AQA
Realising potential

Focus on success: GCSE science

Maths in science

Build on your students' assessment performance using our self-guided, modular training pack

Pre-reading booklet

Contents

Using this resource

This pack is designed to help you deliver a CPD session on maths in science for your teaching colleagues. It has more activities than previous ones as we wanted to put together all the information that we have gathered over the last few years on maths in science. We have included the materials from a number of previous hub meetings, adding to them to create a useful training resource for you and your colleagues.

For this session, we strongly recommend you meet with a representative for your maths department and, if possible, run this training with your maths department as a collaborative event.

Using the completed pre-session questionnaires and provided route map, you'll be able to design a bespoke session to focus learning on the areas your colleagues are less confident teaching.

There's a lot of information in this pack, so we would advise you to:

- run this as a **number of short** sessions over a **number of training dates**
- **invite your maths department** to the sessions and see this as a collaborative project to improve teaching and learning of maths across the curriculum
- **meet with a representative of the maths department before** you start the training to discuss key elements of this collaborative working. We've designed a **short questionnaire** to support this conversation which will help you to gather the various documents you need to ensure the training session is as effective as possible.

The activities in the pack will help you and your colleagues to:

- establish the level of confidence your teachers have at delivering maths in science
- identify any areas of weakness your teachers and students feel they have with maths in science
- appreciate the different ways students learn the same skills in maths and science
- explore how diagnostic questions may help identify weaknesses quickly
- understand how to apply the mark scheme for calculation consistently
- be familiar with assessment principles at different levels of demand.

Before the session

- Meet with a representative of **the maths department** to discuss key elements using the *Maths department pre-session discussion* on page 15 of this booklet.
- Ask your science colleagues to each complete the *Pre-session questionnaire* on page 16 of this booklet.
- Use the responses to the *Pre-session questionnaire* to tailor the training session to the needs of your colleagues. The *Route map* on page 10 will help you plan which activities to use in the session.
- You'll need **electronic copies of your schemes of work, copies of the science curriculum map and, if possible, the maths curriculum map, both showing terms/year when topics are taught**.
- Ensure each colleague has a copy of the *Activities booklet*. Pre- and Post-session questionnaires will need to be photocopied in advance.

Running the session

- Establish why there is a need to see this as a collaborative project between maths and science departments.
- Establish that the aim of maths in science is not for science students to master all that is required at GCSE Maths, rather that they are competent at particular aspects of common maths skills that scientists use in order to carry out their scientific work.
- The PowerPoint presentation will provide guidance and discussion questions to move you through your bespoke session.

After the session

- Ask your colleagues to each complete the *Post-session questionnaire* (page 17 in this booklet) to ensure the training has been successful and to identify your department's next steps. You'll need to prioritise particular areas as it is impossible to do everything.
- As a group, discuss how you can support each other to embed the learning from this training into your teaching. Use the prompt questions on slide 25 of the PowerPoint presentation to guide your discussion.
- Complete the action plan templates on pages 85-86 in the Appendix.

Summary of activities

Collaboration with your maths department

- Throughout this training module, reference will be made to involving your maths department in the activities, discussions and resource sharing.
- We strongly recommend that the person leading this training meets with a colleague from the maths department prior to the training to discuss the proposed activities. We've provided some suggested questions to help structure that initial meeting which can be found on page 15 of this booklet.
- After this initial meeting, it would be beneficial to involve colleagues from your maths department in the activities and discussions. It's important that the maths and science departments discuss ways to work effectively together, to enhance the learning experience for students and to improve the teaching and delivery of maths skills across subjects.
- Having some concrete collaborative goals between the two departments will help enable these developments to be realised.

For each of the activities below, there is further background reading for the presenter on pages 11–14.

Regulatory requirements

- Slide 3 of the PowerPoint sets out the DfE regulatory requirements of the maths skills. More detailed background notes are available for the presenter on page 11.
- Discuss with your departments the importance of knowing what tier their students are working at in GCSE Maths.

Audit of maths skills

The audit of maths skills has three parts:

- teachers confidence to teach the skills to different ability groups
- departments perception of student weaknesses
- *Student maths skills audit* of their own weaknesses and areas they need to develop.

