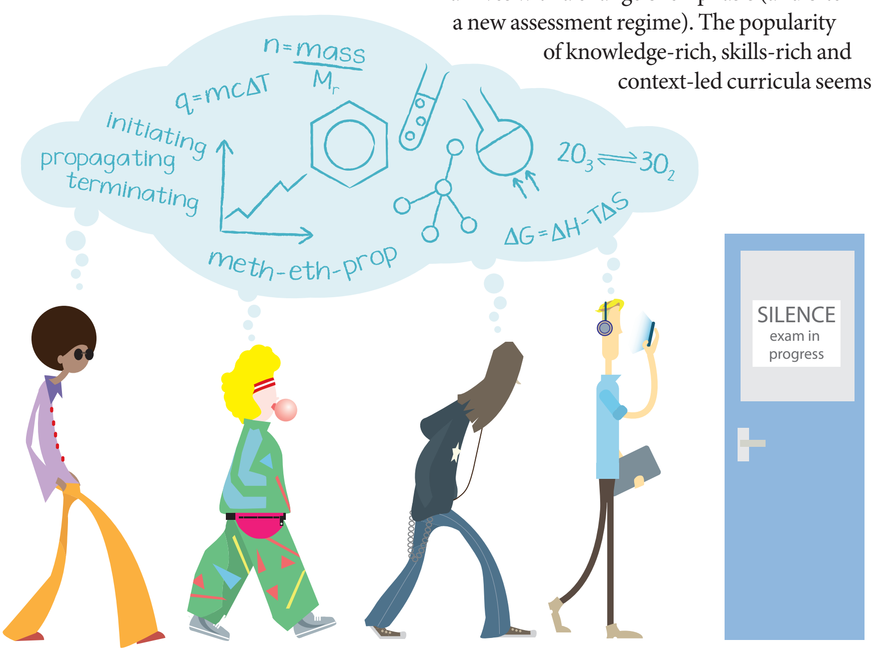
Evaluating ever-changing curricula

Kristy Turner

Experienced practitioners often feel that studying chemistry was harder during their time at school, but is this really true?

How much do you remember of your school chemistry? Perhaps you have a few snapshots of particular moments in time — maybe times you got into trouble or triumphs over rivals in class tests. How about your memory of the concepts you were taught and the exams you took? Somewhat hazier I suspect. If you are reading this article it is a fair assumption that your education in science has extended well beyond compulsory schooling and that your memories of school chemistry have become more diffuse. Time and experience intervene to muddy the memory. Details become blended with later scientific experiences such that we romanticize our own school days: lessons were better, there was more practical work, and exams were harder in our day.



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We have all experienced school chemistry lessons. For many readers (as scientists or just interested observers), this will have been a positive experience. It possibly inspired you to take chemistry to the level where you are now able and actively willing to read a journal such as this. It also means that you probably have an opinion on the chemistry curriculum in schools, informed by your own direct experiences and those of your professional life, whatever those may be.

In the United Kingdom at least, curriculum change seems to be constant rather than occasional. My career as a secondary-school chemistry teacher spans a relatively short 11 years, and yet I have already lost count of the number of different chemistry syllabuses that I have taught. Each new curriculum arrives with a change of emphasis (and often a new assessment regime). The popularity of knowledge-rich, skills-rich and context-led curricula seems to fluctuate with alarming regularity. Practical exams, coursework, and modular and terminal examinations also fall in and out of favour as the government of the day seeks changes that affect schools, teachers and pupils.

Nowhere is the impact of this felt, and commented on, more than in the A-level curriculum taught to pupils who, at the age of 16, have actively chosen to take their study of chemistry to the next level. A-level chemistry is a popular qualification with more than 50,000 candidate entries across the United Kingdom, most in England, Wales and Northern Ireland with smaller numbers entered from (mainly) independent schools in Scotland. It is a qualification that has stood the test of time having first entered the school assessment regime in 1951 and is still considered a 'gold standard' qualification. However, it is not without its critics. It is alternately criticized for being either too narrow or too broad. Many argue that pupils taking A-levels specialize too early by cutting their focus to just three or four subjects at such an early age — a strong argument, certainly. For those studying only sciences and maths, the concern is that this may be to the detriment of their skills in extended writing — skills more consistently developed by those taking arts subjects. University tutors complain about their chemistry students' weak writing skills, while forgetting their own institution or department's role in encouraging applicants to take A-levels in preferred science subjects. It is increasingly the case that pupils will take 3 A-levels following a full 2 years of study (entries for AS-levels, taken at the halfway point after 1 year of study, are on the decline). For further study in chemistry, which subjects would you prefer? Most people I come across want chemistry of course, ideally maths and then preferably physics or maybe biology. For many students, there is simply no room left for a foreign language or other worthy subjects, such as history, which can help them to develop skills that the sciences generally do not.

