ROYAL SOCIETY OF CHEMISTRY

TALENT

The elements of a successful chemistry curriculum:

The Royal Society of Chemistry's vision for 11–19 chemistry education

Introducing our new perspectives series

In a world where global challenges and advances in technology bring both uncertainty and new possibilities, the chemical sciences have a critical role to play. But what will that role be? How can we maximise the impact we make across academia, industry, government and education? And what actions should we take to create a stronger, more vibrant culture for research that helps enable new discoveries?

Our perspectives series addresses these questions through four lenses: talent, discovery, sustainability and knowledge. Drawing together insights and sharp opinion, our goal is to increase understanding and inform debate – putting the chemical sciences at the heart of the big issues the world is facing.

Talent

Talent is the lifeblood of the chemical sciences. But how do we inspire, nurture, promote and protect it? Where will we find the chemical scientists of the future? And what action is required to ensure we give everyone the greatest opportunity to make a positive difference?

Discovery

Chemistry is core to advances across every facet of human life. But where do the greatest opportunities lie? How will technology shape the science we create? And what steps should we take to ensure that curiosity-driven research continues to unlock new opportunities in unexpected ways?

Sustainability

Our planet faces critical challenges – from plastics polluting the oceans, to the urgent need to find more sustainable resources. But where will new solutions come from? How can we achieve global collaboration to address the big issues? And where can the chemical sciences deliver the biggest impacts?

Knowledge

Around the world research fuels scientific progress but the way we are sharing new knowledge is changing. What are the big challenges of the digital era? How can open access become a global endeavour? And what do chemical science researchers really think about the constantly evolving landscape?

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Foreword

A major policy objective of the Royal Society of Chemistry is that everyone should, during their schooling, have access to an excellent chemistry education that is engaging, inspiring and relevant. It should equip them with the skills and understanding they need to be scientifically literate citizens and to pursue the study of chemical sciences at higher levels should they so wish.

We work to achieve this objective in a number of ways. This includes supporting teachers in the classroom with our network of Education Coordinators, providing high quality resources through our online education platform, and with our policy work on the curriculum and teacher recruitment and retention.

The curriculum is fundamental to ensuring that learners experience an excellent chemistry education. So, in 2014, the Royal Society of Chemistry set up a Curriculum and Assessment Working Group (CAWG) to consider the provision of chemistry education throughout school years.

The aim was to develop a curriculum framework that progresses coherently through primary and secondary schooling, by examining the evidence on best education practice and drawing on the expertise of a diverse range of representatives from the chemical sciences community.

The 11–19 curriculum framework presented in this report is designed to allow learners to encounter a wide range of modern chemistry, to demonstrate both its impact on everyday life and its potential to address some of the major problems facing society in the 21st century. The framework provides sufficient flexibility for curriculum developers to design courses suitable for all learners regardless of qualification pathway, across the UK and Ireland.

Whilst we will continue to refine and develop the 11–19 framework, we are also developing our thoughts around primary, technical and undergraduate curricula. We are keen to hear feedback from our community as we continue our work in these areas.

Ultimately, we hope this framework will be a useful resource for policymakers across the UK and Ireland in making future reforms to chemistry curricula.

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Norwich Research School/
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Norwich
CAWG Chair

Gareth J Price
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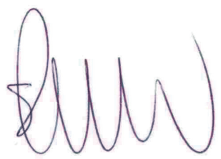

Simon Rees
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Introduction

The chemical sciences are entering an era of unprecedented discovery and impact. They will be essential for finding paths to sustainable prosperity. So it is vital that chemistry education is fit for the future.

The Royal Society of Chemistry aims to influence the development of chemistry curricula and qualifications by governments and other authorities throughout the UK and Ireland. This document presents a proposed framework to inform curriculum design at ages 11–19. While this proposal is intended to be a valuable resource to policymakers and curriculum designers, we hope it will also be of interest and use to teachers.