If you are going to use the insight from the *Student maths skills audit*, you will need to organise this prior to the support session. It can be found as a separate document within this pack.

Activity 1a and 1b: *Teacher audit*

It's important to know how confident different members of the department are in teaching the various maths skills to different groups of students. Support in new teaching approaches may be needed for some of the skills. Your maths department, along with members of your own department, will be equipped to do this so creating a support programme to meet these needs could be a priority.

- **Individually** consider each maths skill using the table on page 5 of the *Activities booklet*.
- Answer the following questions for each skill:
  - how confident are you in teaching the underlying principles?
  - could you differentiate your approach to teaching this skill to different ability groups?
  - share your thoughts with the group.
- **As a group**, identify which maths skills your students find challenging. If you have insight from the *Student maths skills audit,* include this in the discussion.
- You may want to do this for three broad ability groups to help focus future intervention work.
- Slides 7 and 8 list aspects of maths skills that have caused students issues in recent exams which may be of use in the discussion.

Maths and science

Teachers have shared examples with us of where they have experienced differences with the way maths and science teachers either teach or assess certain skills. For each of these differences, we have given an example from our exam papers, to act as a prompt for the discussion.

Activity 2: Differences between maths and science departments

For each of the examples on pages 6–10 of the *Activities booklet* discuss:

- approaches and language used with students to help them access this type of question
- how this approach and language might be different in maths lessons
- whether there are any other skills that have different approaches or language used between the two departments
- how differences could be resolved.

Slide 12 summarises some of the differences in teaching approaches between maths and science that we are aware of. This list is not exhaustive and you might not have these differences in your school.

Diagnostic questions and misconceptions

Even within the same school, students will come to lessons with different levels of knowledge and some ingrained misconceptions. Activity 3 looks at how you might use diagnostic questions as a quick way to identify each student's strengths and weaknesses. The examples given are based on edited exam questions. The activity provides an opportunity for staff to consider some common misconceptions around maths skills that may impact on students' learning.

Activity 3

- As a group, look at the two examples of diagnostic questions on pages 11–16 of the *Activities booklet*.
- Discuss if you think this approach might be helpful as a starting point to gauge each student's level of competency for a particular skill.
- Using the Physics question on momentum, edit the question so it could be used to quickly assess students' ability to tackle equations generally, rather than assess understanding of momentum.
- Discuss if there are any other maths skills you could incorporate into the equation question.
- As a group, familiarise yourselves with some of the common misconceptions and errors we have seen in *Misconceptions and common errors* table found on pages 18–21 of the *Activities booklet*.
- Discuss what strategies you could use to help address these common misconceptions.
- The *Diagnostic question examples* table found in the Appendix lists other suggested questions from 2018 that might be useful to edit as diagnostic questions.

Curriculum planning

The teaching order of maths skills won't necessarily be the same in maths and science because of differences in the curricula. It's not always possible, or desirable, to change the teaching order for either subject. This may mean that science teachers need to teach or develop a particular maths skill to their group before it is taught in maths. Having a good awareness of the different timings will help teachers plan the teaching of the maths skills at the appropriate level.

It's important to remember that all the skills are introduced at KS3; though a student may not have mastered them to the required level for the start of GCSE, they should at least be familiar with the concepts.

This activity, in particular, requires a pre-meeting with the maths department and, if possible, their attendance at the session.

Activity 4

- **Ideally** use your own school's maths and science curriculum route maps for this activity. If your school doesn't have curriculum route maps, we've included generic AQA examples for maths and science in the additional PowerPoint, *Editable curriculum route maps*. These can be easily edited to reflect the teaching at your school prior to this session.
- Compare the maps and then annotate your science curriculum plan for each maths skill to show if science teachers need to teach the skill first because it is not already covered in maths.
- Discuss any timing issues.
- Refer to your electronic SOW and review the lessons where the maths opportunities first arise. See if they are appropriate now you have this timing knowledge.
- While you are doing this, consider the questions below.
    - Am I teaching this for the first time building on KS3 knowledge?
    - Am I revising the skill with students building on their experience in maths GCSE?
    - Am I embedding the skills introduced earlier in a different science topic?
- If there's time, review the SOW to see if there are any more good opportunities you can add.

Applying a mark scheme

AQA apply a consistent approach to marking calculations across all science awards.

