Introduction and background

As in English and maths, the attainment gap between disadvantaged pupils and their peers in science is significant; pupils start to fall behind at key stage 1 and the gap widens throughout primary and secondary school. The report from the Education Endowment Foundation (EEF) offers 7 recommendations which are relevant to all pupils, but especially to those who struggle with science. The recommendations are based on the best available international research and on consultation with experts. The report also provides general guidance about teaching for engagement. The full report contains a number of useful links to further reading and to resources which can be accessed by science teachers.

Key points

Teaching for engagement

- There is often a problem with engagement in science. Many pupils feel that although science is important, it is ‘not for them’ and they do not see it as relevant to their lives. This issue worsens as they progress through compulsory schooling.
- The ASPIRES study has shown that pupils who aspire to study science share a high level of ‘science capital’. There are 8 key dimensions of science capital which include: the scientific skills and knowledge of the pupil’s family; participation in out-of-school science contexts; and knowledge about the transferability of science. Awareness of these features has led to the development of a ‘Science Capital Teaching Approach’ which aims to further the development of science capital amongst pupils. There is promising evidence that the approach is motivating more pupils to study science at A level.
- Science is a practical subject and research by the Wellcome Trust has found that enjoying practical work and having a good teacher play a key role in positive attitudes towards science.
- A further advantage of science is the ease with which links can be made to real-life issues which matter to pupils. A major review of evidence found that science courses which focus on links with everyday life foster a more positive attitude to school science. This personalisation and localisation of science is a key element of the above-mentioned ‘Science Capital Teaching Approach’.

Recommendation 1: Preconceptions

- Students come to the science classroom with a number of preconceptions based on sensory experience and social interaction. These ideas may be misconceptions which are not aligned to scientific understanding.
- Learning science involves going through a process of adjusting these ideas or replacing them with correct ones.
- Teachers need to be aware of the preconceptions and misconceptions which pupils may have. There is strong evidence that learning is more effective when prior knowledge is taken into account.
- In order to correct misconceptions, the principle of cognitive conflict is often used. This involves leading pupils to make observations which challenge their misconceptions and requiring them to restructure their way of thinking to accommodate new evidence.

Recommendation 2: self-regulation

- Self-regulation consists of: cognition (pupils’ understanding of strategies they can use); metacognition (the ability to check and monitor learning); and motivation. Several large studies show strong links between self-regulation and attainment in science. Studies also show that programmes specifically aimed at improving self-regulation have had a positive impact on student outcomes in science.
- Pupils need to be explicitly taught how to plan, monitor and evaluate their learning. It is helpful if teachers work through a new problem aloud with a class, modelling this process.
- Group discussions are important for promoting metacognitive talk and dialogue. However, in order to be effective, there must be clear ground rules such as the necessity for everyone to be listened to until they have finished, or the need for the group to reach a consensus. It is also vital that group members justify their opinions and arguments. Research suggests that group discussions work better if a specific stimulus is provided as a scaffold (e.g. talking heads).

Recommendation 3: modelling

- Scientific knowledge can be difficult to acquire as it moves between 3 levels. These levels were conceptualised by Alex Johnstone as the macroscopic, the sub-microscopic and the symbolic. The macroscopic may refer to physical objects, sub-microscopic to forces and reactions, and the symbolic to formulae. Pupils often find it hard to relate their experience to the latter 2 levels. Models can help them to...
do this. Teachers should, however, ensure that the model is something with which pupils are familiar. For example, if using water flow to model electric current, pupils may also need to know about water pumps and turbines.

- It can be helpful to provide pupils with a range of models which are relevant to a particular concept. This avoids pupils focusing solely on the model rather than the concept it is meant to explain.

**Recommendation 4: memory**

- Knowledge of new concepts and vocabulary which is embedded in long-term memory is an important step in progressing to more complex understanding.
- Pupils use working memory and long-term memory. Working memory is where information which is being actively processed is held. Working memory is very limited in how many new items it can hold at once. However, it does not have this limitation if an item being used is coming from long-term memory. Long-term memory is a constantly evolving store of knowledge stored in schemas. Schemas are categories of information and the links between them.
- Teachers should be aware that tasks which exceed the limit of working memory will result in cognitive overload. This will, in turn, lead to misunderstandings and prevent the information from being encoded in long-term memory.
- Teachers can help to prevent cognitive overload by: avoiding ‘split attention’ where pupils need to refer to multiple sources to complete a task; using worked examples showing each step of a process; or tackling a task step-by-step and letting pupils write down what they know at each step.
- A key way of preventing cognitive overload is by encouraging pupils to commit important and frequently used pieces of information to their long-term memory.
- Teachers can help pupils to commit information to long-term memory by using spaced review. This involves revisiting a topic after a ‘forgetting gap’. Teachers should ensure that they build in this review time whether at the end of a topic, or after a specific time period.
- Retrieval practice is another effective way of embedding information into long-term memory. It may involve tests, practice questions or concept maps. Research shows that retrieval practice is most effective when carried out at least a week after the new material has been covered.
- Elaboration involves describing and explaining in detail something which pupils have covered. It supports learning by integrating new information with prior knowledge. It often involves ‘how’ and ‘why’ questions, e.g. tell me how an electric motor works…. Why does it turn faster when the current is higher?

**Recommendation 5: practical work**

- Teachers should consider the purpose of any practical work undertaken and ask whether it is being done to teach a skill, to introduce a new phenomenon or to teach principles of scientific inquiry. Pupils should always know why they are doing an experiment.
- Teachers should always consider how a practical activity fits in with other work on the topic. They need to consider which prior knowledge and skills pupils will need in order to derive maximum benefit from the practical.
- Practical work should be used to develop scientific reasoning. For example, the control of variables should be explicitly discussed when teachers introduce an experiment such as the limiting factors for photosynthesis.

- Teachers should use a variety of approaches to practical science such as computer simulation and open-ended projects. International research on the impact of open-ended projects showed several benefits including improved attitudes towards science careers and the learning of science ideas.

**Recommendation 6: science literacy**

- Research shows that pupils need to be explicitly taught new science vocabulary; direct instruction is a good way of doing this. Pupils have most difficulty with familiar words which have a different meaning when used in a scientific context (e.g. ‘field’ or ‘random’).
- Teachers should make a conscious choice about the words to be taught and remember that a deep understanding of a few words is better than superficial understanding of a large number of words.
- Pupils should be taught to segment words according to their unit parts (morphemes). For example, the word ‘photosynthesis’ can be broken down into ‘photo’ (light), ‘syn’ (with), ‘thesis’ (setting, putting placing).
- Knowledge organisers can be a useful way of demonstrating links between words and showing how words link across topics.
- New vocabulary should be reinforced and teachers should focus on getting pupils to use it as much as possible in different contexts.
- Students should be supported to read a range of authentic scientific texts such as news articles and popular science books. They need to be taught the necessary vocabulary and to engage with structured activities which facilitate understanding of the text.
- When writing about science, pupils need a strong sense of purpose and audience, i.e. they need to consider why they are writing something and who it is for. Frameworks such as the Science Writing Heuristic can be helpful in aiding structured coherent writing.

**Recommendation 7: feedback**

- Formal tests, lower-stakes assessments, observations and class discussions all help teachers to build the necessary picture of their pupils’ understanding.
- Feedback is better provided as comments rather than as marks. Effective feedback does not always have to be written; it can be given to individuals or groups during lesson time.
- Smaller quantities of rich feedback is better than a lot of superficial marking.
- It is important to ensure that pupils have time to respond to feedback. It is helpful to frame feedback as a question; it should be clear and easy to act on.