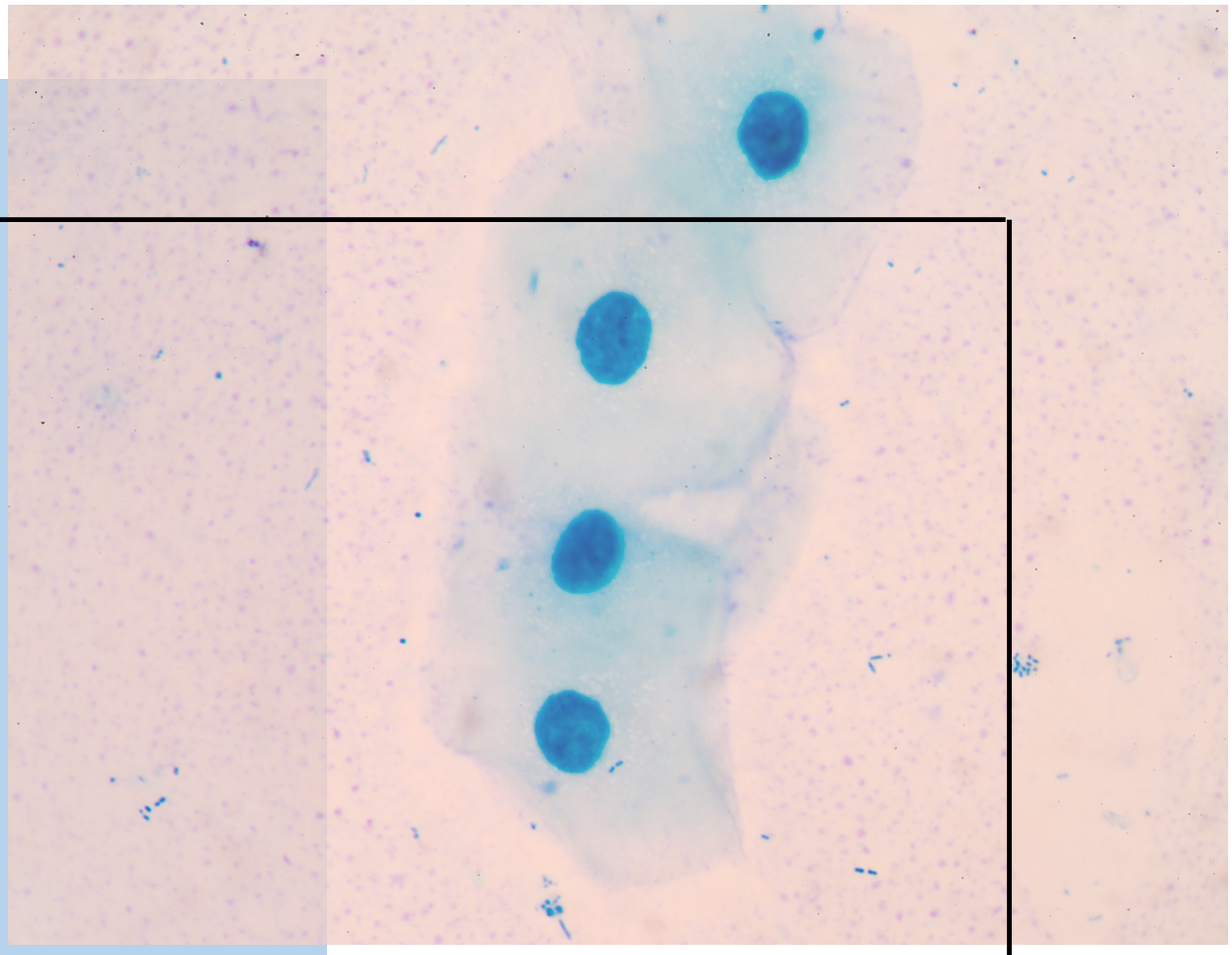

Science Mastery and the OFSTED science research review

Science
Mastery

On 29th April 2021 OFSTED published their science research review which explored the research relating to the field of science education. Its purpose is to identify factors that can contribute to high-quality school science curriculums, assessment, pedagogy and systems. In its conclusion, this review detailed key principles that play a central role in influencing many aspects of science education that lay the foundation for subject quality.

In this document, we will outline the key features of high quality science education as identified in the OFSTED science research review, and show how these are exemplified through the Science Mastery curriculum programme.

