Discover Chemistry: an education partnership between Pfizer and the Royal Society of Chemistry

David N. A. Fox

ABSTRACT In July 2008, the Royal Society of Chemistry launched *Discover Chemistry*, a chemistry education partnership with Pfizer UK, to help secure a pool of talented, motivated scientists with skills to meet the future needs of employers, particularly in the pharmaceutical industry. This review describes the background to the programme, the principal objectives and the resources and activities that have been funded through this partnership.

It has been well documented that the number of students applying to UK universities for chemistry-based courses has risen steadily over the last few years. The experience in the pharmaceutical industry, however, is that, although the number has risen, students who seek career opportunities within chemistry are often insufficiently skilled in certain areas required by an ever-changing and increasingly demanding industrial environment. As the demands on chemistry graduates continue to grow, we face the real risk of a diminishing pool of suitable graduates to meet our needs for the coming decade. Before considering the possible causes of this shortfall and how they might be addressed through an education partnership, it is worth considering briefly what external factors are contributing to this challenging environment for graduate chemists.

A changing environment

Over the last decade, large pharmaceutical companies such as Pfizer have been changing the way they carry out their research activities to keep in step with the increase in complexity and uncertainty of the scientific landscape. As a result, many of the day-to-day activities that would typically have been carried out by graduate chemists are now being outsourced to lower-cost providers, many of which are based in Asia. At Pfizer, more than 30% of our synthetic effort is provided in this manner and the external chemists have become an integral part of the organisational planning within the department. This strategic move serves a number of purposes. Firstly, by diverting routine aspects of research to these providers, the overall costs of research are reduced and Pfizer employees can focus their efforts on higher-value/higher-complexity research endeavours, such as development of new synthetic routes and generation of biologically active compounds that help to advance our understanding of disease pathways. Secondly, as demands on specific programmes/research areas wax and wane, this outsourcing model provides a flexible and versatile way of adjusting the level of resource assigned to specific areas. Thirdly, the geographical location of many of these providers (India and China in particular) means that collaboration of this type provides a mechanism for expanding the intellectual capital of EU- and US-based organisations into areas of future strategic and scientific importance. Such trends are unlikely to be unique to Pfizer and over coming years a range of chemical and pharmaceutical industries are likely to make similar changes.

The effect of all this on the graduate chemist is quite significant. In particular, there is a much greater expectation that, after joining the organisation, they will develop rapidly into problem solvers, addressing the more ambiguous problems that we face in research. This requires a skill-set that is beyond what would have been demanded previously, where attributes such as scientific independence and leadership were often monopolised by the traditional team-leader, who would typically enter at the PhD intake level. There is now a greater emphasis on the need for chemists to use their fundamental scientific and mathematical knowledge to solve problems in unfamiliar contexts and to reinforce their ideas through practical experimentation. They also need to be committed to building upon their existing knowledge base and skill-set to keep up with the rapid pace of change. Given the unprecedented nature of the science, chemists are required to promote and engage in scientific challenge, recognising that effective solutions to complex problems are more likely to emerge from such debate and through productive partnerships and collaborations. In this much more unpredictable environment, those who succeed will tend to be those who are energised by (rather than feel threatened by) change and uncertainty and who can demonstrate resilience and leadership. This skill-set is a challenging one even for chemists entering the industry with PhD/postdoctoral research under their belt, but sets a foundation for a highly fulfilling and stimulating career that enables them to capitalise on their excellence in the discipline. For the chemist fresh from their undergraduate education, the challenge is even greater since they are likely to find themselves competing with more qualified chemists for these roles.

Whatever the entry point, it is vital that our UK-based education and training is geared-up to cultivate these skills and behaviours to ensure that a competitive edge is maintained in an increasingly globally competitive scientific environment.

Discover Chemistry

Early in 2008, Pfizer UK donated £600K to the Royal Society of Chemistry (RSC) to initiate a three-year education programme (with a possibility of extending for a further two years) to help ensure that the future pipeline of talent would be suitably skilled and motivated to meet the needs of industry over the next decade. Alongside the donation, a senior director from the Pfizer Sandwich Discovery Chemistry department was seconded to the RSC for a 15-month period to work with the RSC education team to help design and embed the programme of activities and resources. Within the first six months, a full-time project officer was recruited to the RSC who would work alongside the Pfizer secondee and ultimately assume responsibility for delivery of all aspects of the programme. In order to help shape the project, it was decided to consider three key areas that were likely to be contributing factors to the emerging skills gap.

