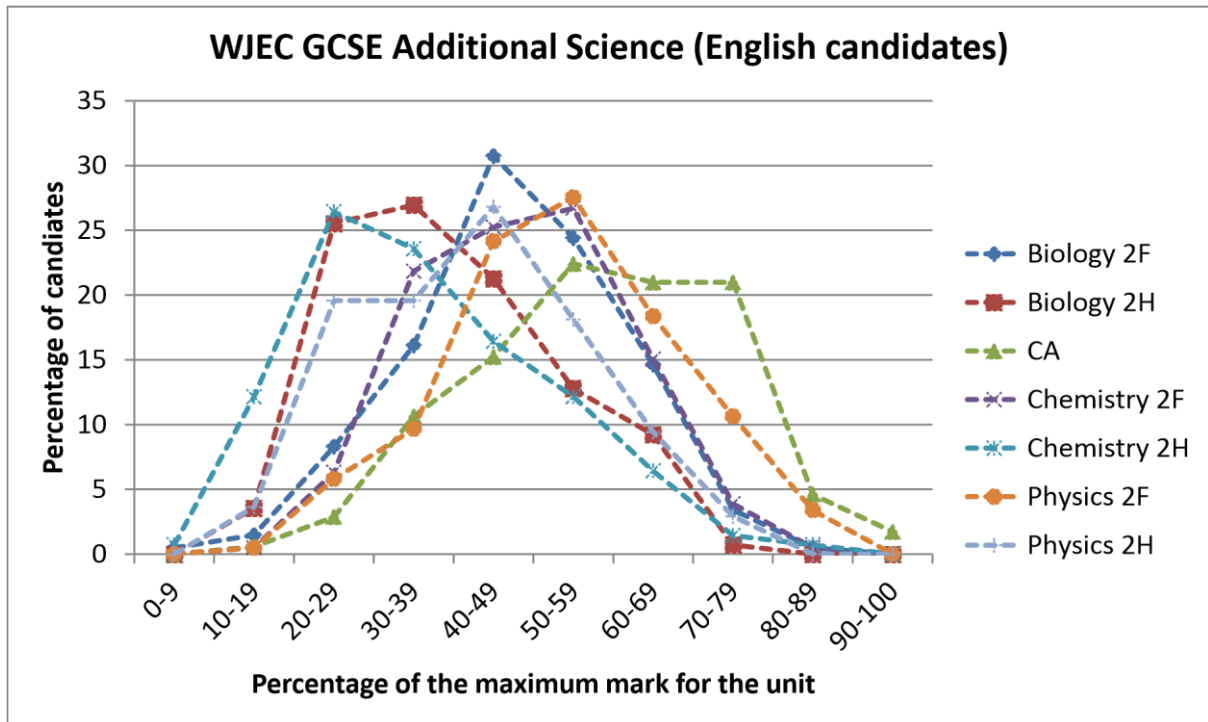
Additional Science



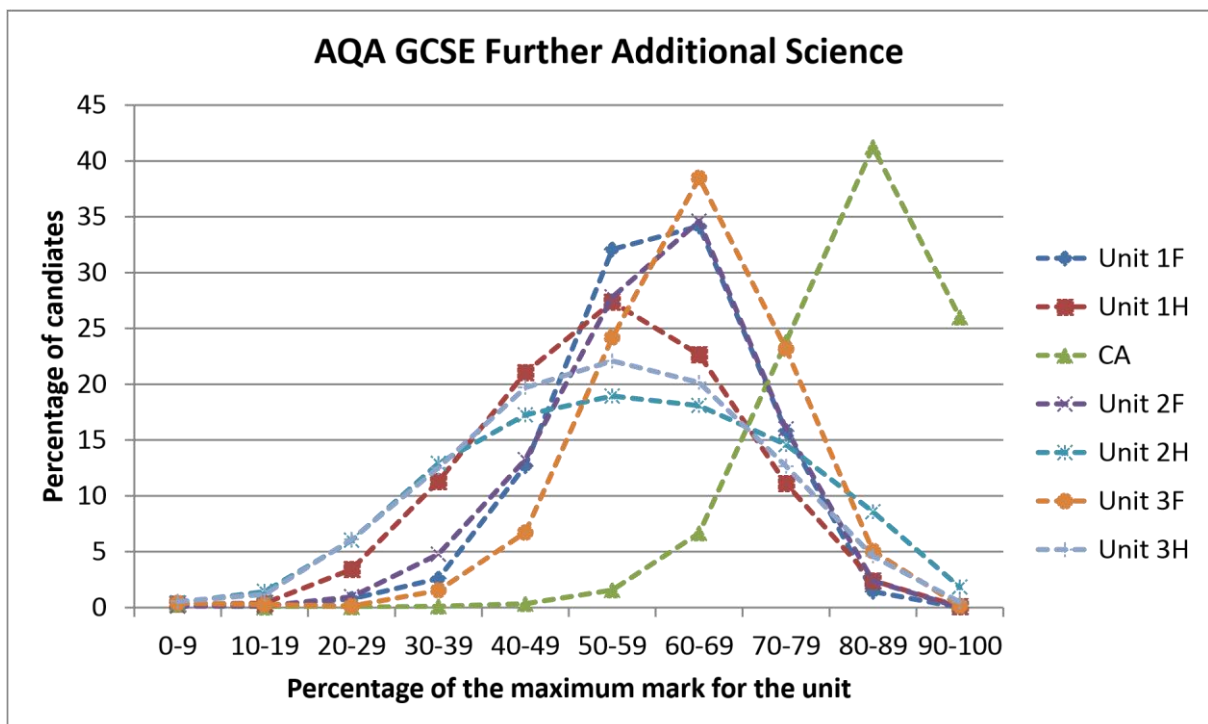
³⁵ Note that owing to the low entry numbers for WJEC sciences in England, confidence intervals are wider for this data than for other qualifications.