The ideas in this document rest on a much greater body of work, which is still being refined, as well as extended to other stages of education. The framework presented here represents what we see as the core of an ideal chemistry curriculum, but by no means its totality. While our ideas about good curricula should always be reviewed in the light of evidence and experience, we aim here to present something that is enduring and can be used flexibly in different education systems and types of qualification.

We want to engage with the chemical sciences and education communities to inform the next steps in this work, so that we are aligned with their needs and have broad support for our proposals. This is the beginning of a longer conversation; future publications will expand on the ideas in this report.

A community and evidence-informed framework

The curriculum framework presented here has been developed by a succession of curriculum and assessment working groups.

The working groups referred to evidence on good curriculum design in general and on effective learning in chemistry in particular, as well as looking at current practice. They thought about the most important knowledge and skills to teach to learners aged 11–16 years and 16–19 years, as well as the guiding principles that should underpin good curriculum design. From these discussions, our curriculum framework emerged.

We have tested our ideas with teachers and other educators through reviews of draft documents, focus groups and other discussions. Practice was also shared with our sister professional bodies, the Institute of Physics and the Royal Society of Biology, which are conducting parallel exercises. We are grateful to everyone who has shared their insights with us.

Members of our Curriculum and Assessment Working Group

The Royal Society of Chemistry is grateful to the following members of the working group for their contributions to the work that led to the development of this document.

- **Professor Judith Bennett FRSC**, Department of Education, University of York
- **Dr John Carroll**, Nottingham Institute of Education, Nottingham Trent University
- **Elizabeth Coppard**, curriculum specialist
- **Andrew Croydon**, Association of the British Pharmaceutical Industry
- **Dr Jeffrey Deakin FRSC**, education advisor
- **Dr Gordon Dent SFHEA**, Medical Schools Council Selection Alliance
- **Judith Green**, National Space Academy
- **Helen Harden**, curriculum specialist
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- **Andrew Hunt FRSC**, curriculum and assessment specialist
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- **Dr Susan Wyn Jones FRSC**, School of Education and Human Development, University of Bangor
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Our vision for chemistry education

The Royal Society of Chemistry believes everybody is entitled to an excellent chemistry education, whether they go on to pursue a career in the chemical sciences or take their place in society as scientifically literate citizens.

At an individual level, a chemistry education should:

Inspire people with a sense of curiosity and wonder about the fundamental nature of the world around them

Empower them to make decisions about their own lives and critically evaluate scientific and technological developments that impact society.

Equip them with the knowledge and skills to pursue further study and rewarding careers in the chemical sciences and a wide range of related fields.

At a national level, it should ensure we have a sustainable supply of people with the curiosity, knowledge and skills to:

Enable growth and productivity – the chemical sectors, add £14.4 billion[1] in value to the UK economy every year.

Address global challenges such as climate change, water and food security, health and energy.

Our aim

Focusing initially on students aged 11–19 years, the Royal Society of Chemistry has developed a chemistry curriculum framework that sets out what we value in, and about chemistry in a way that aims to be coherent, inclusive and appropriate for all school-age students.

The framework covers areas of chemistry that all learners should encounter by the end of the compulsory study of chemistry – ideally age 16. Students should then cover all areas in more detail if they choose to study chemistry post-16. If teaching time allows, other topics could be added or a more comprehensive range of applications presented.

This framework is not intended to be a scheme of work or an exam specification, or to imply any particular teaching sequence. It is designed to guide the development of more detailed courses of study and qualifications that will suit learners and serve progression paths throughout the UK and Ireland.

Chemistry curricula differ considerably between England, Scotland, Wales, Northern Ireland and the Republic of Ireland. Each of these curricula have their strengths but also areas where they could be improved. We have already drawn on the framework to engage with curriculum reforms in Wales and the Republic of Ireland, as well as the development of T Levels in England.