Let us consider the content of A-level chemistry. Despite changes implemented by successive governments, the core chemistry content has remained largely the same and seems unlikely to change: atomic structure, bonding, periodic trends, many fundamental chemical calculations, thermodynamics, kinetics, redox, equilibria and numerous key aspects of organic chemistry (including mechanisms and spectroscopy) are mainstays of the curriculum. Content changes that have been made could easily be characterized as 'tinkering' around the edges. As an example, I taught students the concept of the equilibrium constant in terms of partial pressures, K_p, from 2006 until the reforms of 2009, and I was not too troubled by its removal from the syllabus (in my youthful arrogance, I considered it to be just the same as K_c). Recent reforms have seen the mathematical requirements for A-level chemistry increase and K_p has returned, providing an excellent basis for unstructured calculations that involve multiple steps and potential unit conversions.

Other concepts have been and gone, perhaps never to return. My research into historical assessment shows that radioactivity was a core concept in A-level chemistry from its initial design until the early 1980s, when it was incorporated into physics. Although this continuous cycle of reform may be irritating for many stakeholders, it also presents regular opportunities to review content and attempt to include modern chemistry developments. Reforms in the past 10 years have introduced ^{13}C NMR to the suite of spectroscopic techniques studied (although, frustratingly, we still have to teach that tetrachloromethane is a commonly used NMR solvent). We no longer teach the outdated magnetic model of the mass spectrometer, and some exam boards have gone as far as introducing the specific study of the time of flight method. But what about hybridization of the orbitals of carbon, the close packing of solids or the differential notation for rate equations? Arguments over subject content inevitably turn to what is felt to be missing, with many, particularly those in higher education, fervently pursuing the inclusion of their own pet concept. However, the A-level timeline is finite — around 20 months of study in total. The inclusion of something new or increasing the depth of study in a particular area must come at the expense of something else (one of the current losers in this respect is coordination chemistry). There is a delicate balance to be struck.

And so to the main point of this discussion: are A-levels easier today (non-UK-based readers should substitute their equivalent qualification)? In truth, it is extremely hard to measure difficulty. Even with past exam papers for reference, it is a challenging task to assess their relative difficulty given that this is inextricably linked to several social and contextual factors. It is certainly true that more pupils now gain A grades than in the past, although this has plateaued more recently. There are many factors that contribute to this; some are hidden in the complexities of the difficult balance between norm and criterion referencing, others are more transparent. From 1964, A-levels were purely norm referenced; 10% of candidates gained grade A, 15% B, 10% C, 15% D, 20% E and a further 20% allowed an O-level pass. In a norm-referenced system, there is an assumption that the numbers of pupils taking the exam are large enough to ensure that standards will not vary greatly from year to year. From 1987 to 2000, a purely criterion-referenced system was used. Criterion referencing sets standards against published criteria of performance. For example, a driving test is criterion referenced; candidates achieve a pass simply based on performance and not against an annual limited number of certificates available in a competitive environment.

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For a while it was possible (and even encouraged) for pupils to resit modules until they gained a good result. If they sat the first chemistry module in January of their first year of study this offered the opportunity to resit that module three times, with only the best mark being carried forward to the overall grade. In addition to this, the past 15 years have seen a revolution in the way that we access information. Past papers, mark schemes and examiners' reports are now freely available online, and social media has enabled the rapid sharing of information between exam candidates, presenting significant challenges for examiners setting coursework-type exercises. Everyone in the modern education system has facts at their fingertips; how do you design an exam for the 'Google' generation?

I had a conversation recently with an 18-year-old student who asked, “Why do exam questions have to be so hard? Why do they have to have so many twists and turns?” It would be easy to dismiss this as the usual teenage dissatisfaction with hard work (teenagers typically being minimum energy, maximum entropy systems). But it does highlight the main difference between the modern A-level and its earlier incarnations. In the past, many exams included a large proportion of questions that required simple recall; it was enough to just know a lot of chemistry. There was a lot of chemistry to learn and the very best students were able to remember, apply and link particular concepts. Thus, many pupils got by and got decent, door-opening grades by relying on memory. Memory is the first line of defence for the stressed student who is overwhelmed by the task ahead and possessing a tendency to want to just learn facts. This is the criticism I hear most often levelled at young people when they transfer to higher education. However, the world no longer needs young people who can simply remember facts; we have computers that are able to do that far more cost effectively. For the Google generation, creativity and the synthesis of new ideas that are developed through the application of knowledge and exams that assess problem solving will be far more important. So where does that leave us? I would like to think that more than 60 years after its design, the A-level in chemistry is pretty good, providing a sound basis in chemistry for pupils to build on no matter where their future leads them. It is a challenging qualification; many candidates fall by the wayside or choose never to attempt it. To remain relevant, it must keep reforming to keep up with new developments and with the needs of employers and higher education both within and beyond chemistry itself.

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