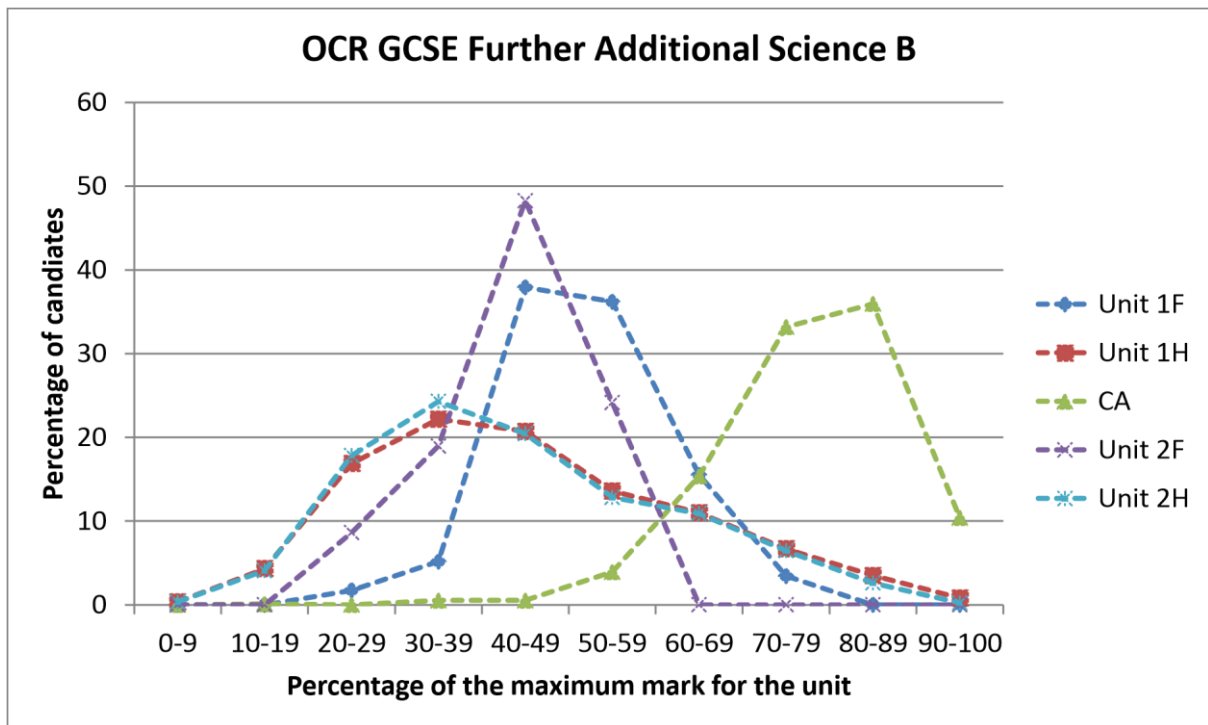
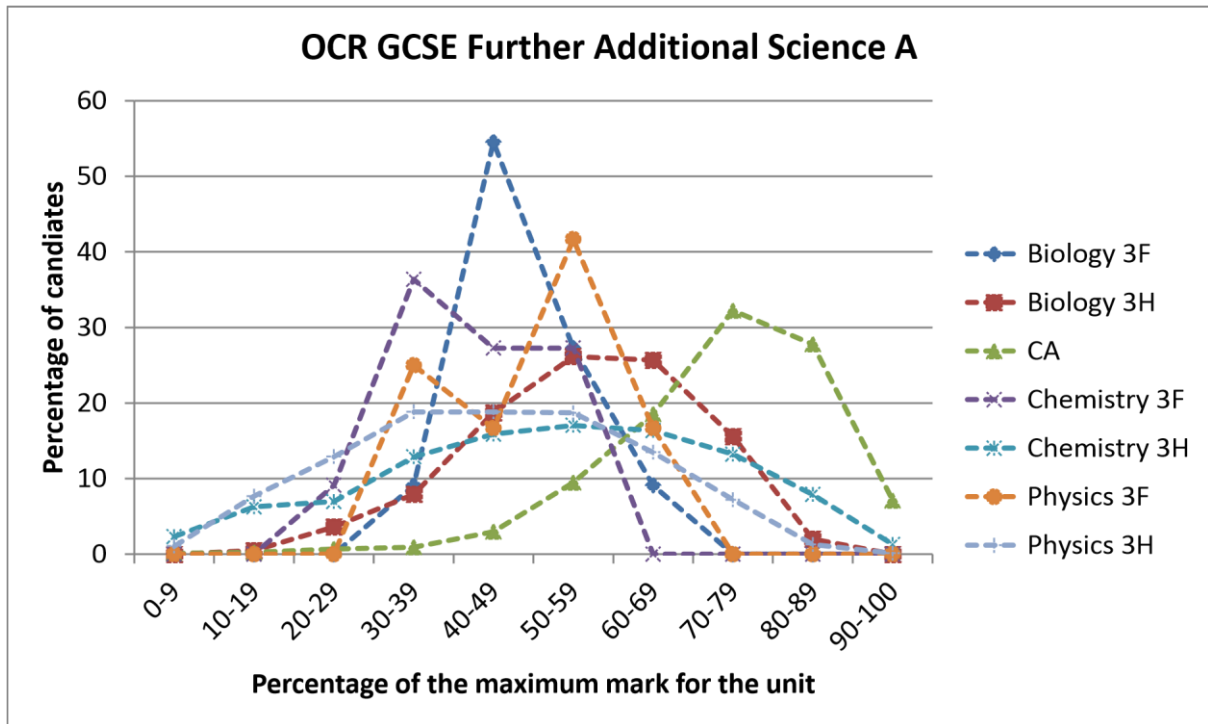