Whilst we are not actively advocating for curriculum reform, we will continue to engage with and influence reforms as they occur in the different regions of the UK and Ireland. Overall we are looking for curriculum design to:

- Be more coherent and interconnected, moving away from disjointed topics.
- Make the fundamental principles of, and about, chemistry more explicit.
- Better integrate learning about the applications and impacts of chemistry, including using up-to-date examples.
- Have a better progression of learning through the educational stages

[1] Source: The Chemical Industries Association https://www.cia.org.uk/Policy/Economics

The curriculum framework

Our approach to developing the framework

A curriculum for all

In designing this framework, we have carefully considered the skills and knowledge learners will need at each stage of education to pursue further study and work. This includes helping them understand the variety of contexts and careers in which chemistry is used so they can make informed decisions.

We also recognise that most learners will ultimately not work in the chemical sciences, and so it is important to consider their needs as future scientifically literate citizens.

To achieve these aims, the curriculum needs to support good understanding of conceptual knowledge, development of relevant skills, and an understanding of the importance of chemistry to society.

Guiding principles

The Curriculum and Assessment Working Group considered the existing curriculum documents for the nations of the UK and Ireland, as well as views from experts in curriculum design to arrive at a set of guiding principles that underpinned the development of the curriculum framework. These guiding principles are as follows:

- **A clear framework or narrative** that gives a coherent 'big picture' of chemistry as a subject, explains why it matters, and shows how different areas of content are connected.
- **Clear progression**, in which deepening understanding is built on a secure foundation in each aspect of the framework.
- **Encourage understanding of fundamental principles** (as opposed to surface learning of facts). This promotes deeper conceptual understanding and the ability to apply learning to novel situations.
- **Incorporate the procedural knowledge**; and **skills**, (including practical skills), that are core to the discipline of chemistry.
- Be informed by the **available evidence**[2], including findings from research, best practice, and views from informed stakeholders.

In using this framework, it is also important to ensure that fully developed curricula offer:

- **Appropriate alignment** with the wider curriculum in related subjects.
- **A defined learning entitlement** that sets out clearly the level of understanding and skill that learners are expected to achieve at each stage.
- **A level of demand** that is aspirational but also allows an educational experience that is inclusive of all learners.
- **A considered amount of prescribed content**, to allow time within the curriculum to develop understanding and the flexibility for teachers to introduce meaningful contexts and applications that demonstrate the breadth of chemistry and its contribution to society.

The importance of contexts

The central and enduring ideas of chemistry, which further the learner's understanding of chemistry as a discipline, form the backbone of the framework. We have also left space to include up-to-date and relevant contexts. The use of contexts to help students understand how chemistry is applied in the real world is vital. It helps students to understand the relevance of the ideas studied, how the discipline is evolving, develop scientific literacy, and appreciate what chemistry brings to our society. We recommend that contexts are chosen for national, regional and local relevance to enrich the curriculum and support maximum engagement. Structuring the framework in this way means that over time, different contexts and applications can be chosen to illustrate these core ideas without the need for full-scale curriculum reform.

[2] A list of the references used can be found here: https://rsc.li/chemistry-curriculum-framework