Attracting talented students

Chemistry is unique in that the practical elements of the subject not only help to demonstrate the theoretical principles but also serve to excite and inspire students through a visual (and sometimes spectacular) insight into how the world around us works. It is this practical, hands-on component that often sparks the fascination in students and forms the basis of a life-long love of the discipline. As stated in the Sainsbury review of the Government's science and innovation policies, *The race to the top* (Lord Sainsbury, 2007), '*Evidence shows that pupils decide what to study at a young age, often before they are 14 years old*'. Given this, we felt it was imperative to develop resources that would serve to excite pre-GCSE students (under 16s), through active engagement in experimental work, and help bring their school curriculum to life. This review will focus largely on two of these: *Discover spectroscopy* and *Masterminding molecules*.

Retaining talented students

For A-level students (16- to 18-year-olds) looking to higher or further education to continue their studies, many factors will contribute to their choice of subject. Amongst these will be questions such as:

- How much do they enjoy the subject?
- What sort of careers does the subject lead to?
- What would their likely earning power be?

This arm of *Discover Chemistry* has focused on resources and activities that help students make an informed choice of future subject and paint a picture of chemistry careers as stimulating, dynamic and fulfilling. This article describes two specific programmes: *The design studio* and *Careers posters*.

Skills development

In the introduction to this review, we set out a future state of industry that will have high expectations of its incoming scientists. To help ensure that the available talent pool in the UK has the appropriate balance of skills, *Discover Chemistry* has invested significantly in this area of the education–training continuum. At the university undergraduate level, a *Maths for chemists* resource will provide one-stop Web support for undergraduate chemists, as it is well documented that a lack of competence and/ or confidence in mathematics is a particular stumbling block in undertaking chemistry courses. This resource, which will evolve as the user community helps shape its content and scope, might well eventually have application at A-level too. At the postgraduate level, the scheme offers travel bursaries for emerging academics to attend conferences covering areas of strategic importance as part of their continuing professional development. For schools and colleges, a flagship programme *Discover LabSkills* supports the delivery of A-level experimental skills. This review will also detail the scheme's sponsorship of the *STEM Leaders Qualification*.

Attracting talented students

Discover spectroscopy

Discover spectroscopy (see *Websites*) is an outreach activity based on the RSC *Chemistry for our future* activity *Spectroscopy in a suitcase* and has been set up at the University of East Anglia for schools in the East of England. This region was selected because it would complement the existing RSC programme, which did not extend to the East of England. In addition, there was already an active schools outreach programme being run out of the University of East Anglia. *Discover spectroscopy* has also formed the basis of year 9 (ages 13–14) Gifted and Talented workshops in the London and Eastern regions, organised through *Chemistry: the next generation* and *The chemistry network* respectively. It includes practical-based activities for both GCSE and A-level students, covering topics such as spectroscopy and chromatography as well as an introduction to 3D visualisation of molecules (using red/blue stereo spectacles that the students get to keep). The full activity involves the transport of equipment (FT-IR, UV-Vis spectrometer, UV-viewing cabinet purchased specifically for this programme) from the University of East Anglia to each of the schools with programmes delivered to the schools by outreach ambassadors drawn from a pool of trained postgraduate students. A dedicated outreach coordinator based at the university is responsible for scheduling the school visits and organising the ambassador training. The resources are designed to be flexible such that availability of IR equipment is optional and not essential. Full sets of teacher and student resources are available online at the *Discover spectroscopy* website address.

In the GCSE (ages 14–16) version of the activity, the students are introduced to the concept of thin-layer chromatography (TLC) by drawing an analogy with shoppers in a shopping centre (mobile phase and stationary phase respectively) (Figure 1). This provides an everyday way of explaining how the rate of progress of compounds up a silica plate can be influenced by factors such as solvent and the affinity of the compound for the stationary phase (e.g. silica plate).