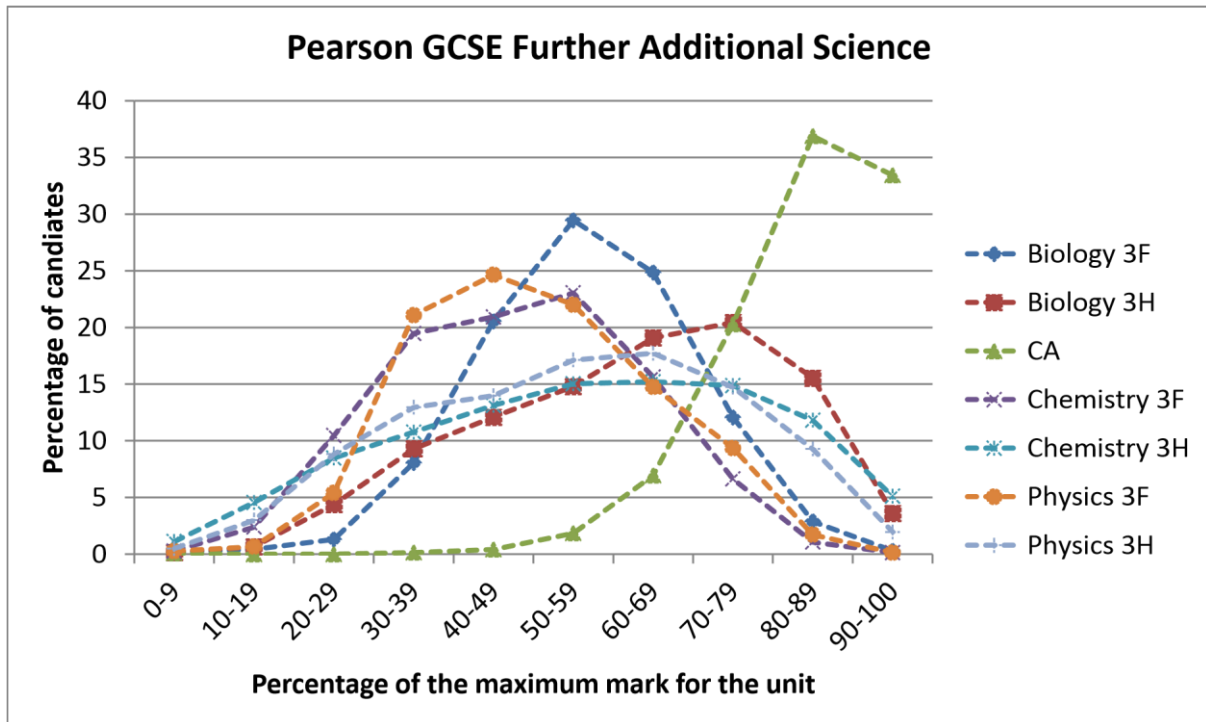




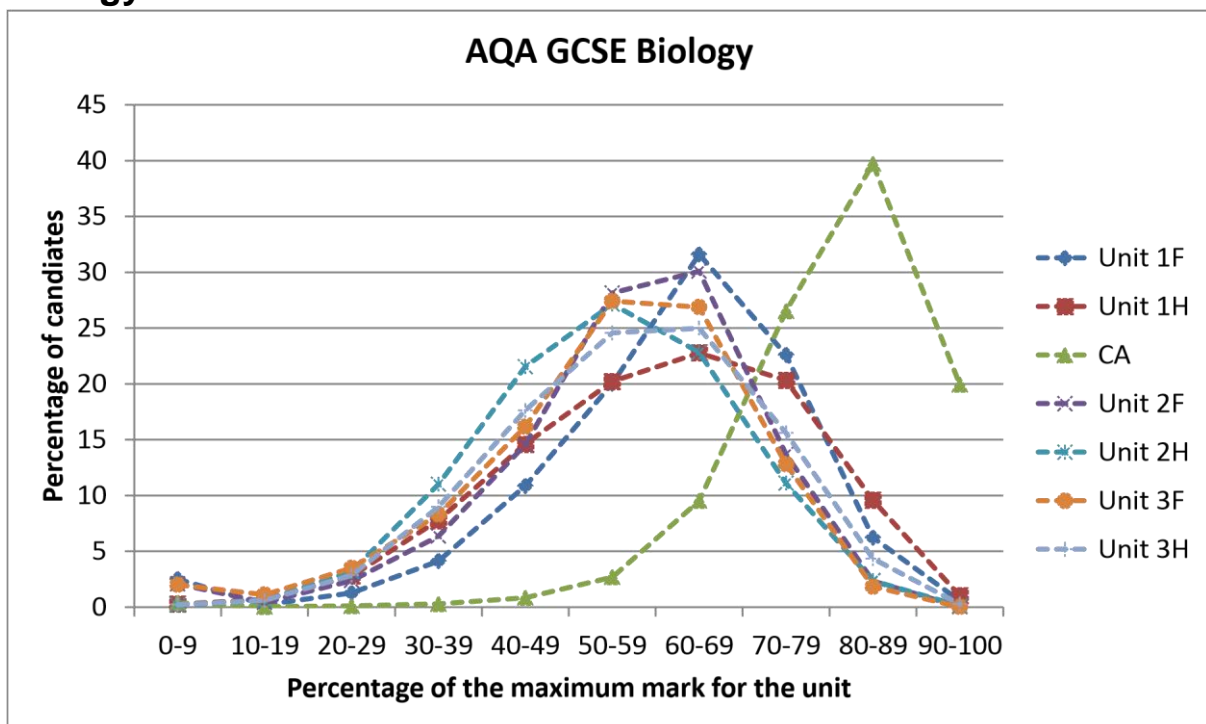
Further additional science

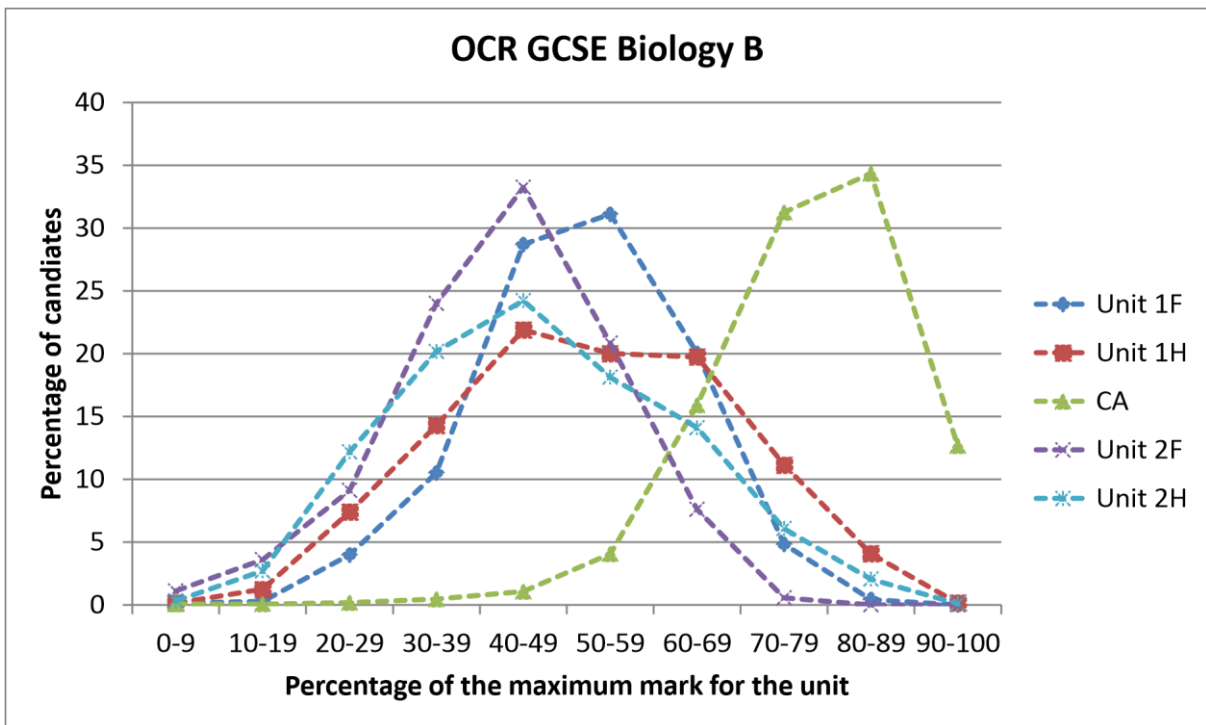
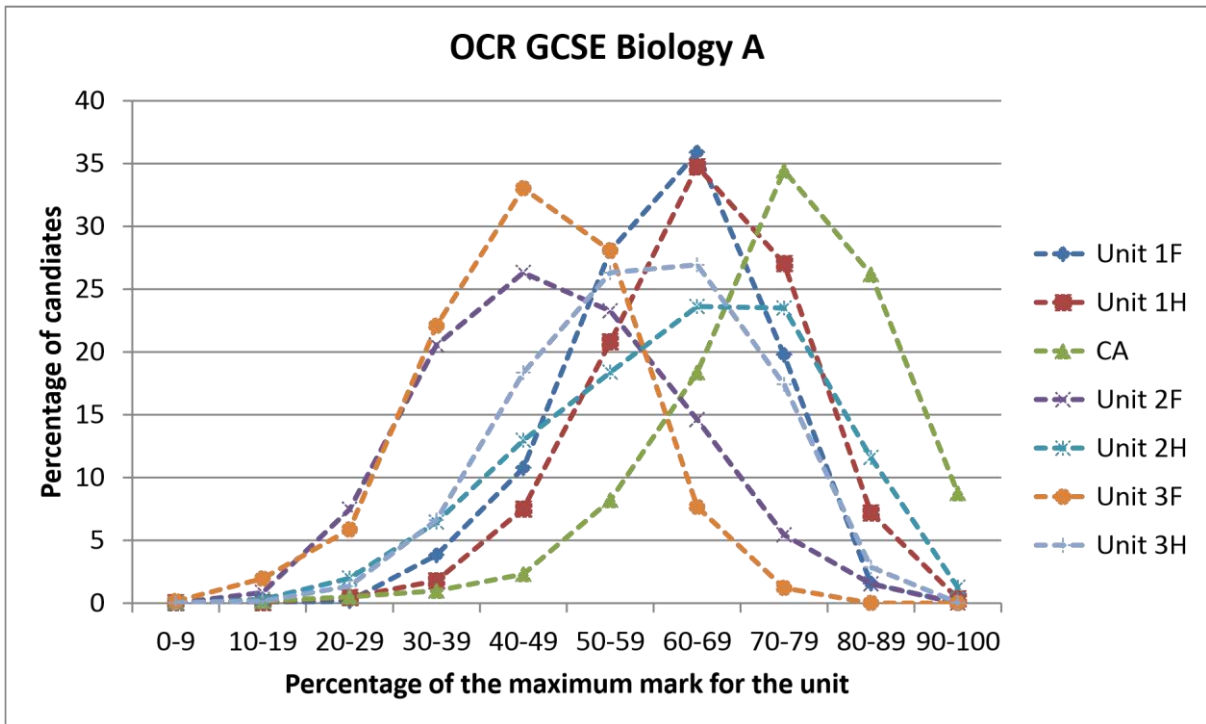