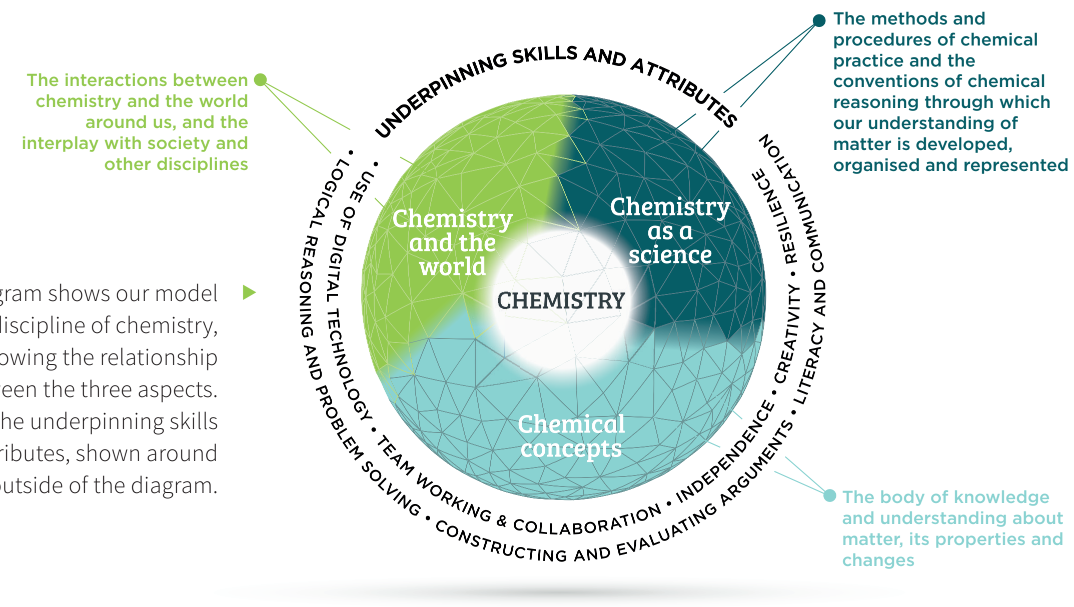
A framework for a successful chemistry curriculum

A complete view of chemistry

Developing an understanding of what chemistry is, and how we can use it, is central to a successful chemistry curriculum. So we have thought deeply about what matters in, and about, chemistry and how our discipline[3] is evolving.

At the heart of the framework sits our model for the discipline, shown in the diagram below. The approaches to reasoning and enquiry that are important in chemistry are covered in *Chemistry as a science,* whilst the fundamental understandings of the material world that we have developed so far are covered in *Chemical concepts*. *Chemistry and the world* focuses on how we use these practices and concepts and how they impact society and the world. Whilst each of these aspects of chemistry is important in its own right, and should be made explicit as so, chemistry as a discipline can only be understood through the relationship between them.

This diagram shows our model for the discipline of chemistry, showing the relationship between the three aspects. Note the underpinning skills and attributes, shown around the outside of the diagram.



An overview of structure

The following pages lay out more detail on the hierarchy of the framework. Stepping down from the three aspects that make up chemistry as a discipline, the next level of structure is a set of "Big Questions". This approach ensures there is a narrative that learning can be connected to, whilst also reflecting the enquiring nature of chemistry.

Within each Big Question we have identified the key ideas that we envisage that all learners should encounter by age 16, and in more depth in post-16 qualifications. These key ideas should not be viewed as teaching topics or suggestions. Rather they are an indication of the core ideas that need to be understood to answer each Big Question. The Big Questions and key ideas are considered further in the following pages.

We have also undertaken more detailed thinking on exactly what content could, and should, be included at each educational stage, for each Big Question. This level of detail is not presented in this report.

The structure of this framework is intended to be flexible enough that it can be applied to technical and academic pathways and be appropriate for any educational system in the UK and Ireland.

Underpinning skills and attributes

Beyond the subject-specific content, the curriculum should enable learners to develop a broader range of skills necessary for a future in science as well as a wide range of study and career options. Whilst not a curriculum component specifically, learners should have the opportunity to develop these skills within a chemistry context.

[3] By discipline we mean an area of learning that has a particular object of research, but also specific range of practices used to further understanding in that field.

The Big Questions and key ideas

Our approach to developing a clear narrative has been informed by expert thinking on curriculum design, in particular the *Big Ideas of Science Education*[4], which explains how the links between ideas and experience is better preserved in a narrative form than in a list of disconnected points.