- Calculations are laid out in the mark scheme in the sequence of steps that the examiners feel is the logical approach. However, examiners will mark the whole response and give appropriate credit regardless of how the student has laid out their answer.
- Each step in the calculation that gains a mark is shown, with alternative acceptable approaches in the second column.
- Mark points where compensation marks can be gained for a previous mathematical error are highlighted in the second column.

Activity 5

Please note that the example student responses used in this section have been re-written for copyright purposes

- Look at the examples on pages 23–40 of the *Activities booklet*.
- Using the mark scheme provided, mark the student responses showing where you award each marking point.
- Discuss with the group where the marks were awarded and address any misconceptions teachers may have about how calculations are awarded marks.
- Compare your marking to the examiner reports and commentaries for Activity 5 found in the Appendix.

Assessment principles

Becoming familiar with the assessment design principles for key maths skills at each level of demand will help differentiation, support concrete learning of the skill at the appropriate level and encourage students to progress to the next level of demand.

Activity 6

- For each of the following skill areas, work through pages 42–70 in the *Activities booklet.*
    - Using expressions in standard form
    - Using an appropriate number of significant figures
    - Graphing skills
    - Equations

- Familiarise yourselves with each skill's assessment design principles and typical exam requirement for each level of demand. These are set out in the *Activities booklet*.
- Mark the student responses and discuss:
  - what level of demand the question is and why
  - what the common errors are
  - what possible strategies you could use with the students to overcome them.
- Having completed all the skill areas, think about each of your different teaching sets. Discuss what the appropriate learning would be for them to ensure concrete learning and progression.

Maths in science route map

Area for development

Pre-session meeting with Maths lead

Audit of Maths skills:
Are all members of the department confident at teaching all the maths skills?

Activity 1a:
Individual audit to gauge teacher confidence in:
- teaching the skills
- differentiating this teaching for different ability groups'

Activity 1b:
Students audit their own performance in each maths skill

Handout:
Student maths skills audit

Group discussion:
Discuss if there are any common themes between:
a. what teachers find difficult to teach
b. what students in different ability groups find challenging.

Maths and science:
Have you worked collaboratively with your maths dept to develop consistent approaches to T&L of maths skills?

Activity 2:
Discuss T&L approaches used in maths and science of key areas for possible differences

Group discussion:
Are there any common ways forward to a more consistent approach?

Diagnostic questions:
Do your teachers have a quick and easy way of assessing strengths and weaknesses of students' maths skills?

Activity 3:
Using and developing diagnostic questions to identify strengths and weaknesses

Group discussion:
How might the use of diagnostic questions help to identify basic errors?

Curriculum Planning:
Have the maths and science departments compared their timings of when skills are introduced and developed?

Activity 4:
Using both departments' curriculum maps, identify timings for teaching maths skills

Handout:
Curriculum route maps
Electronic science SOW

Discuss:
Are current lessons focusing on maths skills still set at the appropriate level?

Applying a mark scheme:
Does your department apply the mark scheme consistently when marking calculations?

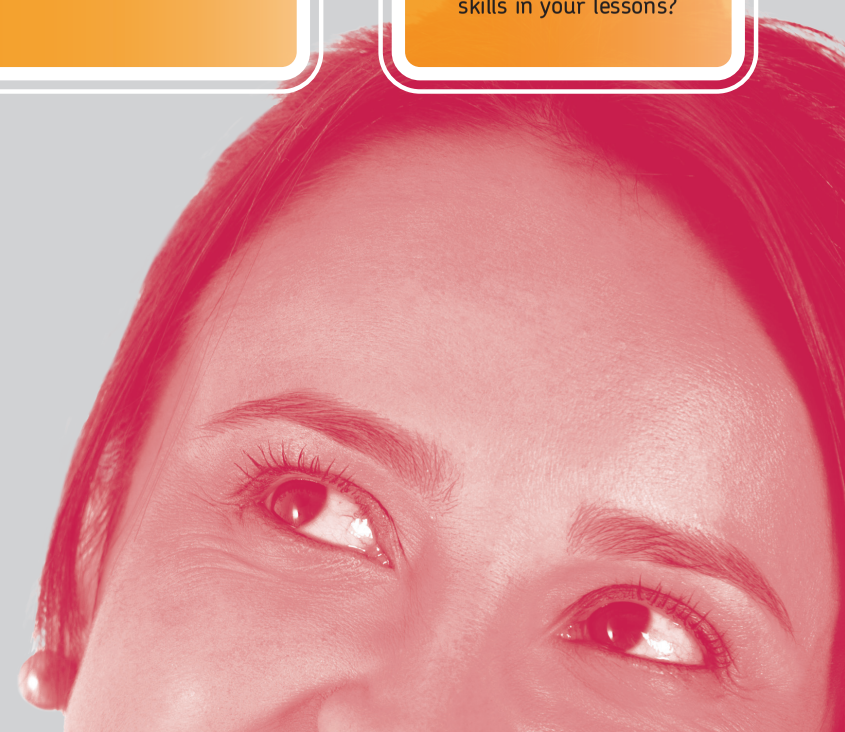
Activity 5:
Mark student responses to ensure the mark scheme is being consistently applied