Having grasped the concept of chromatographic separation in these basic terms, the students are then introduced to infrared (IR) spectroscopy again by relating the concept to an everyday experience (Figure 2). In this case, they are shown a football shirt (a blue and red Barcelona shirt – a universal brand) and asked to think about why they see the shirt as being

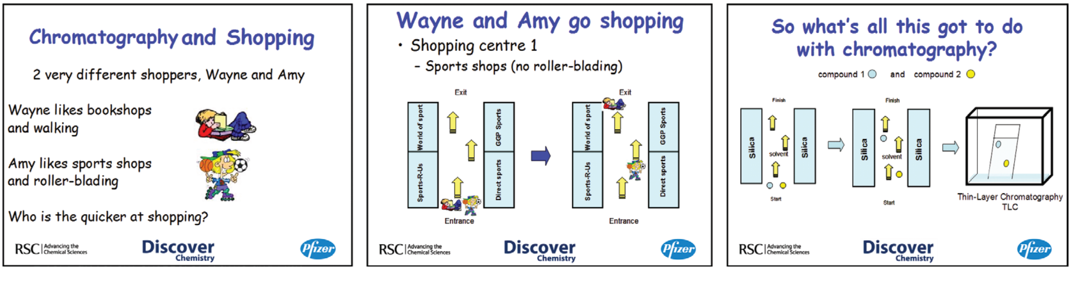

Figure 1 Introduction to thin-layer chromatography from *Discover Spectroscopy*

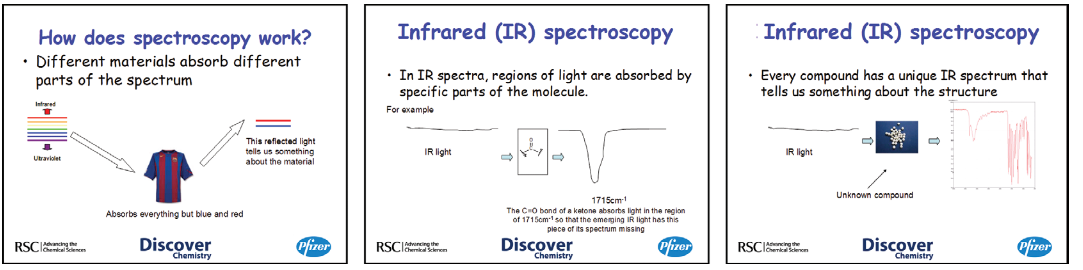

Figure 2 Introduction to infrared spectroscopy from *Discover Spectroscopy*

blue and red. With some encouragement and gentle guiding, the more able students will offer the explanation that the shirt is absorbing all colours apart from red and blue and what the eye is receiving is the light that is reflected. An alternative explanation is that all the light is absorbed and then certain colours are emitted.

At this stage, the students can make the link between vision and spectrometers, realising that the eye, in observing the shirt, is acting like a spectrometer. Taking this to the molecular level, an infrared beam that is intercepted by a molecule will emerge with components missing, depending on the nature of the molecule. For example, if the molecule contains a keto group, the IR radiation that emerges will show a reduction in intensity at around 1715 cm^{-1} as a result of absorption of radiation at this frequency by the C=O double bond. [Note: wavenumber (the reciprocal of wavelength expressed in cm) is a unit of frequency commonly used in spectroscopy.] In both cases, the properties of the light that emerges tell us something about the material that the light has encountered. This introduction then ends by explaining that chemicals contain a host of different groups that absorb at different parts of the spectrum and what results is a pattern or spectrum that is unique to that particular compound (like a fingerprint).

At this stage in the session (generally 15 minutes), the students are now equipped to solve a mystery: a death in the laboratory that has been caused by an overdose of either aspirin or paracetamol. A 'plasma sample' of the victim is provided – this is in fact a solution of aspirin in ethanol – and the students are invited to run their own TLC and IR spectra (or use reference IR spectra if the equipment is not available) to solve the mystery. Working in small groups, the students grind-up tablets, dissolve them in organic solvents, spot the solutions onto silica gel plates and then visualise the plates using an ultraviolet visualiser (under strict supervision). Where the IR spectrometer is available, there is the added buzz of having the opportunity to get their hands on state-of-the-art analytical equipment. Invariably, these practical sessions are very lively and generate a real enthusiasm to apply what they have learned to arrive at the solution.