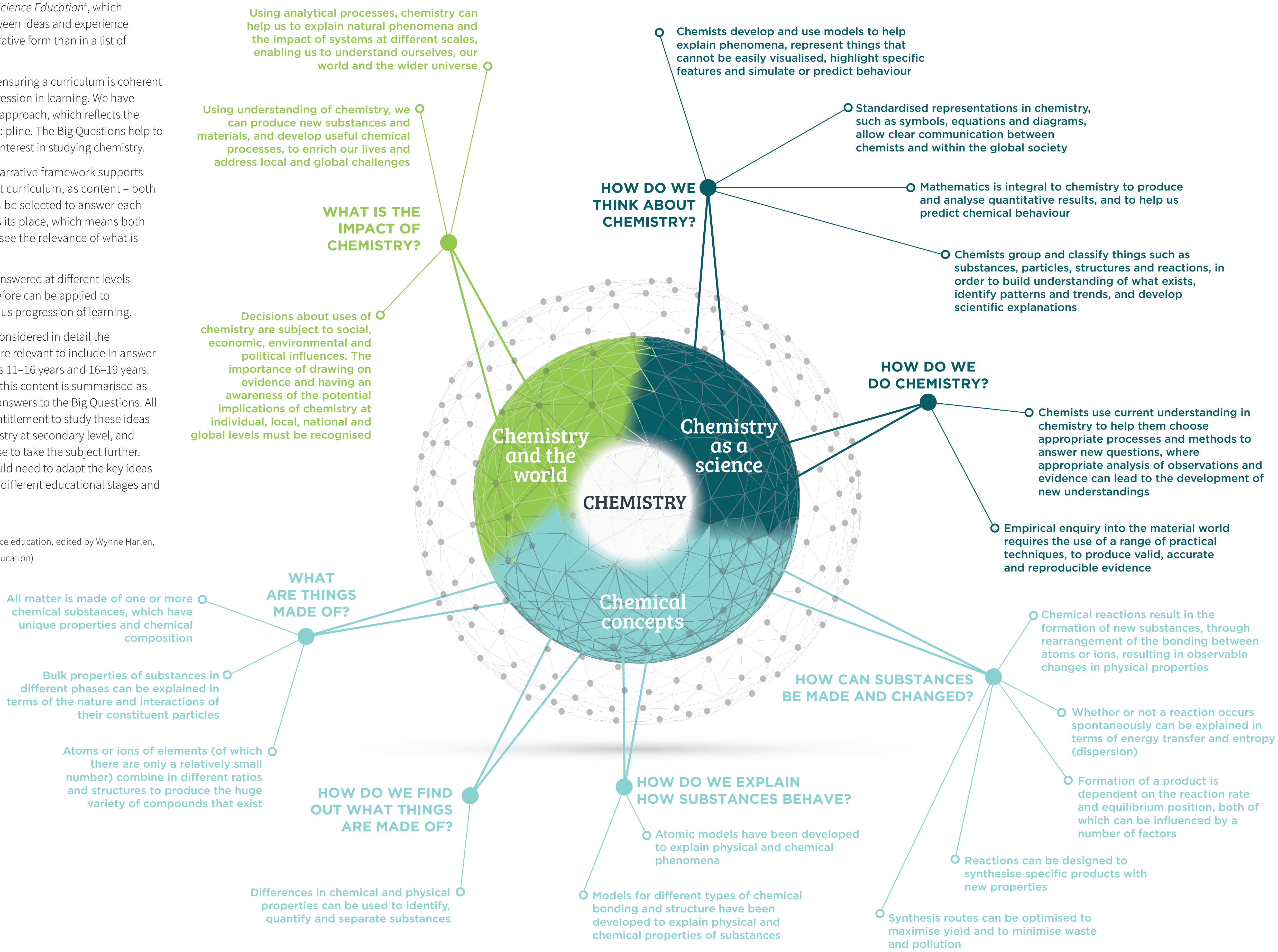
A narrative is important in ensuring a curriculum is coherent and aids planning for progression in learning. We have adopted a "Big Questions" approach, which reflects the enquiring nature of the discipline. The Big Questions help to define the central areas of interest in studying chemistry.

