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(clockwise from left) Claire-Lise Braun, Paul Wyatt, David Smith, Russell Cox, Nick Norman, Tom Podesta, Tim Obey, Dudley Shallcross, Tim Harrison, Sue Williams, Karen Shallcross.
One of the great privileges of being Vice-Chancellor of a university as distinguished as Bristol is that one encounters so many bright, enthusiastic people and a plethora of innovative and exciting projects.

Bristol ChemLabS is an initiative of which the University is especially proud, and the people who run it are outstandingly effective. It represents a significant advance in the teaching and learning of Chemistry, both for Bristol and for the nation as a whole. It is also a pioneer in the field of public engagement, helping to inform and enthuse a wide range of people – particularly schoolchildren – in some of the most fascinating and important areas of science.

I have no doubt that Bristol ChemLabS is already exceeding expectations and that the University, the Higher Education Funding Council for England and the project’s many other partners and stakeholders will delight in its excellence.
Bristol ChemLabS

Professor Nick Norman
Bristol ChemLabS Chief Executive

The Bidding Process
In early 2004, the Higher Education Funding Council for England (HEFCE) announced an invitation for departments or consortia of departments in higher education institutions to bid for funds to become Centres for Excellence in Teaching and Learning (CETLs). In April of that year, the School of Chemistry, through the University of Bristol, submitted a bid to the Stage 1 process, the primary focus of which was to become a Centre for Excellence in the teaching and learning of practical, laboratory-based chemistry. The Stage 1 bid made a strong case for existing excellent practice but stressed that future improvements in the teaching and learning of practical chemistry would become increasingly difficult without refurbishment of the existing teaching laboratory infrastructure; a point strongly made in a University of Bristol Departmental Review in 2002. Accordingly, the Stage 1 bid requested a sum of £2m for capital projects in addition to £2.5m in recurrent funds to run the programme over the defined five-year period of CETL funding. Both these sums were the maximum for which bids could be made. The case for the laboratory refurbishment was made stronger by a commitment from the University of Bristol to provide the additional funds required to complete the refurbishment, together with further funds to re-clad and replace the windows of the School of Chemistry West Block, in which the teaching laboratories are housed. The University of Bristol also agreed to commit resources for the construction of some contiguous research space. In all, this University commitment amounted to a sum in excess of £16m.

Notification that the Stage 1 bid had been successful was received from HEFCE in June 2004. Nationally, 106 bids out of 259 were successful at this stage. The School of Chemistry was then invited to submit a bid to the Stage 2 process, providing more details, specifically about budgetary matters and addressing issues that were raised as part of the feedback from the Stage 1 process. Notification that the Stage 2 bid had been successful, and therefore that the School of Chemistry had been awarded funding to become a CETL, was received from HEFCE in December 2004 with a public announcement following in January 2005. Nationally, 74 such bids were successful. Bristol ChemLabS (Bristol Chemical Laboratory Sciences), as the CETL is known, officially started on 1st April 2005 with a planned duration of five years and is the only CETL devoted to chemistry. The University of Bristol was also successful in securing funding for another CETL housed in the Faculty of Medical and Veterinary Sciences, the AIMS (Applied and Integrated Medical Sciences) CETL.

Later in 2005, HEFCE announced that additional CETL capital funds were available and that CETLs could submit bids for up to £350k. In December 2005, Bristol ChemLabS and AIMS submitted a joint bid for £700k for additional capital projects, together with a request for further funds should these become available. In February 2006, notification was received from HEFCE that the bid for £700k had been successful and in April 2006, HEFCE acceded to a request for a further £335k in capital funding, £167.5k for each CETL. These additional capital funds have been used to establish additional teaching space by refurbishing existing 4th Floor link areas between the West and South, and South and East Blocks of the School of Chemistry as well as enabling in-fill building projects for social space on the 3rd Floor.

Aims and Objectives
The primary focus of the Bristol ChemLabS project is to engage, educate and enthuse students at all levels of experience and to create a major national resource for the teaching and learning of practical experimental science. The central aim was to create flexible, modern facilities, along with processes for the teaching and learning of the vital practical elements of chemistry.

Specific objectives outlined in the Stage 1 and Stage 2 bid documents included:
(i) The establishment of enhanced, e-facilitated, learning of practical chemistry for undergraduates and postgraduates. Central to this objective would be the development of an interactive, web-based Dynamic Laboratory Manual (DLM) incorporating elements of an Electronic Laboratory Notebook (ELN).
(ii) The construction of renewed infrastructure including professional-standard laboratories, state-of-the-art instrumentation and facilities, and materials for e-learning of modern laboratory chemistry.
(iii) The hosting of University Teaching Fellowships allowing staff to focus on educational innovation, School Teacher Fellowships for seconded schoolteachers, Continuing Professional Development (CPD) courses for chemistry educators and industrial scientists, outreach events to inspire students in pre-University education and public engagement events to inform a wider audience.
(iv) Exporting enhanced protocols and methods for learning practical sciences into other Bristol contexts.
(v) Disseminating new protocols and methods nationwide through the Higher Education Academy and the Royal Society of Chemistry (RSC).
(vi) Evaluating and devising ways of sustaining these activities, so that they may be embedded into the mainstream curriculum.