In the final few minutes of the session, the concept of absorption of light is taken a stage further with a description of colour filters and how they are used to create 3D images (Figure 3). The students are then provided with their own pair of 3D spectacles and invited to view the stereo images of paracetamol and aspirin, recognising that these molecules are not flat but actually have shape and volume. These structures are accessible

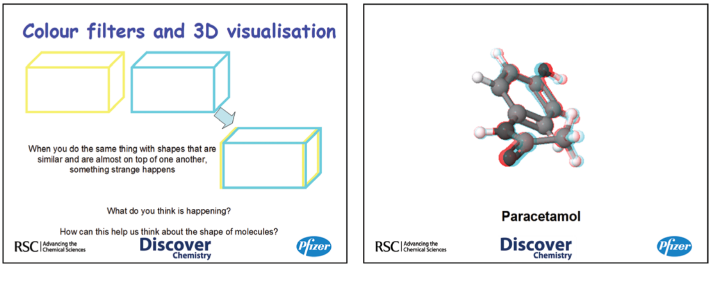

Figure 3 Viewing molecules in 3D in *Discover Spectroscopy*

from the *3D Chem* website where, amongst other things, the top 50 prescription medicines are viewable. This, in combination with the 3D spectacles, offers a clear mechanism for students to recount to their parents what they have learned and can form the basis of further investigation.

The A-level (post-16) version of *Discover spectroscopy* follows a similar structure, although, in this case, an additional section on the use of UV/visible spectroscopy to quantify concentrations is included, adding significantly to the practical experience.

Masterminding molecules

This is a game (see *Websites*) aimed at students up to the age of 16 and is being developed in partnership with Learning Science Ltd. Based largely around the code-breaking game *Mastermind*™, this interactive resource seeks to develop logic and reinforce the principles of fair testing. It also introduces the importance of concepts such as shape, polarity and drug-like properties in the discovery of new medicines. Developed initially in prototype form, the full version is expected to launch in January 2010 and will be freely available to all. The game will comprise three levels, each building on the last in terms of opportunity for rational design. At each level, the student is required to build representations of molecules by modifying four highlighted positions (Figure 4).

Once all four choices have been made, the 'molecule' is sent for testing and the student receives feedback on how close their design is to the solution. The levels are interspersed with a quiz section to test the student's knowledge of their subject and the questions will draw from a substantial database of questions relating to the various GCSE curricula. The better the student does in this quiz, the more budget they will have available for their research and therefore the more opportunities they will have to discover the solution. We envisage that this game could be used in a variety of settings. At one basic level, it represents an engaging way to reinforce the principles of rational thinking, fair testing and problem solving. Beyond this, it is a vehicle for helping to get across the concepts of shape and structure and their importance in the design and function of medicines. As such, it could form part of a broader outreach session to schools and the wider community on chemistry and its applications. There is even the potential to develop a customised touch-screen version for installation in science and technology museums or interactive centres and this option is being actively explored.

Retaining talented students

The design studio

The design studio assignment (see *Websites*), aimed predominantly at A-level students, is designed to support aspects of the A-level curriculum, such as 'How science works'. It begins with an introduction to diseases and gives a broad overview of the concepts of shape, enzyme inhibition, potency, drug-like properties and the need to achieve a balance of properties to discover effective medicines (Figure 5). The students are then invited to design and test molecules based on their knowledge of the enzyme active site and the properties of a range of chemical groups (substituents). They are able to view a molecular model of their design bound in the enzyme active site before committing to a round of testing. A sense of urgency is created, with a dial indicating how well the project is going relative to competitors, and emphasis is placed on the importance of well-judged analysis, design and hypothesis-testing. Following each