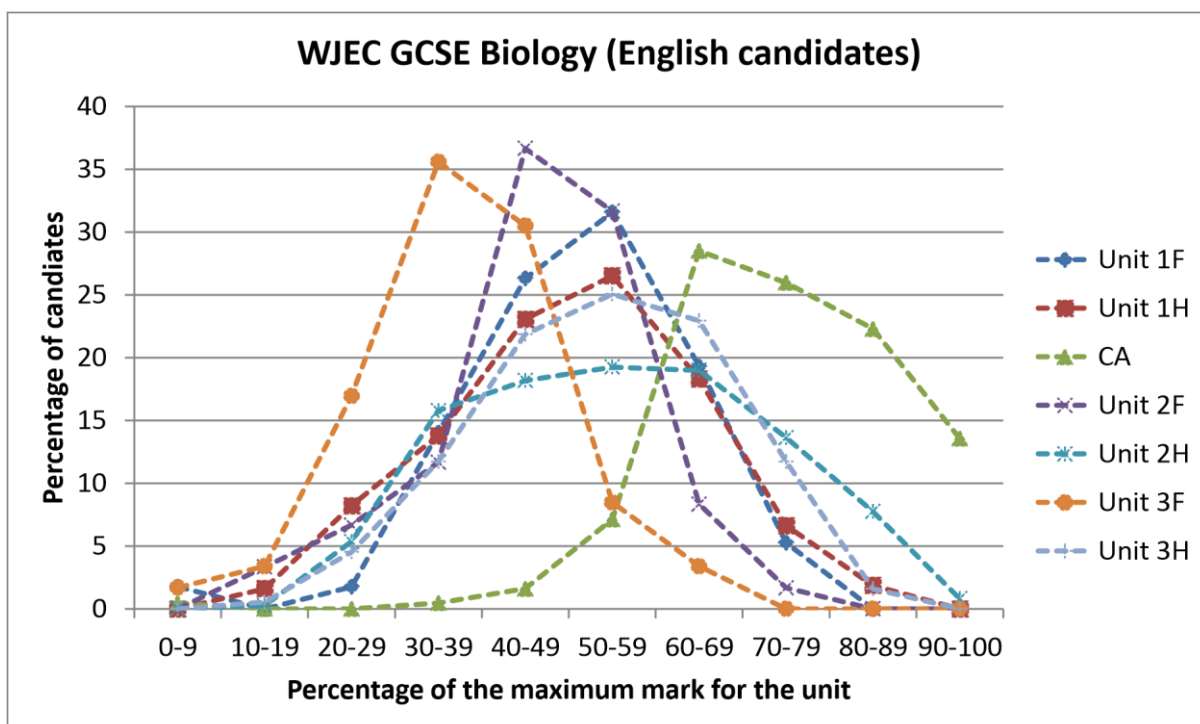
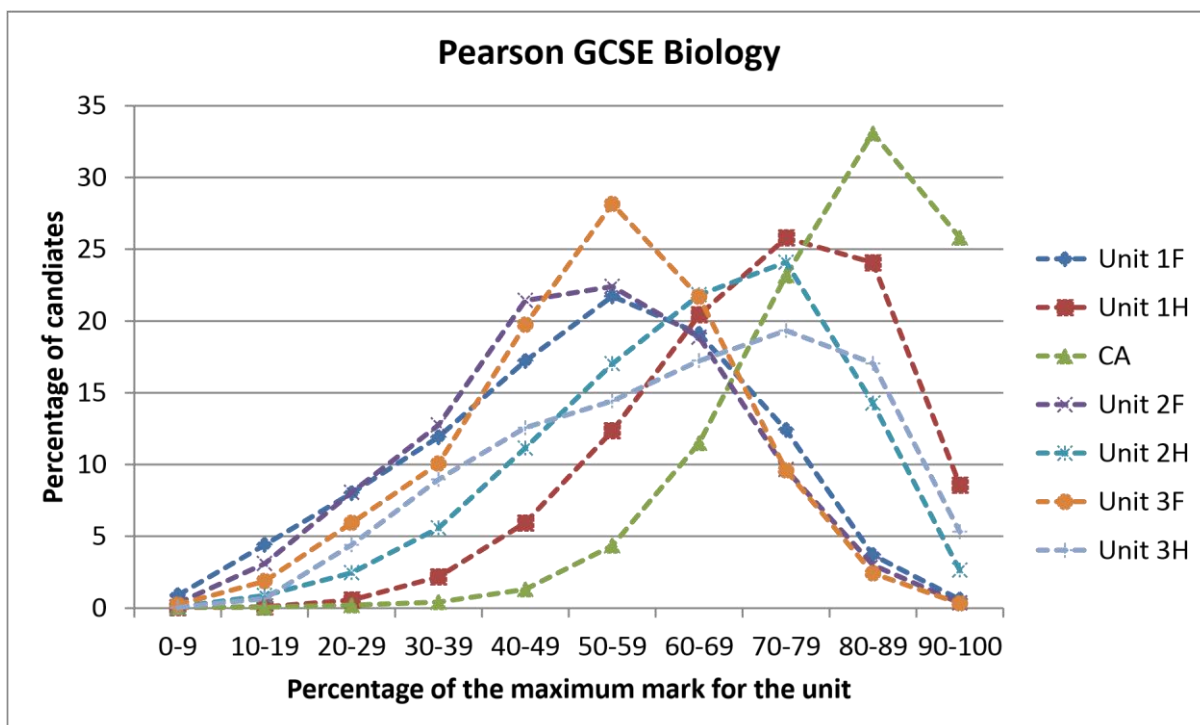




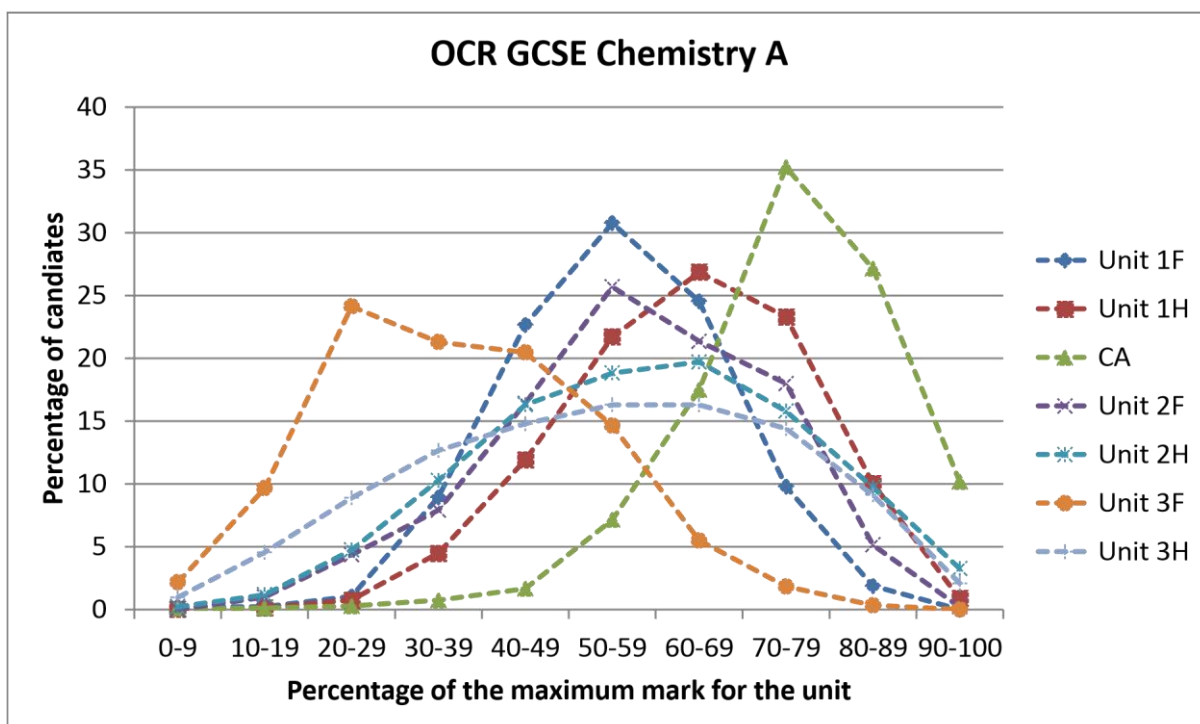
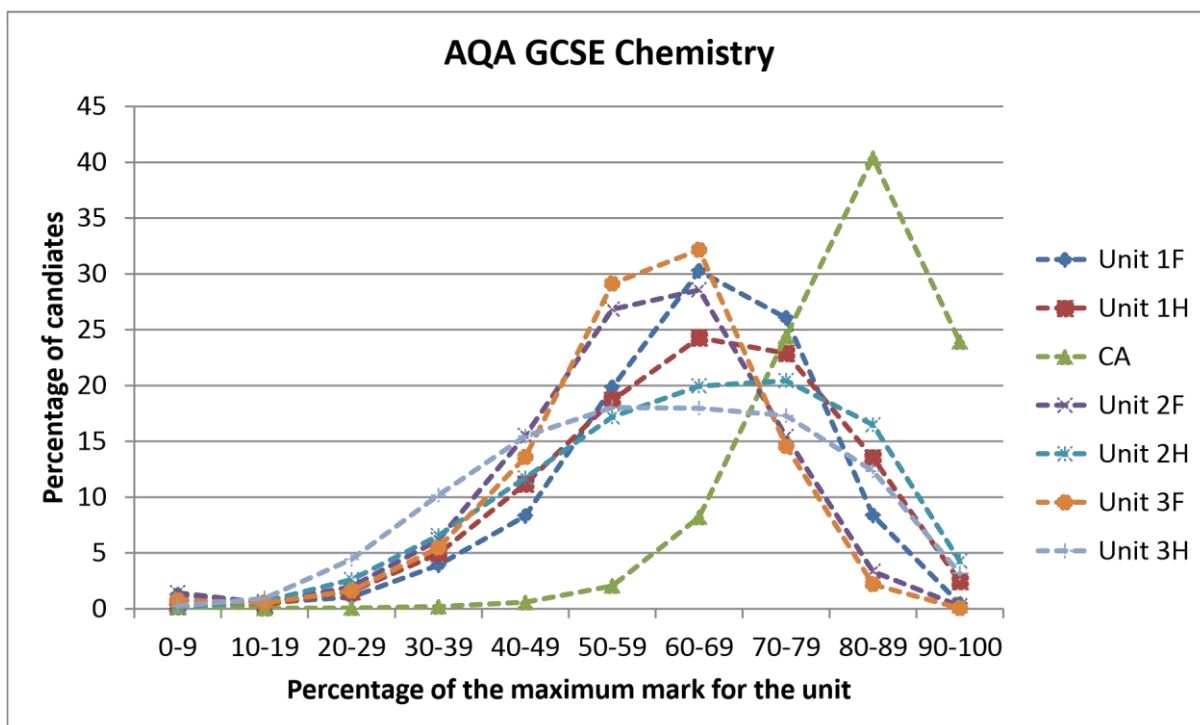
Biology