Discuss:
Is everybody confident at applying the mark scheme consistently?

Assessment principles:
Are teachers familiar with the progression in skill levels for certain maths skills?

Activity 6:
Familiarising and applying the design principles to student responses to understand requirements at different levels of demand

Discuss:
How can you use the assessment design principles to plan for progression of maths skills in your lessons?



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Essential background information

Regulatory requirements and level of demand

Maths skills have always been assessed in science GCSEs, but not to the extent as they are in the reformed GCSEs. The regulatory requirements are set out in the DfE subject criteria document, *GCSE Subject Level Conditions and Requirements for Combined Science*. The mathematical skills required by the students are listed in **Section 9** of all the science specifications. A small number of the skills are specific to either one or two of the sciences; this is clearly shown in the specification. However, as the majority of students will be following all three sciences, from a teaching and learning point of view they will need to be able to apply all of the skills.
The assessment of maths skills account for the following minimum percentage of marks:

- GCSE Biology 10%
- GCSE Chemistry 20%
- GCSE Physics 30%
- GCSE Combined Science 20% (ratio of 1:2:3)

We don't specify numbers of marks to any one maths skill and we also don't allocate large numbers of marks to any one of the skills as we don't want to over-assess one skill to the detriment of others. All the criteria for a specification have to be assessed over the lifetime of the specification, at all levels of demand.

The DfE states that questions targeting maths skills should be at a level of demand appropriate to each subject. In respect of assessments for the **foundation tier,** the level of demand should **not be lower** than that which is expected of learners at **Key Stage 3**, as outlined in the *Mathematics programmes of study: key stage 3*.
In respect of assessments for the **higher tier,** the level of demand should **not be lower** than that of questions and tasks in assessments for the **foundation tier** in a GCSE Qualification in Mathematics. (© *GCSE Subject Level Conditions and Requirements for Combined Science*. OfQual. Reproduced under the Open Government Licence V3.0.)

It's worth pointing out here that, because of the **30% common question** on each tier, there may be maths questions set at GCSE Maths foundation standard on the science foundation tier paper. In theory, this shouldn't be an issue, as all students will be following GCSE Maths. If they are operating at grades 4 -5 in science, you would no doubt expect them to be competent at foundation GCSE Maths skills. However, as teachers know, once knowledge and understanding is put in a context it raises the challenge for students. This, coupled with the issue students have of transferring skills from one subject to another, may mean that maths skills assessed on the common questions might pose problems to some students.

Cross curricular approaches and language

Everyone agrees that a consistent approach and use of language between the maths department and the science department would help students with maths questions. The ASE *The Language of Mathematics in Science: A Guide for Teachers of 11-16 Science* document is an excellent source. Some common differences in approach and language schools have shared with us are in the teaching of:

- graphs
- using (applying) formulas/equations
- calculating percentages
- calculating percentage change.

By collaborating with your maths colleagues in Activity 2, you'll be able to discuss these differences and ways forward. In some cases, it may not be possible to have a common approach, in which case agreeing to illustrate the differences with students may be the best answer. At least then students are aware of the differences and will do the appropriate thing in each subject.