Figure 4 *Masterminding molecules* prototype screenshots

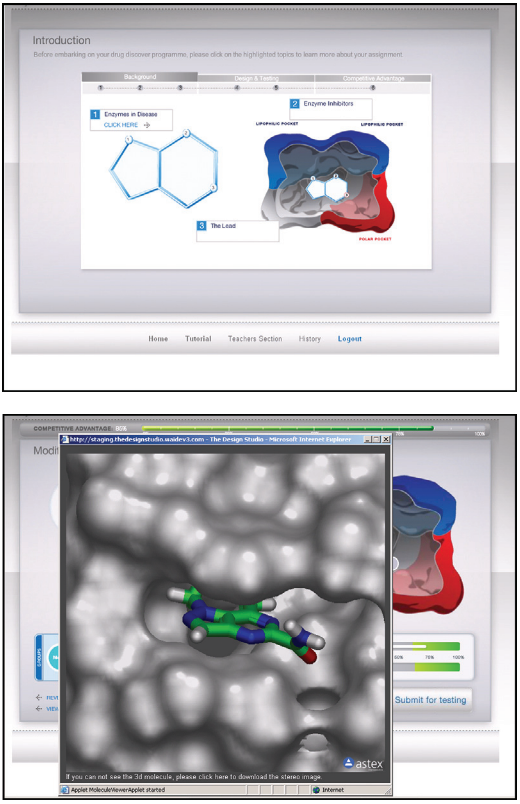

Figure 5 *The design studio* prototype site

round, the chemistry expertise of the students is tested in areas directly linked to the A-level curriculum – the more questions they get right, the more competitive their research becomes. The students can further improve their competitiveness by referring to a series of tutorials that provide additional guidance on the principles underlying the design of medicines.

When students eventually identify one of the possible solutions, they can submit their candidate molecule for clinical development. At this stage, they are faced with the reality of the challenges and costs associated with the development of medicines. This assignment is being developed in collaboration with World Archipelago Ltd and, as with *Masterminding molecules*, the final product is due to be launched in January 2010 on a free-to-use basis via a weblink. The resource is expected to have wide utility within the classroom, where it will help to illustrate the critical place chemistry has in the industrial environment and serve as a vehicle to stretch the knowledge and understanding of more-able students. Beyond the formal school environment, *The design studio* could also form the basis of an interactive education tool for the general public about the pharmaceutical industry.

A related, practical-based project has been developed recently at Pfizer in collaboration with a selection of chemistry A-level students from a local grammar school. Here, the students were introduced to the concepts of medicinal chemistry design and the influence a compound's structure has on its shape and its behaviour in biological systems. The students were then given some background information on a genuine drug discovery programme and tasked with coming up with a new design that, based on the existing data and knowledge, would be expected to have improved overall characteristics. The students with the most compelling designs were then invited onto the research site to make their compounds and to submit them to biological testing. This practical extension of *The design studio* could form the basis of a suite of activities to support classroom teaching, and work is currently underway to translate the exercise into a series of off-the-shelf A-level resources.

Careers posters

As part of the *Discover Chemistry* strategy to help students appreciate the link between their education and future career opportunities, a set of careers posters has been developed that connects chemistry with a wide range of global scientific challenges. Although originally designed for university undergraduate students, these posters have also proved popular with A-level students who have received them via the RSC-sponsored network *ChemNet*. The principle behind these posters was to take themes such as healthcare, climate change and fossil fuels and, through provocative questions, underline the unique view a chemist brings to these challenges (Figures 6, 7 and 8). The topics covered include, amongst others, energy, food and human health. These are some of the priority themes that have emerged from recent exercises such as the RSC 'roadmap' (RSC, 2009) and the EPSRC 'grand challenges' (see *Websites*) that set the direction for future research efforts and research council funding over the coming decade. The posters are available free of charge in A2 format or as a pdf file (see *Websites*).