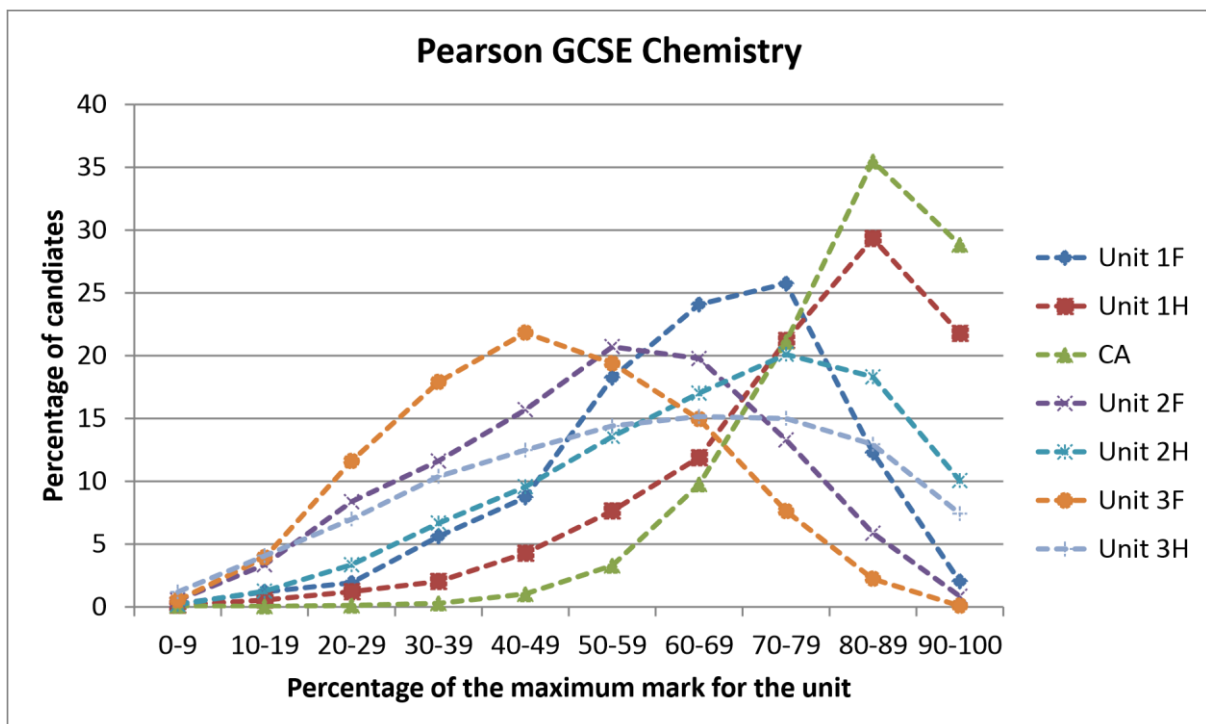
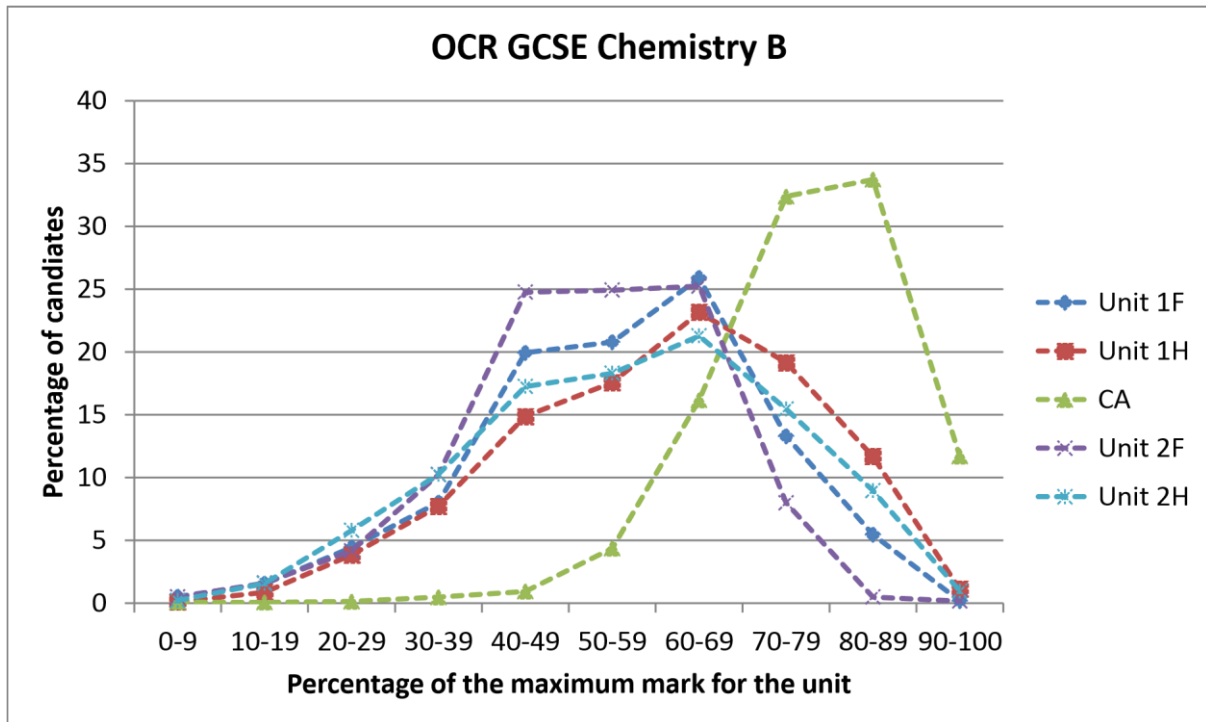