1. Curriculum Progression: What it means to get better at science.

The research says that high quality science education has the following features:

- The curriculum is planned to build increasingly sophisticated knowledge of the products (substantive knowledge) and practices (disciplinary knowledge) of science.
- Disciplinary knowledge (identified in the 'working scientifically' sections of the national curriculum) comprises knowledge of concepts as well as procedures.
- When pupils develop their disciplinary knowledge, they learn about the diverse ways that science generates and grows knowledge through scientific enquiry. This is not reduced to a single scientific method or taken to mean just data collection.
- The curriculum outlines how disciplinary knowledge advances over time and teaches pupils about the similarities and differences between each science.
- Pupils are not expected to acquire disciplinary knowledge simply as a by-product of taking part in practical activities. Disciplinary knowledge is taught.
- Scientific processes such as observation, classification or identifying variables are always taught in relation to specific substantive knowledge. They are not seen as generalisable skills.

How does Science Mastery exemplify these features?

- The curriculum framework outlines in detail the substantive and disciplinary knowledge that students will be taught in each unit.
- Substantive knowledge is mapped as a series of detailed knowledge statements which build on the National Curriculum.
- The Science Mastery curriculum is organised under 14 'big ideas' of science (Harlen, 2010, 2015). This allows pupils to make links between topics, building ideas into a coherent picture of how the world works. Presenting new information under the umbrella of a familiar 'big idea' helps pupils to recognise the connectedness of science, and also how each new topic connects to everyday life and familiar contexts. This approach allows for the planned interleaving of prior learning with new learning in a meaningful way.
- The disciplinary knowledge aspect of the Science Mastery curriculum is comprised of 100 practical, enquiry and mathematics skills.
- Disciplinary knowledge is mapped carefully over 5 years, ensuring that students experience each skill numerous times, within a variety of contexts and across subjects. Disciplinary knowledge is always taught alongside relevant substantive knowledge.
- Disciplinary knowledge is taught explicitly, with opportunities to practise and apply these skills in relevant contexts, and with a focus on developing students' competency over time.
- Disciplinary skills are divided into four categories; 'Think Like a Scientist', 'Skills of Science', 'Analysis, Data evaluation and Mathematics', and 'Units and Quantities'.

2. Organising knowledge within the subject curriculum

The research says that high quality science education has the following features:

- In the early years, pupils are introduced to a wide-ranging vocabulary that categorises and describes the natural world. These words are not too technical but provide the 'seeds' for developing scientific concepts that will be built on in later years.
- Attainment targets, specification points and early learning goals are broken down into their component knowledge.
- Substantive knowledge is sequenced so that pupils build their knowledge of important concepts such as photosynthesis, magnetism and substance throughout their time at school.
- Knowledge is sequenced to make the deep structure of the scientific disciplines explicit. This allows teachers and pupils to see how knowledge is connected.
- Disciplinary knowledge is sequenced to take account of:
- its hierarchical structure
- the best substantive contexts in which to teach it.
- Once disciplinary knowledge is introduced, it is used and developed in a range of different substantive contexts.
- Planning for progression takes account of what is taught in other subjects. For example, the science curriculum should be coherent with what is taught in mathematics. Where there are differences, these are made explicit to pupils and teachers.

How does Science Mastery exemplify these features?

- Pupils are introduced to a wide-ranging vocabulary that builds in complexity and specificity over time, with the support of student glossaries and key words for each lesson.
- Precise knowledge points are defined for each unit, and these are further broken down by lesson. Each lesson has clearly defined learning objectives.
- Substantive knowledge is sequenced under 'big ideas' of science (Harlen, 2010, 2015). This allows pupils to make links between topics, build ideas into a coherent picture of how the world works, recognise the connectedness of science, and also how each new topic connects to everyday life and familiar contexts. Key components of each big idea (e.g. photosynthesis, chemical reactions, forces) are developed cumulatively over 5 years, with an increased linking of ideas from across topics and subjects.
- Prior knowledge is interleaved with new learning in a meaningful way, for example within 'Do Now' activities and opportunities for retrieval practise.
- Disciplinary knowledge is mapped carefully over 5 years, with opportunities to practise and apply these skills in relevant contexts, and with a focus on developing students' competency over time.
- Our Maths in Science resources are written in collaboration with Maths teachers to ensure consistency of language, methods and representation of concepts. Asynchronous PD for teachers supports high quality teaching of Maths in Science.

3. Other curricular considerations

The research says that high quality science education has the following features:

- Sufficient curriculum time is allocated for pupils to embed what they have learned in long-term memory through extensive practice before moving on to new content.
- The component knowledge pupils need in order to read, write, represent and talk science is identified and sequenced.
- Curriculum plans consider how component knowledge introduced at one point in time influences future learning. This ensures that knowledge builds incrementally from pupils' prior knowledge and so pupils' misconceptions are less likely.
- The curriculum anticipates where pupils are likely to hold misconceptions. These are explicitly addressed, and pupils learn how the misconception is different to the scientific idea.
- Pupils know when and why models and rules can be used in science, which includes knowing what they can and cannot be used for.

How does Science Mastery exemplify these features?