Figure 6 Careers poster: Petrochemicals

Figure 7 Careers poster: Analytical

Figure 8 Careers poster: Pharmaceuticals

Skills development

Discover LabSkills

In January 2009, *Discover Chemistry* launched *Discover LabSkills* (see *Websites*), a two-phase scheme for A-level chemistry teachers. In phase 1, all 600 PGCE chemistry trainee teachers in the 2008–2009 cohort were provided with free access to *AS LabSkills*, the innovative practical chemistry teaching resource developed by Learning Science Ltd in collaboration with the University of Bristol Chemistry Department (Figure 9). This interactive web tool, which promises to revolutionise the way A-level practical chemistry is taught, enables both trainee teachers and chemistry students to carry out preparatory work ahead of practical classes, so maximising the quality of the time they spend in the laboratory. In particular, it enables students to really engage in experiments rather than view practical chemistry as a recipe-following exercise. In this way, the resource complements and enhances but does not replace practical classes and is expected to help develop excellence in experimental skills. This is backed up by the report of an evaluation carried out by the National Foundation for Educational Research (NFER), which can be downloaded from the website. Findings are very encouraging (see Figure 10 for an example of the quantitative data) and it is hoped that the second phase of the project can build on this success.

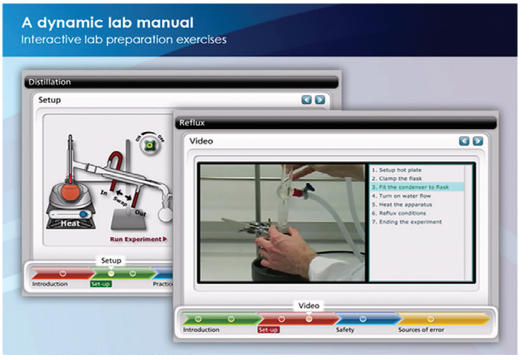

Figure 9 The *AS LabSkills* website

Phase 2 of the project began in September 2009, when a CD of the new, combined AS/A2 version of *LabSkills* was made available to the new (2009–2010) cohort of 1000 PGCE chemistry trainees via their tutors for the duration of their training year. In addition to the expanded scope, this latest version includes several new elements to help trainee teachers and students revisit practical skills.

As a separate part of this second phase, the *Discover LabSkills* project is giving all UK schools free access to a networked version of the teaching resource for a three-month period via the Web. This

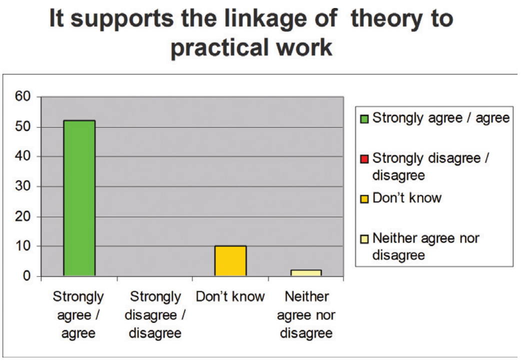

Figure 10 Selected output from the evaluation of *AS LabSkills*

will give all chemistry teachers the opportunity to see this unique and inspirational software in action. Non-PGCE trainee teachers (e.g. GTP and TTT) will be eligible to apply for access to the networked resource for the full ten months.

With an ever-increasing emphasis on the need for experimental- and problem-solving skills in the industrial environment, *LabSkills* aims to banish teachers' fears about 'letting students loose' in the lab, addressing the call for more practical science support for teachers. A component of phase 2 of this project will look to use the findings from the NFER research to leverage further funding and ensure new chemistry teachers in the future have the resources to deliver high-quality practical chemistry lessons with confidence.

Sponsorship of the *STEM Leaders Qualification*

One consistent theme across the suite of *Discover Chemistry* resources is the importance of encouraging a life-long learning approach to education. An essential component of this is the ability to understand how new skills and knowledge have been acquired in the past and applying these principles to future learning and development. This reflective learning approach can often be neglected in the drive to cover subject matter and prepare for assessments but it is a learning style that, if embedded at an early stage, can have widespread and long-term benefits. To underline the importance of this, *Discover Chemistry* has formed a partnership with the Centre for Science Education (CSE) at Sheffield Hallam University and is providing sponsorship of a new initiative, the *STEM Leaders Qualification* (SLQ) (see *Websites*). This new qualification, equivalent to a full GCSE, helps students to develop personal skills alongside their academic achievements, drawing upon the Personal Capabilities model (see *Websites*) that has been extensively researched and developed for a decade by the CSE. It is founded on three core domains of leadership – collaboration, self-belief and thinking – and supports the development of essential personal skills and capabilities relevant for life and work. Students are required to submit a *STEM Leaders Qualification* information guide, which will demonstrate their learning on one particular SLQ unit and could serve to support other students working on the SLQ. In addition, the students are required to submit a step-by-step guide, which explains to a peer group how to demonstrate/develop a particular area of leadership.