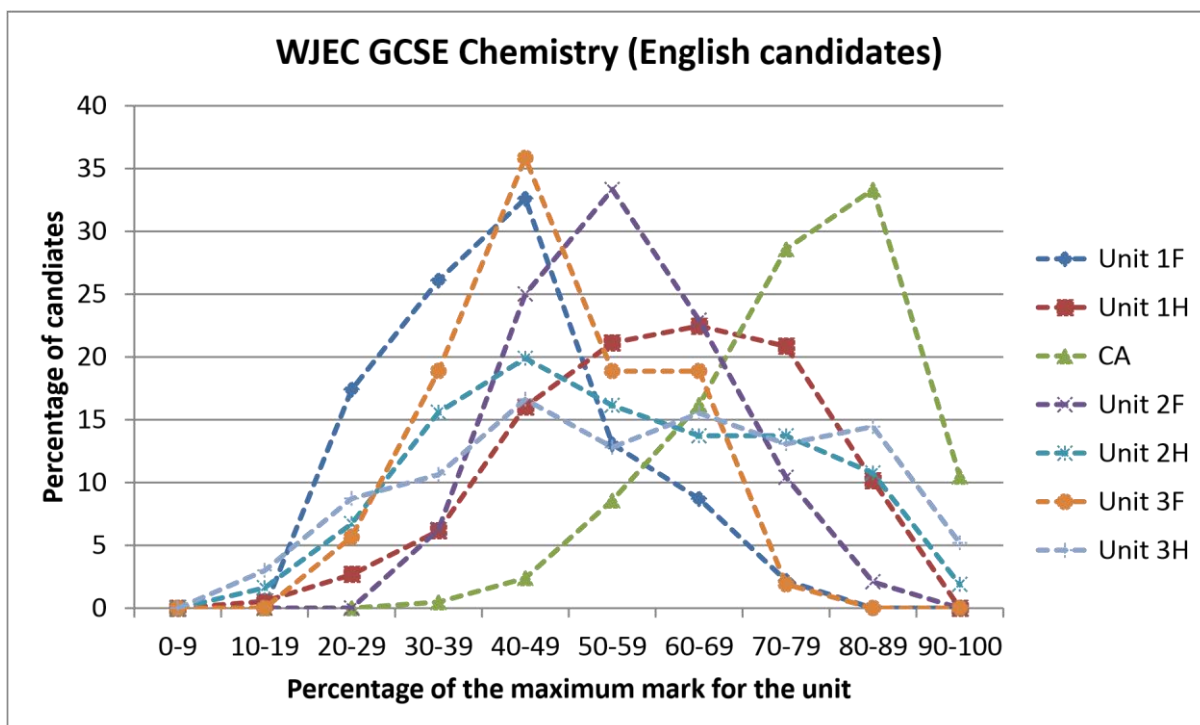




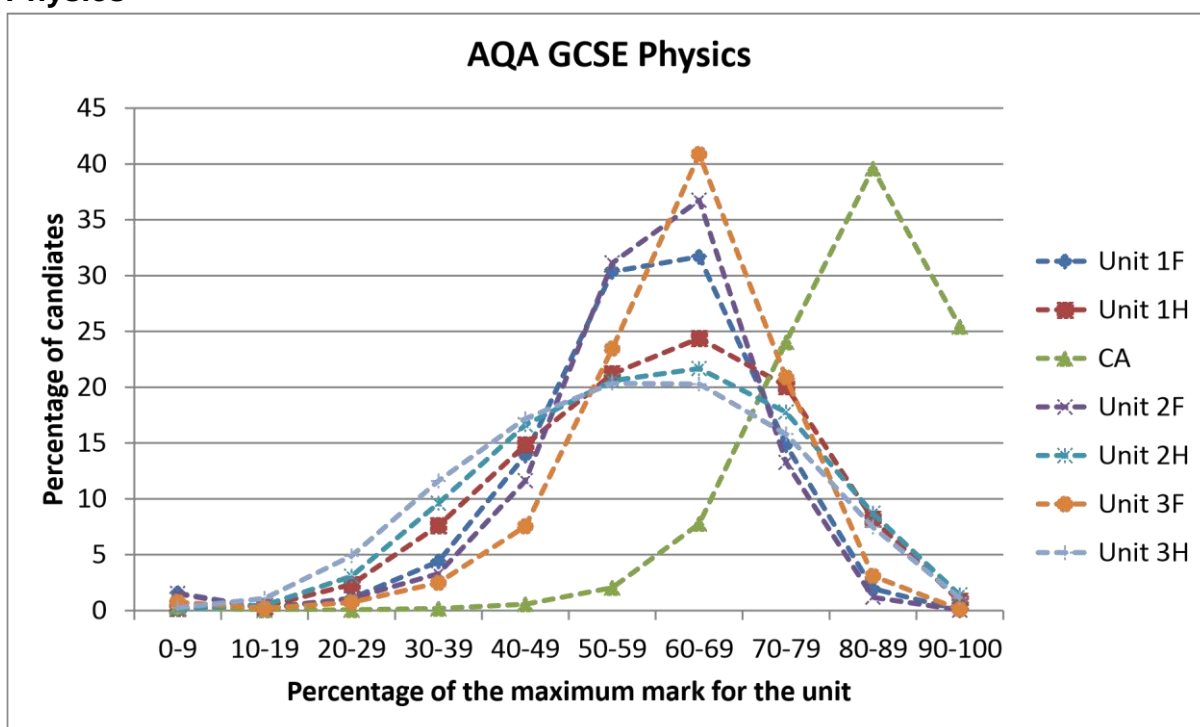
Chemistry

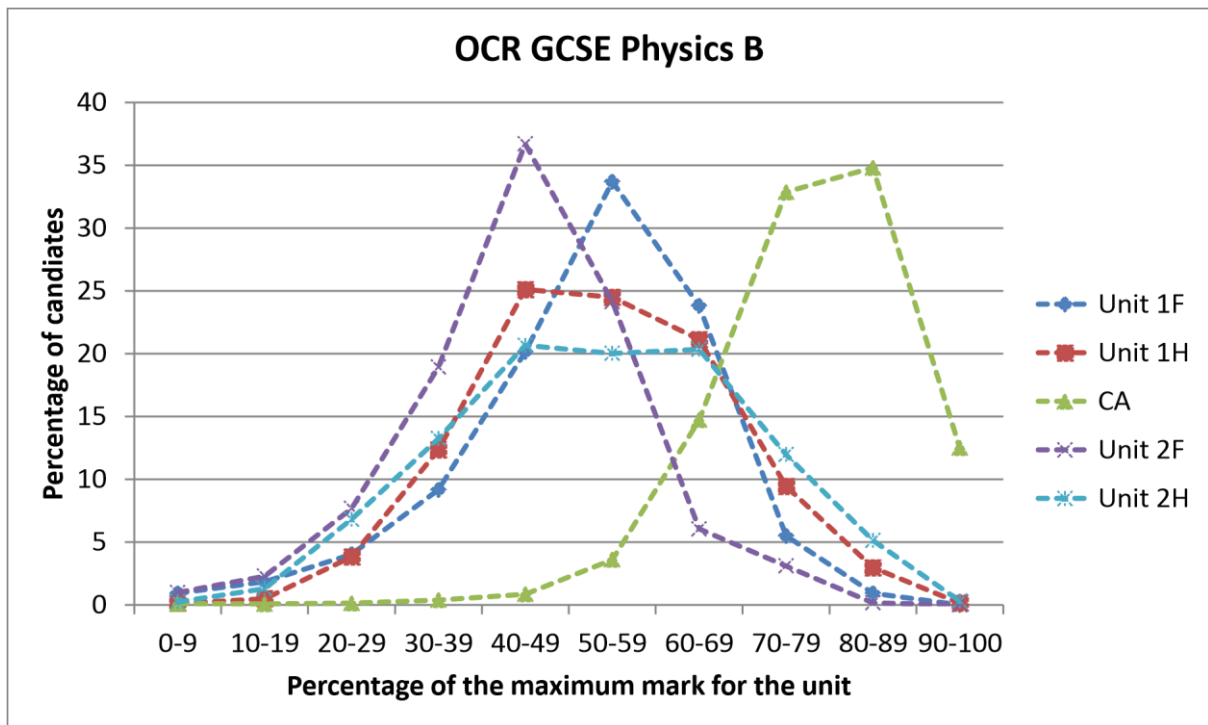
