Consultation on GCSE science criteria for first teaching in 2011

An Institute of Physics response to the Qualifications and Curriculum Development Agency.

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The Institute welcomes the opportunity to submit a response to the QCDA consultation on the criteria for science GCSEs.

Our response highlights a number of the Institute’s concerns about the criteria and the way in which they have been developed without a clear rationale or reference to evidence.

Charles Tracy
Head of Education Pre-19
Background
The main purpose for this review of the GCSE criteria for science is to bring them into line with other GCSE criteria by:

- instigating 4 assessment units,
- introducing controlled assessment.

However, we feel that there are some unnecessary and arbitrary changes that have weakened the criteria and some missed opportunities.

Overview: Changes and opportunities
A. There is an opportunity for the criteria to address the criticisms in recent reports about lack of rigour in the assessment of:

- How Science Works (Ofqual report),
- mathematical skills and How Science Works (SCORE report).

The changes in these criteria appear to be an attempt to dilute the ‘problem’ of How Science Works rather than address the criticisms about its assessment.

B. There are also changes in these criteria without any obvious rationale; and they do not seem to be based on evidence or need. The result is a loss of guiding principles. We believe that the changes to the criteria should aim to:

- build on the 2006 curricula – and on identified successes within those curricula;
- further improve progression to AS and A-level sciences;
- provide continuity for teachers;
- be based on evidence.

We feel that the revised criteria do not take all of these aims into account.

C. We are concerned that some of the changes seem to have been made in response to public and media criticisms of existing specifications; in particular it appears that two of the central, related principles of the 2006 specifications – which arose from the Beyond 2000 report – have been tacitly sidelined. These are that:

- the content of the (Core) Science GCSE should be chosen to give all students access to a core of ideas about science (knowledge, understanding and skills);
- students should learn about and be assessed on How Science Works.

This is a shame. Where there have been criticisms of the principles, they have either been unfounded or they have been directed at assessment rather than content. There is no educational research to support significant modifications to How Science Works. QCA (now QCDA) held consultation meetings in the spring of 2009 and presented no evidence on the need for it to change.

D. There appear to be implicit changes to progression routes without a clear explanation of why these changes have been made. We do not want to see Science plus Additional Science lost as a route to A-level.

E. Finally, the implicit nature of some these changes is a concern. Too often, it is left to the reader to infer meaning or changes in policy. Throughout this response, we ask for clauses to be clear and principles to be explicit rather than implicit.
A. Rigour

Much of the criticism of the 2006 curricula has been aimed at the lack of rigour in exam questions. This has been particularly true in the assessment of How Science Works and mathematics.

How Science Works and its assessment

How Science Works has been undermined by trivial assessment (from some Awarding Bodies) and adverse media coverage. However, there is no evidence that the content has either put students off science or lowered standards. The proven problem is with assessment, not the content.

How Science Works is an important aspect of the 2006 GCSEs, preparing all young people with ideas about science. Teachers have taken on a lot of new ideas and developed teaching and learning resources to support it.

There is a sense that the new criteria have diluted some aspects of How Science Works. This sense is strengthened by the fact that the term ‘How Science Works’ is no longer being used.

1. Paragraph 6 in the Learning Outcomes appears to contain aims related to How Science Works. However, this is not made clear – we are left to infer it. We would like to see a statement about How Science Works in the head of paragraph 6.

2. There follow a number of statements in paragraph 10 which resemble the previous statements relating to How Science Works. However, the scope seems to have been reduced in these criteria. For example, risk and the nature of enquiry and evidence have been down graded.

We would like to see the statements relating to How Science Works strengthened and show continuity with existing GCSEs. We recommend that they relate to the 2001 Delphi study What should we teach about science.

3. We assume that paragraph 10 will be assessed by written papers and paragraph 11 will be assessed by controlled assessment. If this is the case, it should be stated clearly in the criteria.

And, if it is the case, we have some further concerns.

4. The first concern is that How Science Works will be assessed only by written papers. Although, in the current GCSEs, there have been some difficulties in some specifications with assessing How Science Works through internal assessment, there have been some successful schemes. The new criteria should be based on what has been shown to work. It ought to be possible for Awarding Bodies to develop engaging and effective tasks to assess How Science Works – as well as it being assessed through written papers.

5. Our second concern is that paragraph 11 looks very similar to the old Sc1 assessment. It will be essential that Awarding Bodies set interesting and engaging tasks for the controlled assessments.

