Research and analysis
Research review series: science
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Summary Crib Sheet- Designing the Science Curriculum

Substantive Knowledge- knowledge of the products of Science, such as concepts, laws, theories and models.

- **Physics-** 'builds its explanations on measurable quantities that can be put into numerical relationships
- **Biology-** seeks to understand living organisms and life
- **Chemistry-** explains the behaviour of matter

Disciplinary Knowledge- knowledge of how scientific knowledge is generated and grows including how to carry out practical procedures. (Dependant on pupils having learned a domain of knowledge)

1. Knowledge of methods that scientists use to answer questions
2. Knowledge of apparatus, techniques, including measurement
3. Knowledge of data analysis
4. Knowledge of how science uses evidence to develop explanations

1. Fair testing, use of models, chemical synthesis, classification, description and identification of correlation (pattern-seeking)
2. Carrying out scientific procedures and protocols safely, accurate measurement and recording of data mitigation of error.
3. Processing and presenting scientific data in a variety of ways to explore relationship and communicate to others. Usage of table and graphs and identifying correlation.
4. How evidence is used, distinction between correlation and causation, how scientific models, laws and theories develop overtime and the importance of technology and

A curriculum focusing on either substantive or disciplinary knowledge leads to at least 2 problematic models of curriculum design that misrepresent the discipline of science. Disciplinary knowledge needs to be embedded within the substantive content of biology, chemistry and physics. This enables pupils to see the important interplay between the two.

Scientific enquiry and enquiry-based instruction are not the same- disciplinary knowledge of scientific enquiry is different to the pedogeological approach of enquiry-based teaching.

Key Takeaway-
Sequential knowledge broken down into meaningful components > sound conceptual frameworks where pupils organise and make sense of scientific knowledge > improved understanding and learning

Curriculum Design Recommendations:

Based on the above, high-quality science education may have 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.

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Summary Crib Sheet- Teaching the Science Curriculum

'…there is a clear relationship between young children's general science knowledge and their latter science achievement. Results from a 12-year longitudinal study show that early introduction to science concepts in primary school positively influences subsequent science learning throughout secondary school…Schmidt, Wang and McKnight found that strong curriculum began with teaching a few of the most fundamental topics of science, such as classification of matter…'

Implicating Factors

Teacher-directed Instruction

'Teacher-directed science instruction is positively associated with science performance in almost all countries. (PISA 2015)
Teacher-directed instruction (as defined by PISA) involves the following:
-the teacher explains scientific ideas
-a whole-class discussion takes place
-the teacher discusses our questions
-the teacher demonstrates an idea'

Subject Knowledge & Expertise

'Shulman identified the importance of both content knowledge and pedagogical content knowledge to teacher education. It is therefore important that teachers have access to high-quality subject-specific CPD. This needs to be focused on the content and how to teach it, as opposed to generic pedagogies and so should be aligned with the curriculum that teachers teach.'

Assessment

'One study found that formative assessment in science is most effective for pupils when it is embedded within a lesson sequence, occurring at the same time as new knowledge is taught… Assessment as learning draws on the cognitive principle that pupils are more likely to remember knowledge if they practise retrieving that knowledge over extended periods of time. This is known as the testing effect.

Oracy and Discussion

'Pupils need opportunities in lessons to recap and to orally rehearse and structure their thoughts, using scientific language. This is important in helping them to use scientific language clearly and precisely. Young pupils benefit from using talk to rehearse their text before they write it… Through structured writing and speaking, pupils retrieve and reorganise their knowledge as they communicate their mental representation of a scientific idea. For very young pupils, this might include labelling diagrams.

Curricular Considerations:

- Time for both new component knowledge to be introduced but also for this knowledge to be practised and securely remembered
- Explicitly defining what aspects of disciplinary literacy pupils need to know. E.g., words with multiple meanings such as 'cell' or 'model.'
- Exploring misconceptions drawing on previous conceptions from the history of science, can allow pupils to see how their initial conceptions mirror those of early scientists.

On textbooks/workbooks… 'The implementation of the intended curriculum can either support or undermine its coherence. Evidence suggests that quality textbooks, when used well, have a particularly important role to play in creating a coherent learning progression. They can also free up teachers' time. In contrast, resources that focus teachers' attention on activities, rather than on the underlying content, are not associated with positive science achievement.'

On practical work… 'An important first step of effective practical work is to clarify its role in relation to specific curriculum content. E.g., pupils may add sugar to water to help them learn the substantive knowledge of dissolving. In this case the concept of dissolving is the goal. However, the activity itself may also be the goal e.g., using a thermometer to carry out a specific type of scientific enquiry…practical work should form just a part of a wider instructional sequence and pupils should have a sufficient prior knowledge to learn from the activity.

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