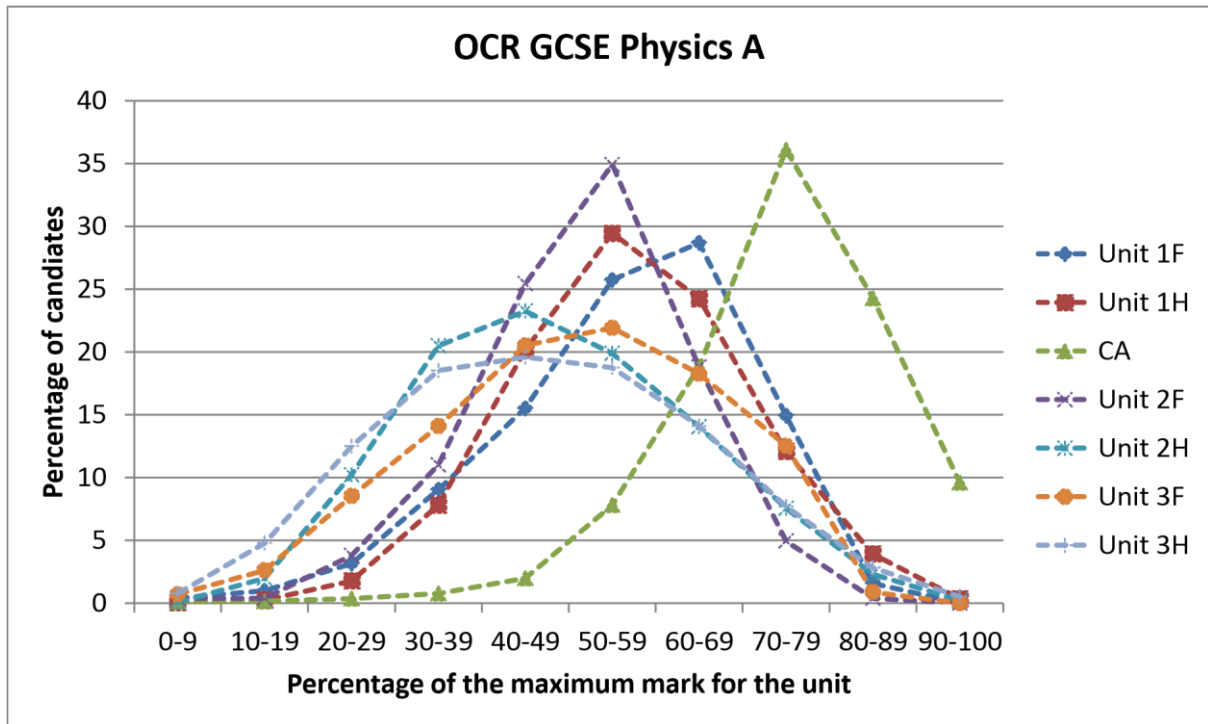


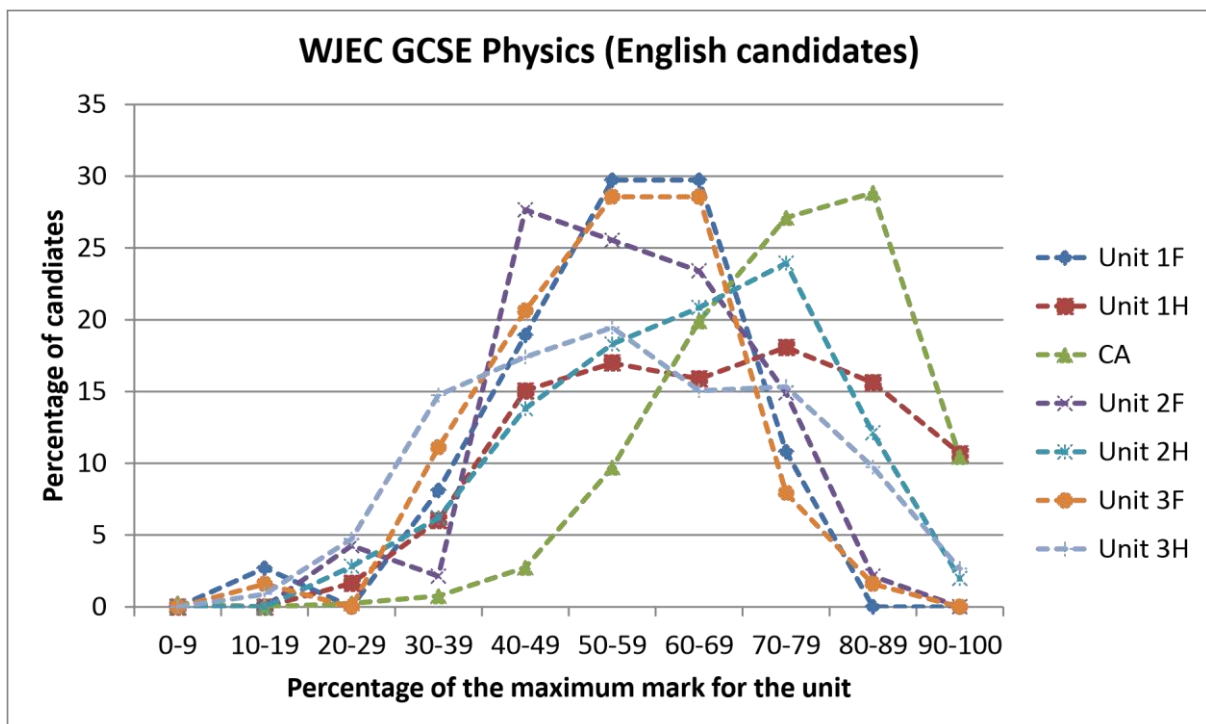
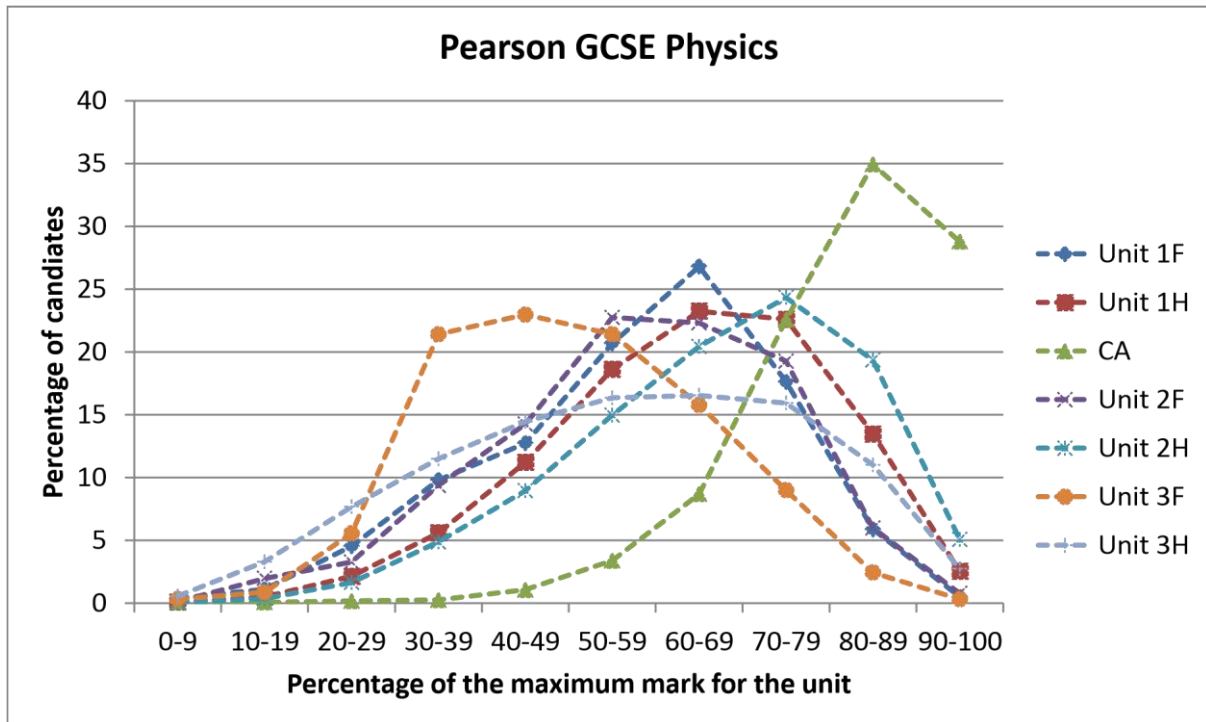