Mathematics and its assessment

6. Mathematics is the language of science. In line with the SCORE report, we would like to see more, and higher level, mathematics in physics questions in all of the science GCSEs in higher tier papers.
7. The mathematical content should include relationships, an understanding of their origin and meaning, and the ability to manipulate them. As they stand, the criteria do not make clear what mathematical skills are expected; and the reader is left to infer a number of relationships (for example momentum – see 33 below). The criteria should make these requirements explicit and clear. This clarity of expectation will help ensure that the mathematics appears in specifications and is tested in the exams.

8. Currently, it is not clear where the mathematics is assessed. It appears in paragraph 6 but there is nothing about mathematical manipulation in paragraph 10. Also, it is not stated what weighting is given to mathematics in paragraph 12. This assessment objective should be clarified.

B. Building on success

9. The new (2006) GCSE courses (or some of them) seem to have worked at engaging students in science – there has been an overall 10% increase in AS level uptake for the first cohort who began in 2008. Whilst there has been some criticism (mainly media but also from teachers) about a loss of rigour, this can be addressed without throwing the baby out with the bath water. Much of the criticism is about assessment – the setting of trivial exam questions. We believe it is possible to retain the engagement and improve the rigour.

10. There is an issue with the timing of the revision. It does seem a little reckless to be making changes to philosophy, content and the wording of statements before students who sat the new (2006) GCSEs have passed through to A-level (or even AS at the time of the first consultation meetings).

Since those meetings, there is evidence that the 2006 GCSEs have been successful in engaging students. AS level numbers have risen by 10% and research from the university of York suggests that schools that offered the Twenty First Century Science courses saw a 30% increase in AS level numbers.

The new criteria should build on successes in the 2006 specifications. This needs further investigation. QCDA should collect and examine evidence of 2006 courses that have been successful in engaging students and encouraging progression to AS and, next year, A-level. They should use evidence of success in the development of the new criteria.

C. Relationship between the GCSEs

The relationship between the GCSEs in Science, Additional Science and the separate sciences is not clear in the draft subject criteria. There does not seem to be a rationale for the differences in content. The consultation criteria make the three routes look like science, more science and yet more science.

The 2006 Core Science GCSE is built around content that will provide a useful grounding for all students in the sciences and ideas about science. This guiding principle seems to have been lost in the new criteria. Neither is it stated nor does the choice of content reflect such a principle.

11. It should be made clear what the differences are between Science and Additional Science.

12. We would like to see the content of Science chosen so that it exposes and educates all young people in the ideas about science that they will need as citizens. And for this to be stated in paragraph 5.
For example, ionising radiations and half lives should be in Science (it is an idea about science with which everyone should be familiar).

13. There is a sense that Additional Science has the more difficult ideas than Science rather than content being chosen as above. The difficulty of the content should be the same across the different GCSEs. More difficult content should be separated by tiering rather than by being in a different course.

In the example of half lives, the appropriate place to teach is in Science; but the more advanced, mathematical treatment would be in the higher tier only.

14. Currently there are equivalent statements in Physics and Additional Science that are worded differently (see, for example, 29 and 30 below). For nested qualification, the statements must be identical in wording.

15. Currently, there are two extra statements in Physics (as well as the different wordings of some statements). This contributes to the implication that Physics provides a different progression route to Science plus Additional Science.

The criteria for Physics GCSE should be equivalent to the amalgamation of the physics criteria in Science plus those in Additional Science. The Physics GCSE criteria should state that it is up to the Awarding Bodies to add additional coherent content.

This would be similar to the way in which the criteria for Additional Applied Science do not specify any content, allowing Awarding Bodies to develop appropriate content in detail.

D. Progression

16. There is an implication that Physics GCSE might become the preferred route to AS and A-level. We can infer this from the extra bullet points in paragraph 10 of the Physics criteria and the different wording of paragraph 6 in Additional Science and Physics.

The implication is strengthened further by the wording of question 3b on the questionnaire which refers to “. . . further study in physics” for Physics GCSE and “. . . further study in science” for Additional Science. We are not even asked on the questionnaire whether Additional Science would be suitable for further study in physics (or chemistry or biology).

17. Furthermore, the Institute would be opposed to such a change in policy. We welcome the identity given to physics and the opportunity given to students by the separate science GCSEs. However, it would be regrettable if it became the only route to further study in physics; this would reduce the pool of candidates and would be likely to lead to a reduction A-level numbers; it would also leave Science plus Additional Science as a dead end.