As part of the sponsorship by *Discover Chemistry*, prizes of £500 and £300 (for winners and runners-up respectively) are offered on a twice-yearly basis to the top-performing students in this scheme.

Future directions

A major emphasis for *Discover Chemistry* in its initial phase has been the design and delivery of resources to support key areas of the curriculum and learning. As the programme moves into its third year, the focus at school and college level will shift towards reinforcement of key messages about the role of chemistry in industry and the wider world, and a major strand will be to strengthen the links between teachers and industry. As part of this, the programme will team up with Chemicals Northwest and Business Education Matters Ltd (BEM) on their outreach scheme *Collaboration of Schools & Industry Science for Life*, or CoSI (S4L), which directly supports science courses in schools and colleges and helps to establish scientific links with local industry partners. It includes teacher placements into industry, industry-related work in school/college for students, student visits to industry and an effective cascade process of the older students working with younger students as a means of amplifying the impact of the visits. BEM identifies suitable industries and encourages them to work with schools/colleges, sets up and enables the necessary meetings between interested schools/colleges and industries and subsequently supports these ongoing partnerships and manages the project as a whole. As well as providing direct support for this programme, *Discover Chemistry* will look to extend the scope of this outreach model and encourage schools, colleges and industries across the UK to draw upon these successful schemes when developing their own programmes.

Summary

This article has provided an overview of *Discover Chemistry*, the chemistry education partnership between Pfizer and the RSC, outlining the drivers for Pfizer's investment in the scheme as well as the resources and activities that have been developed for schools and colleges. As with many such investments, the perennial question that arises is how to measure success and impact. On one level, the delivery of resources that target specific areas of need is one measure, although clearly this does not really get to the more important question of impact. The extent to which the resources are used and serve to help deliver the curriculum and inspire students to study chemistry would be a more effective measure, although, of course, *Discover Chemistry* is not an isolated initiative and its distinct contribution to these outcomes would be difficult to tease out. Ultimately, the most important outcome will be in 5 to 10 years' time when chemistry-based industries are trying to recruit talented and skilled scientists from the UK to meet their demands. If the talent pool is suitably enriched to address these needs then, at the very least, the objective behind the investment will have been achieved. More immediately, perhaps the most telling measure of success will be if programmes such as *Discover Chemistry* lead to a series of related investments into science education from other UK-based companies. This would suggest that they have recognised the value of this type of intervention as a way of helping to secure a pipeline of scientists in the future who possess the knowledge, skills and behaviours that they will be demanding.

References

Lord Sainsbury of Turville (2007) *The race to the top: a review of Government's science and innovation policies*. London: HMSO. Available at: www.hm-treasury.gov.uk/media/5/E/sainsbury_review051007.pdf

RSC (2009) *Chemistry for tomorrow's world: a roadmap for the chemical sciences*. London: Royal Society of Chemistry. Available at: www.rsc.org/roadmap

Websites

3D Chem: www.3dchem.com

Careers posters: www.rsc.org/Education/DiscoverChemistry/CareersPosters.asp

Discover LabSkills: www.rsc.org/Education/DiscoverChemistry/DiscoverLabSkills.asp

Discover spectroscopy: www.rsc.org/Education/DiscoverChemistry/DiscoverSpectroscopy.asp

EPRSC grand challenges: www.epsrc.ac.uk/ResearchFunding/Programmes/PhysSci/RC/ConsGrandChallengesChemSciEng.htm

Masterminding molecules: mastermindingmolecules.rsc.org (live from January 2010)

Personal Capabilities model: www.personalcapabilities.co.uk

STEM Leaders Qualification: www.rsc.org/Education/DiscoverChemistry/DiscoverChemistrySLQ.asp

The design studio: thedesignstudio.rsc.org (live from January 2010)

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