Using Big Questions as a narrative framework supports development of a coherent curriculum, as content – both knowledge and skills – can be selected to answer each question. All content earns its place, which means both teachers and learners can see the relevance of what is being taught.

The Big Questions can be answered at different levels of sophistication, and therefore can be applied to development of a continuous progression of learning.

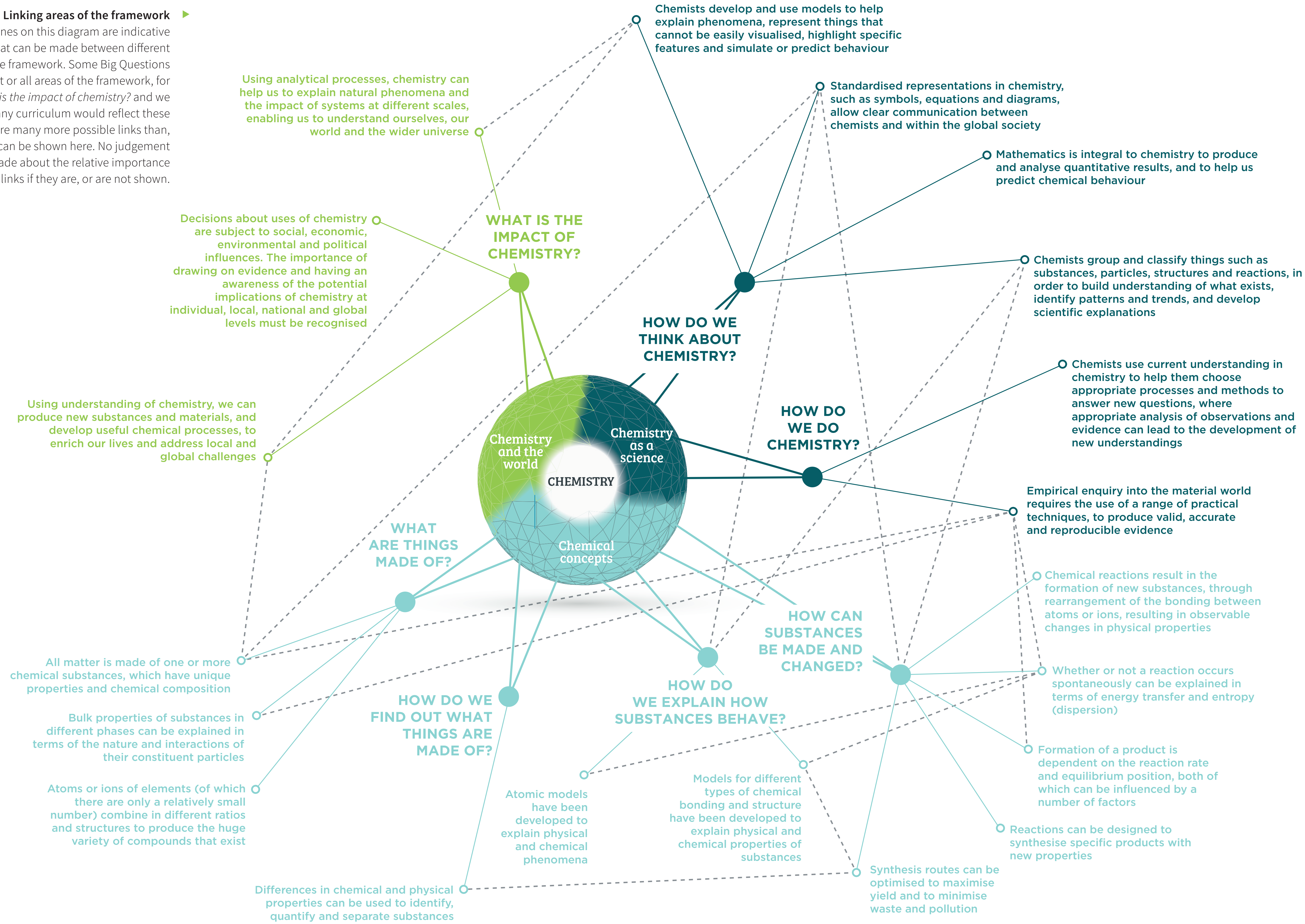
The working groups have considered in detail the knowledge and skills that are relevant to include in answer to the Big Questions at ages 11–16 years and 16–19 years. In the framework diagram, this content is summarised as the key ideas that provide answers to the Big Questions. All learners should have the entitlement to study these ideas during their study of chemistry at secondary level, and in more depth if they choose to take the subject further. Curriculum developers would need to adapt the key ideas to the appropriate level for different educational stages and qualifications.