Diagnostic questions and levels of prior learning

Students will have been introduced to the vast majority of the maths skills needed at GCSE science in KS3, however their experience and their level of understanding will vary even within the same class. This variation may be challenging to identify. Teachers need a quick way to gauge the level of knowledge and understanding of that skill for each of their students. Using a diagnostic question as a starter activity may be a useful starting point. Selecting, amending and using this question needs some care as it needs to focus on the maths skill rather than the science. This is not attempting to be a maths lesson, more a way of finding out what your students starting point is. Some suggested questions, taken from 2018, are shown in the *Diagnostic questions examples* table in the Appendix of the *Activities booklet.* Word versions of the questions can be found on *Exampro* using the search tool so you can tailor questions to meet your own needs.
Students will also arrive to their science lessons with some well-established maths misconceptions which teachers won't necessarily be familiar with. Exploring these with your maths colleagues will help you gain a better understand of some of your learners' difficulties with maths.

Curriculum planning

The timing of when science teachers want students to understand and apply the maths skills will not necessarily match with when the maths department cover them. This may result with science teachers having to teach or develop the maths skill to their group before it's taught in maths. It's not always possible or desirable to change teaching orders for either subject. Being aware of any differences will help teachers plan appropriate lessons when maths skills are being incorporated into them. It's important to remember that all the skills are introduced at KS3; even if students haven't mastered them to the right level, they should at least be familiar with the concepts. In order to make this activity as useful as possible, it's highly desirable to do it in collaboration with your maths department, to have held a pre-meeting with the maths lead to discuss this, and to look at each department's curriculum plan.

We've included a separate PowerPoint in this pack that has an AQA mymaths, editable curriculum route map and one we have made for combined science.
Topic lengths and order can easily be adjusted to match your school's route through the specification. You'll need to have identified which topics are most suitable to introduce each maths skill prior to the meeting. During the activity, you'll be able to consider if your teaching approach for each skill is at the correct level to reflect students' experience in maths.

Applying a mark scheme for calculations

AQA apply a consistent approach to marking calculations across all science awards. However, it has become apparent that there are a number of misconceptions around how calculations are marked. Below are the key points that may need to be clarified with your teacher.

- The mark scheme sets out the most common approach to the calculation, but any correct method will gain credit.
- Examiners will mark the whole response and give appropriate credit regardless of how the student has laid out their answer.
- The mark scheme shows where marks are awarded for each different step of the calculation. However, if a student doesn't write down each step but has clearly gone through that step, they will still be given the mark. For instance, the mark scheme may show a mark for substitution, a mark for rearrangement and a mark for the calculation. Using V = I × R as an example, the mark scheme shows substitution given the numbers 40 = I × 230, then rearrange to give I = 40/230 and then calculate I as x. If a student misses the first step and simply shows I = 40/230, they have clearly done the first step and would gain that mark even though they haven't written it down. Similarly, in a chemistry calculation where the first step in the mark scheme is to calculate the Mr then use that value in a further calculation, if the student is clearly using the correctly calculated Mr in their calculation, the fact that they haven't written it down would not stop them from getting the mark for it.
- It's really important to encourage students to show their working out as there may be compensation marks for the correct use of incorrectly calculated numbers. The mark scheme clearly shows marking points where **compensatory marks** can be gained in these instances. The significant figure mark is one example: in this case, it will only be given if the examiner can see the number is relevant to the calculation, not just randomly generated.
- 'Error carried forward'(ecf) applies to calculations only and is awarded for correct use in a calculation of a number incorrectly calculated from a previous question.
- If the student just writes the correct answer and shows no working they will be awarded full marks.
- When rearranging equations, students can either rearrange or substitute first, as long as it is correct. AQA mark schemes follow our convention of substitution then rearrangement but either way, if **correct**, will gain the marks. If a student rearranges incorrectly, then substitutes values into the incorrect equation, they won't get any marks. This is because we can't credit incorrect recall of the equation, which is what the rearranged equation is without any numbers in it
- It appears that students often miss or forget the instruction stated earlier in the question to express their answer in standard form, so from Summer 2020 it will be repeated on the answer line to remind them. For example:

  Acceleration (in standard form) = _____

- This was a similar case for significant figures, so from Summer 2020 it will be repeated on the answer line to remind them. For example:

  Acceleration (2 significant figures) = _____

Understanding assessment principles

These materials are taken from the summer 2020 science hub meetings, but we have replaced the questions and student responses with 2018 examples. Some of you colleagues may be familiar with these ideas. However we felt this was a valuable resource which needs to be shared widely and teachers can benefit from revisiting this material. By being familiar with the design principles for key maths skills at each level of demand, it will help teachers differentiate their teaching and learning, while also encouraging progression to accessing the next level of demand for all students. Having a concrete understanding of what is required at the level a student is working at is essential to ensure students are confident when going into the exam. Yet it is also important to be aspirational and encourage students to strive to the next level, as they often surprise us with their performance.