- Science Mastery schools allocate a minimum 4 hours per week for science in Years 7-9, and 5 hours per week for Years 10-11, ensuring sufficient curriculum time for students.
- The substantive and disciplinary knowledge that students are expected to learn are precisely defined and sequenced over 5 years.
- The lesson planning process relies on information about pupils' prior knowledge, and each lesson includes opportunities to 'fix' misconceptions, and 'close the gap'.
- Teacher guidance includes information about likely student misconceptions and how to address and preempt these. Formative assessment opportunities embedded in every lesson ensure timely diagnosis of misconceptions. Mark schemes for teachers advise on next steps where misconceptions are evident.
- Teacher scripts provided for the introduction of new information model exposition which ensures that science is represented accurately and misconceptions are addressed directly.
- The correct use of models to represent scientific ideas is taught explicitly. Students are also taught to compare, critique and evaluate models and their features.

4. Curriculum materials

The research says that high quality science education has the following features:

- Online resources match what the curriculum is intending pupils to learn and are not a source of errors/misconceptions.
- If science kits are used, they help achieve the curriculum intent and the activities themselves do not become the curricular goal.
- High-quality textbooks are used as an important resource for learning and teaching science.

How does Science Mastery exemplify these features?

- Science Mastery is a complete curriculum programme – all resources required by teachers and students for high quality science lessons are provided, and have a place within the 5-year curriculum map.
- The design of all resources is informed by misconceptions identified in the literature and experienced science educators and academics, with careful consideration given to the use of language, diagrams, symbols, notation, examples and models.
- The Science Mastery resources are continuously developed in collaboration with a large Network of teachers and schools, and are informed by best practise in classrooms, as well as feedback from classroom observation and experience.
- All Science Mastery student facing resources are fully editable by teachers
- Fully editable unit workbooks are provided for additional support in lessons, as well as for remote learning and independent work.

5. Practical science

The research says that high quality science education has the following features:

- The curriculum is sequenced so that pupils have the necessary disciplinary and substantive knowledge to carry out practical work successfully and learn from it.
- The purpose of practical work is clear in relation to curriculum content so that practical activities can be set up and managed to develop pupils' disciplinary and/or substantive knowledge.
- Practical activities form part of a wider instructional sequence that gives pupils time to connect theory to observation.
- Pupils are not expected to learn disciplinary knowledge only through taking part in practical work – disciplinary knowledge should be taught using the most effective methods.
- Pupils encounter the full range of objects and phenomena they are studying through both laboratory and fieldwork. These encounters should take pupils beyond their everyday experiences to develop a sense of wonder and curiosity about the material world.

How does Science Mastery exemplify these features?

- Practical, enquiry and Maths skills are an integral part of Science Mastery and essential to great science education. The wide range of practical and enquiry opportunities embedded over 5 years enhances students experience of the subject, and ensures that upon completion of the programme they are equipped with a wide range of skills.
- A suite of CPD supports teachers and technicians of all levels of experience and expertise to develop the teaching of practical skills and enquiry in their school. Practical guides are written by expert technicians for both technicians and teachers, to guide the set-up and running of practical activities. They include real example data, expected observations, photos to aid set-up, and alternative methods.
- The disciplinary knowledge aspect of the Science Mastery curriculum is comprised of 100 practical, enquiry and mathematics skills.
- Disciplinary knowledge is mapped carefully over 5 years, ensuring that students experience each skill numerous times, within a variety of contexts and across subjects.
- Disciplinary knowledge is always taught alongside relevant substantive knowledge, with key links between theory and practice made explicit.
- Disciplinary knowledge is taught explicitly using explanation, demonstration and modelling, with ample opportunities planned to practise and apply these skills in relevant and novel contexts.
- Competency frameworks support teachers to develop students' competency in practical and enquiry skills over time.

6. Pedagogy: teaching the curriculum

The research says that high quality science education has the following features:

- Activities are carefully chosen so that they match specific curriculum intent.
- Teachers use systematic teaching approaches, where learning is scaffolded using carefully sequenced explanations, models, analogies and other representations to help pupils to acquire, organise and remember scientific knowledge.
- Teaching takes account of the limited working-memory capacity of their pupils when planning lessons.
- Pupils are not expected to arrive at scientific explanations by themselves without sufficient prior knowledge.
- Systematic approaches, alongside carefully selected texts, are used to teach the most important vocabulary in science.
- Pupils have regular opportunities in the early years and primary classrooms to learn vocabulary through story and non-fiction books, rhymes, songs and oral rehearsal.

How does Science Mastery exemplify these features?