[4] Principles and big ideas of science education, edited by Wynne Harlen, 2010 (Association for Science Education)



Linking areas of the framework

The dotted lines on this diagram are indicative of links that can be made between different areas of the framework. Some Big Questions link to most or all areas of the framework, for example *What is the impact of chemistry?* and we envisage that any curriculum would reflect these links. There are many more possible links than, for clarity, can be shown here. No judgement should be made about the relative importance of links if they are, or are not shown.



Practical skills

Development of competency in practical skills should remain a core aim of a chemistry curriculum. Practical work supports understanding of chemistry as an empirical science, and provides the opportunity to learn skills that are useful not only for progression into further study and careers in the sciences, but also more widely. Examples of wider relevance include the ability to take accurate measurements, an understanding of hazard and risk, and an appreciation of application and innovation in the sciences.

While not explicitly expressed in the framework diagram, practical work should be understood as a core part of answering the question '*How do we do chemistry?*' Learners should encounter a range of techniques appropriate to their stage of education and linked to other areas of the curriculum, and understand the place of experimentation and observation in the wider processes of investigation.

Coherent progression across 5–19 education

To ensure coherent progression in understanding it is important that the narratives remain linked, while specific aims at different education stages are accounted for. This will support age-appropriate conceptual development of the subject. While each stage has its own set of aims, they stay connected through the Big Questions.

We set out the key aims for each educational stage below. We have included ages 5–11 years as we believe the Big Questions can be adapted for this age group. We are still in the process of developing a more detailed framework for this educational stage.

Aims for each educational stage

5–11 years

Lay the foundations of chemistry education within a science framework, in terms of scientific knowledge, skills and enquiry. Learners start to become informed about the part that science plays in the world around them.

11–16 years

Provide a broad and balanced chemistry education for all learners, including about the role of chemistry in the world around them. Prepare learners who wish to pursue either an academic or a technical pathway.

16–19 years

Prepare learners for further study on academic or technical pathways and careers related to chemical sciences, through developing essential skills and embedding a secure knowledge base.

Appendix: A note on assessment

Assessment is an indispensable tool in ensuring that learners are making progress against expectations, and in planning next steps for teaching and learning. Any programme of assessment should include all three components outlined in this curriculum framework, including practical work and contextual awareness.

We are developing our recommendations in this area. At present we suggest the following key principles for designing assessments:

- Assessments should be **tailored to the setting** in which the curriculum is delivered and likely progression routes, whether academic or technical.
- A **broad range of types** of assessment should be used to cover a variety of competences, cater for diverse learners, and minimise any negative impacts associated with particular tasks.
- Assessment of **theoretical concepts** should focus on learners' **understanding of and ability to apply** concepts, including to unfamiliar contexts. It should also evaluate learners' ability to analyse and evaluate new information and data, and to bring together ideas and skills from across the breadth of the curriculum, rather than focusing on rote memorisation.
- We acknowledge that **recall of core knowledge** is also important in developing fluency of understanding and may therefore feature in assessment.
- Some aspects of the curriculum may be better assessed through **'can-do' tasks** that most learners can achieve. For example, competence in certain practical skills.
- Every effort should be made to **avoid bias**, including on the basis of gender, socio-economic background, ethnicity or disability.

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