We would like the statement in paragraph 5 of the criteria for Additional Science to make it clear that it is a route to further study in physics (and the other sciences).
Specific statements of content

Science

Paragraph 5.

18. There should be a statement that one of the aims of the Science course is that it familiarises students with ideas about science and allows them, as a citizen, to engage, in an informed way, with scientific and technological issues and debate.

19. There should also be specific mention of How Science Works – this is a term with which teachers have become familiar and there is no evidence to suggest it should be removed.

Paragraph 10.

20. Radiation and radioactivity should be in Science. Certainly there will be issues of tiering – numerical analysis is likely to be higher tier. However, an understanding of the issues about ionising radiation, including half-life, is something that we would expect all students to have.

Given that ionising radiations are in the Key Stage 4 Programme of Study, they ought to be in the Science GCSE criteria.

21. Bullet 10 expects knowledge and understanding of the generation of electricity. Are we to assume that electromagnetism is in Science? This statement seems to have more content than existing GCSEs. The principle for including content in Science is that it is an idea that we want all 16 year olds to be familiar with. Efficiency & power are important ideas as are methods of generation – so these should be in Science. However, an understanding of electromagnetism and the how generators work are not; they are more appropriate in Additional Science.

22. Bullet 11 The distinction between transverse and longitudinal waves are not a central idea about science. Bullet 11 would be better if it were about radiation and waves rather than the properties of waves.

23. Bullet 22. The statement on risk is bland. It looks like it might apply solely to a school practical – the phrase ‘risk assessment’ is usually applied in a laboratory context. This statement should be much broader and stronger and include the identification and analysis of risks on a larger scale (e.g. nuclear power plants or mobile phones); risk should be a conceptual tool and students should be able to reason about risk.

The statement should also say something about balancing risk with benefit.

Paragraph 11.

24. We assume that paragraph 11 is the content for controlled assessment. If so, this should be stated.

25. The statements should be based on paragraph 5. Currently, a number of the How Science Works learning outcomes are not being assessed in paragraph 11. This implies that they will be assessed solely by written papers (or not at all). It would be preferable to assess some aspects of How Science Works through controlled assessment, building on successful assessment schemes of the current GCSEs. This is because there is a real danger of examiners being able to set only trivial question about some aspects of How Science Works.

26. Bullet 2. Students of Science GCSE probably do not need to plan an investigation.
Additional Science

Paragraph 5
27. There is an implication here that Additional Science is not a route to further study in physics: “. . . decisions about further study in science and related subjects.” The equivalent statement in Physics GCSE refers to physics. To avoid ambiguity and prevent this ambiguity becoming policy, the Additional Science statement should mention progression to physics (and chemistry and biology).

Paragraph 10.
There are a number of statements here which are not consistent with Physics GCSE. The statements in Additional Science should be worded in exactly the same way as the equivalent statement in Physics GCSE.

28. Bullet 7. The phrase “The relationship between work and energy” makes little sense. The relationship between work, force and distance would be more useful. The closest equivalent statement in Physics GCSE is “the relationship between power, energy and time”. We suggest that both Additional Science and Physics have these two statements:
   • The relationship between work, force and distance; how to carry out calculations using changes in gravitational potential energy & kinetic energy.
   • The relationship between energy, power and time.

29. Bullet 9 about Newton’s laws is different from the equivalent bullet in Physics GCSE (which is better). A one dimensional treatment is enough at GCSE.

30. The three bullets on radioactivity should be in Science and not Additional Science. Particularly bullet 11, which is in the Programme of Study for KS4.

31. There are two additional statements in the Physics GCSE – bullet 3 on the kinetic theory and bullet 9 on wave properties. These should be in Additional Science as well.

32. Longitudinal and transverse should go in Additional Science rather than Science.

33. Bullet 9 is an example of ambiguity about mathematical relationships. What is expected for momentum? \( p=mv \), conservation of momentum, \( \Delta p=Ft \)? And what mathematical treatments are expected? This should be made clear for this relationship and all mathematical relationships.

34. There is an opportunity to address some of the criticisms about rigour by specifying mathematical content. We would like to see a statement about mathematical skills:
   • Use mathematical manipulations to solve multi-step problems and make predictions.

Physics

Paragraphs 10 and 11
35. The statements for physics should be the aggregation of statements of Science and Additional Science. There should not be any supplementary criteria for Physics. Instead, there should be a requirement that Awarding Bodies develop additional coherent content.

36. For any given statement the wording should be identical to the equivalent statement in Science or Additional Science.