- Activities are impactful in helping students to achieve the lesson objectives and developing students' practical, enquiry or Maths skills.
- Model teacher expositions are provided which support teachers to deliver carefully sequenced explanations, models, analogies and other representations to help pupils to progress as scientific thinkers.
- Student facing resources and activities are designed to take account of the limited working memory and cognitive load of students.
- Learning is cumulative, with more complex ideas and explanations developed over time, informed by carefully sequenced prior ideas. Prior learning is assessed at the beginning of every lesson with short answer retrieval practise 'Do Now' questions.
- Students are supported to answer command words within resources, with model answers and a focus on key command words across specific units.
- Pupils have regular opportunities to develop literacy in science, with extended reading and writing activities, and a specific vocabulary focus each lesson.
- Every lesson includes opportunities for students to discuss their ideas as part of a 'talk task'.

7. Assessment

The research says that high quality science education has the following features:

- Teachers and pupils are clear on the purpose of assessment. There is clarity about what is being assessed.
- Assessment is not overly burdensome on teachers' time in relation to marking, recording or feedback.
- Feedback is focused on the science content and not on generic features. Teachers have sufficient subject knowledge to be able to do this.
- Pupils regularly retrieve knowledge from memory to help them remember and organise their knowledge. This is coupled with feedback. Teachers think carefully about what pupils are being asked to retrieve and whether this prioritises the most important content.
- Overuse of external assessment items, such as GCSE or A-level questions, is avoided because this narrows the curriculum and leads to superficial progress that does not prepare pupils for further study.
- Systems are in place to support teachers to make accurate decisions when assessing pupils' work. This includes supporting primary teachers with statutory teacher assessment of science at key stages 1 and 2.

How does Science Mastery exemplify these features?

- An integrated formative assessment suite ensures that misconceptions and misunderstandings are routinely diagnosed.
- Assessments check students understanding of clearly defined units of learning.
- Quick and easy checks for understanding within the lesson can be administered without having an impact on teacher workload. These allow for a quick snapshot of whole-class understanding. Mark schemes and follow-up teacher guidance are included.
- A diagnostic mastery quiz at the end of each unit includes a detailed mark scheme, which guides teachers in planning appropriate 'fix-it' tasks for pupils to address their misconceptions.
- An exit ticket to check learning at the end of each lesson consists of three carefully written multiple-choice questions, which will identify the key misconceptions from the lesson that are most common according to the latest research.
- The suite of formative assessment resources provided as part of Science Mastery form the basis of the lesson planning process. Training and teacher guidance ensure that teachers are supported to use formative assessment to plan efficiently for the needs of their pupils. Having high-quality lesson resources means that teacher planning time can be spent on that important thinking that we know has a high impact on pupils' progress in science.
- Through formative assessment, students have frequent and impactful feedback specific to their needs and misconceptions, which informs subsequent lesson activities they will undertake.
- An end of year summative assessment is age appropriate, ensuring teachers are not reliant on past GCSE questions which are usually inappropriate for younger students.

8. Systems at subject and school level

The research says that high quality science education has the following features:

- Teachers, teaching assistants and technicians have access to high-quality subject-specific CPD to develop subject knowledge and pedagogical content knowledge. This is aligned to the curriculum.
- In primary schools, there is at least one teacher who specialises in teaching science and science leaders have dedicated leadership time.
- Science teachers engage with subject associations, and take responsibility, with support from the school, for developing their own subject knowledge throughout their career.
- Early-stage teachers in particular have timetables that allow them to develop expertise in one science and that do not give them too many key stages to teach.
- Timetables allocate appropriate teaching time to science, reflecting its status as a core subject in the national curriculum. There are particular concerns that pupils in some primary schools are not receiving sufficient curriculum time to learn science.
- Pupils have access to sufficient practical resources to take part in demanding practical work, either independently or in appropriately sized groups that enable first-hand experiences.

How does Science Mastery exemplify these features?

- Teachers are provided with high-quality topic-specific PD to develop their subject knowledge and pedagogical content knowledge. This is aligned to the curriculum and arranged on a unit by unit basis.
- Science technicians are supported with PD which enables them to contribute to the aims of Science Mastery within the department
- School based Science Mastery Leads have dedicated leadership time and are responsible for supporting other teachers in implementing Science Mastery. SM leads receive additional training to enable them to lead the delivery of Science Mastery within their school.
- Teachers, including early career and non-specialist teachers, are supported to plan lessons collaboratively with more experienced colleagues on a regular basis
- Science Mastery teachers and technicians are part of an active and collaborative Science Mastery Network, with opportunities to discuss current issues in science education and partake in PD with colleagues outside of their own school.
- Science Mastery schools are expected to dedicate a minimum of 4 hours per week in Y7-9 and 5 hours per week in Y10-11 to science lessons
- All students are expected to partake in the practical activities outlined in the curriculum materials in order to develop their practical skills. Practical guides support teachers to plan and deliver practical science lessons, with guidance on setting up and running experiments, expected observations and data, health and safety considerations and managing the laboratory during practical work.