For each of the skills we have looked at, there is a series of bullet points outlining the key design principles for each level of demand. There is then a very useful progression table identifying the requirements of what the examiner might expect a student to do at each level of demand. A number of student responses are provided for teachers to mark, discuss key challenges students have, and see the design principles being applied. There are more examples in the original hub materials which use 2019 questions. These can be found on e-AQA under *Teacher support materials* for each science subject.

It's not possible to provide progression maps for all skills as the change in level of demand for some just involves more complex numbers or the context it is set in, for example the skills of calculating a mean (2b) or calculating areas of triangles and rectangles (5c).

Maths department pre-session discussion

The questionnaire below offers some suggested areas you might want to talk to the maths lead about during this meeting. Discuss each of the questions below and collect the relevant documents prior to your training session .

Questions to ask	Notes and department documents needed for the initial meeting
Would the maths department be prepared to offer training to science teachers on teaching approaches and student learning strategies based on the outcome of the teacher and student audits?	Share maths requirements section 9 of science specification
What differences does the maths department think exist in teaching and learning approaches and language used in science and maths lessons?	Suggested areas may include: • graphs – lines of best fit • using (applying) formulas/equations • calculating percentages • calculating percentage change This will be further explored in Activity 2 during the training.
When are each of the science maths skills taught at GCSE? Does the maths and science department have curriculum maps showing which term/Year each of the relevant maths skills are taught to students? Can you identify from these which maths skills a science teacher may have to introduce and teach to students for the first time since KS3?	Share the maths and science curriculum maps. This will be further explored in Activity 4 during the training.
Have the maths department seen examples of the maths questions used in science exams?	
Would the maths department like to join the science training to input in the sessions?	Input would be beneficial in each session • Activity 1 Audit of maths skills • Activity 2 Differences between maths and science • Activity 3 Using diagnostic questions • Activity 4 Timing of maths skills • Activity 5 Marking maths calculations • Activity 6 Assessment principles of different levels of demand

Pre-session questionnaire

Grade the area of development statements according to your confidence where 0 is not confident at all and 5 is very confident.

Hand back to your Head of Department.

Area of development	Grading 0-5	Reasons/notes/previous training
I know what the maths skills are that my students need to know and I am confident introducing and developing these skills with different ability groups.		
I know which maths skills my students feel they are struggling with.		
I have a strategy to quickly assess what level my students are at for each math skill.		
I am aware of common misconceptions students may have around different maths skills.		
I know when my students cover the maths skill for the first time in their maths lessons.		
I am aware of some of the differences that exist between the way science approach certain maths skills and how the maths departments do, and the different language we both use to describe the same thing.		
I can consistently apply a mark scheme and understand the marking principle applied to calculations.		
I understand the design principles AQA applies to differentiate levels of demand in maths skills and use these to plan my lessons to support progression.		

Post-session questionnaire

Grade the area of development statements according to your confidence where 0 is not confident at all and 5 is very confident.

Area of development	Grading 0-5	Reasons/notes
I know what the maths skills from the teacher audit.		
I know what maths skills my students find challenging from the S*tudent maths skills audit*.		
I am confident introducing and developing these skills with different ability groups.		
I am aware of some of the differences that exist between the way science approach certain maths skills and how the maths departments do, and the different language we both use to describe the same thing.		
I have a strategy to quickly assess what level my students are at for each math skill.		
I am aware of common misconceptions students may have around different maths skills.		
I know when my students cover the maths skill for the first time in their maths lessons.		
I can consistently apply a mark scheme and understand the marking principle applied to calculations.		
I understand the design principles AQA applies to differentiate levels of demand in maths skills and use these to plan my lessons to support progression.		

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