Physics







Appendix 3: Entry information for GCSE sciences 2014

Science

Unit	Number of entries
------	-------------------

AQA GCSE Science A Route 1	
Biology 1F	79850
Biology 1H	92000
CA	165750
Chemistry 1F	81900
Chemistry 1H	89900
Physics 1F	81100
Physics 1H	90750
AQA GCSE Science A Route 2	
Unit 1F	9400
Unit 1H	12250
CA	20900
Unit 2F	9350
Unit 2H	12250
OCR GCSE Science A	
Biology 1F	15100
Biology 1H	32700
CA	44900
Chemistry 1F	15100
Chemistry 1H	32700
Physics 1F	15150
Physics 1H	32550
OCR GCSE Science B	
Unit 1F	17800
Unit 1H	30100
CA	45050
Unit 2F	17700
Unit 2H	30000
Pearson GCSE Science	
Biology 1F	31800
Biology 1H	28200
CA	56200
Chemistry 1F	31800
Chemistry 1H	28250
Physics 1F	32050
Physics 1H	27800

WJEC GCSE Science A (English candidates)	
Biology 1F	400
Biology 1H	200
CA	600
Chemistry 1F	400
Chemistry 1H	200
Physics 1F	400
Physics 1H	200

Additional Science

Unit	Number of entries
AQA GCSE Additional Science Route 1	
Biology 2F	50900
Biology 2H	92350
CA	143050
Chemistry 2F	53750
Chemistry 2H	89500
Physics 2F	52500
Physics 2H	90700
AQA GCSE Additional Science Route 2	
Unit 1F	4350
Unit 1H	9400
CA	13750
Unit 2F	4350
Unit 2H	9400
OCR GCSE Additional Science A	
Biology 2F	7750
Biology 2H	29050
CA	35500
Chemistry 2F	7900
Chemistry 2H	28900
Physics 2F	7900
Physics 2H	28850
OCR GCSE Additional Science B	
Unit 1F	8950
Unit 1H	27500

CA	36500
Unit 2F	8950
Unit 2H	27450
Pearson GCSE Additional Science	
Biology 2F	19700
Biology 2H	27950
CA	47550
Chemistry 2F	19850
Chemistry 2H	27800
Physics 2F	19700
Physics 2H	27900
WJEC GCSE Additional Science (English candidates)	
Biology 2F	200
Biology 2H	150
CA	350
Chemistry 2F	200
Chemistry 2H	150
Physics 2F	200
Physics 2H	150

Further additional science

Unit	Number of entries
AQA GCSE Further Additional Science	
Unit 1F	750
Unit 1H	12800
CA	13600
Unit 2F	850
Unit 2H	12750
Unit 3F	800
Unit 3H	12800
OCR GCSE Further Additional Science A	
Biology 3F	0 ²⁹
Biology 3H	850
CA	850
Chemistry 3F	0 [~]

²⁹ Indicates less than 25 entries

Chemistry 3H	850
Physics 3F	0
Physics 3H	850
OCR GCSE Further Additional Science B	
Unit 1F	50
Unit 1H	900
CA	950
Unit 2F	50
Unit 2H	900
Pearson GCSE Further Additional Science	
Biology 3F	700
Biology 3H	5150
CA	5850
Chemistry 3F	750
Chemistry 3H	5100
Physics 3F	750
Physics 3H	5100

Biology

Unit	Number of entries
AQA GCSE Biology	
Unit 1F	4050
Unit 1H	71550
CA	75350
Unit 2F	4350
Unit 2H	71250
Unit 3F	4850
Unit 3H	70600
OCR GCSE Biology A	
Unit 1F	600
Unit 1H	22350
CA	22800
Unit 2F	600
Unit 2H	22300
Unit 3F	650

Unit 3H	22250
OCR GCSE Biology B	
Unit 1F	700
Unit 1H	21650
CA	22250
Unit 2F	750
Unit 2H	21600
Pearson GCSE Biology	
Unit 1F	1000
Unit 1H	10350
CA	11050
Unit 2F	1150
Unit 2H	10050
Unit 3F	1300
Unit 3H	9850
WJEC GCSE Biology (English candidates)	
Unit 1F	50
Unit 1H	400
CA	450
Unit 2F	50
Unit 2H	350
Unit 3F	50
Unit 3H	400

Chemistry

Unit	Number of entries
AQA GCSE Chemistry	
Unit 1F	3200
Unit 1H	69500
CA	72550
Unit 2F	3650
Unit 2H	69050
Unit 3F	4250
Unit 3H	68450
OCR GCSE Chemistry A	

Unit 1F	500
Unit 1H	22850
CA	23350
Unit 2F	500
Unit 2H	22800
Unit 3F	600
Unit 3H	22250
OCR GCSE Chemistry B	
Unit 1F	600
Unit 1H	21400
CA	22000
Unit 2F	650
Unit 2H	21350
Pearson GCSE Chemistry	
Unit 1F	850
Unit 1H	10350
CA	10950
Unit 2F	950
Unit 2H	10100
Unit 3F	1350
Unit 3H	9650
WJEC GCSE Chemistry (English Candidates)	
Unit 1F	50
Unit 1H	350
CA	400
Unit 2F	50
Unit 2H	350
Unit 3F	50
Unit 3H	350

Physics

Unit	Number of entries
AQA GCSE Physics	
Unit 1F	2750
Unit 1H	69050
CA	71800

Unit 2F	3150
Unit 2H	68700
Unit 3F	3600
Unit 3H	68250
OCR GCSE Physics A	
Unit 1F	500
Unit 1H	22450
CA	23000
Unit 2F	550
Unit 2H	22400
Unit 3F	600
Unit 3H	22350
OCR GCSE Physics B	
Unit 1F	550
Unit 1H	21850
CA	22400
Unit 2F	600
Unit 2H	21800
Pearson GCSE Physics	
Unit 1F	800
Unit 1H	10600
CA	11200
Unit 2F	900
Unit 2H	10350
Unit 3F	1300
Unit 3H	9950
WJEC GCSE Physics (English candidates)	
Unit 1F	50
Unit 1H	350
CA	400
Unit 2F	50
Unit 2H	350
Unit 3F	50
Unit 3H	350

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