The extent to which these objectives have been realised in the first two and a half years of operation is presented in the following sections of this review.

Management Structure
A project of the magnitude of Bristol ChemLabS requires careful management and a committed cohort of staff to ensure that all the aims and objectives are met. Accordingly, a Management Board and an Advisory Board have been established, the remits of which are given below.

The Bristol ChemLabS Management Board has overall responsibility for all matters relating to the running of Bristol ChemLabS, including overseeing the performance of Bristol ChemLabS against the objectives, deliverables and milestones set out in the original bids. The membership of the Management Board is listed in one of the appendices on the CD that accompanies this report. The Board meets 2-3 times a year, is chaired by the Head of the School of Chemistry and receives reports from the Chief Executive, the Director, the Manager, the Outreach Director and the University Teacher Fellow.

The Bristol ChemLabS Chief Executive is responsible to the Bristol ChemLabS Management Board for delivery of its objectives, including its financial performance. The Chief Executive is a
Mr Paul Chin, Manager, Physical Sciences Centre, Higher Education Academy

From its inception, the Bristol ChemLabS CETL has sought to innovate and promote excellence in the teaching and learning of chemistry. The CETL has worked closely with the Higher Education Academy Physical Sciences Subject Centre right from the bidding stage to ensure strong links with the physical sciences community across the UK. By forming such close ties early on, Bristol has been able to keep the physical sciences community well informed of developments, and dissemination to the wider community is at the forefront of their ongoing activities. In addition, their vision also provides clear benefits and applications across a wider range of disciplines - and not by accident. For example, their student-centred approach to the physical refurbishment of laboratories has provided insight and advice for others seeking to re-develop their own student laboratories. This work has produced a teaching and learning environment designed for optimum use by both students and teaching staff. With the development of the new Dynamic Laboratory Manual, students are fully able to immerse themselves in the benefits of up-to-date technology that has been innovative in its design and application. The use of the DLM has potential benefits for a broader range of science disciplines to support laboratory-based work and puts students more in control of their access to learning resources. This is supplemented with a more robust approach to pre-laboratory activities and other curriculum developments which has been demonstrated in the research literature to have major educational benefits for students. Again, a point worth repeating is the fact that these developments provide exemplars for other disciplines to support innovation in the curriculum. Bristol ChemLabS has also had the foresight to consider the formal aspects of their work by building in a clear link to pedagogic research. This means that their work and development of good teaching practice will be based on sound research which can be disseminated to the wider academic community. Even at this early stage of the CETL’s development, Bristol ChemLabS is already producing a wide range of resources, expertise and experience to benefit the Chemistry and broader science communities.

seconded senior member of academic staff in the School of Chemistry and is a member of its senior management and its Planning Committee ex officio. The Chief Executive leads external relations of Bristol ChemLabS with the School of Chemistry, the Faculty of Science, the University and its other departments, the Teaching Support Unit, the Learning Technology Support Service and the Graduate School of Education, as well as the range of external partner organisations working with Bristol ChemLabS, including the Higher Education Academy, the Royal Society of Chemistry, potential industrial sponsors and stakeholders in general.

The Bristol ChemLabS Director is a seconded experienced member of staff in the School of Chemistry who leads the development of all educational matters and is responsible for the management of its core staff.

The Manager supports the activities of both the Chief Executive and Director and has particular responsibilities for all matters relating to evaluation and dissemination of the ChemLabS programme.

Both roles are supported by the University Teacher Fellow, currently a seconded member of the School of Chemistry staff, who has taken a lead role in IT and capital projects.

The Bristol ChemLabS Outreach Director, together with the School Teacher Fellow, is responsible for coordinating and running engagement activities for schools and other organisations. The financial and other administration of Bristol ChemLabS is overseen by the School of Chemistry through its Director of Administration and the University Finance Office and is therefore subject to the robust and established accounting, auditing and monitoring processes of the University. The Management Board reports to the University through the Faculty of Science and to HEFCE, the Higher Education Academy and other stakeholders. The membership of the Board is largely Bristol-based but includes representation from key external partners, including the Higher Education Academy. The membership is designed to include executive and other senior members of Bristol ChemLabS, together with senior members of the management team of the School of Chemistry, as well as undergraduate and postgraduate student representatives. Key University staff from outside Chemistry are also members of the Board. These include the Faculty of Science Education Director, the Director of the Teaching Support Unit, the Director of AIMS, the University’s other CETL, Graduate School of Education staff and the University of Bristol e-Learning Adviser.

The Bristol ChemLabS Advisory Board advises the Management Board on strategic matters and reviews the activities of Bristol ChemLabS. The Advisory Board meets annually and receives an Annual Report prepared by the Chief Executive. The membership of the Advisory Board is also listed as an appendix on the CD that accompanies this review. The Board is chaired by the University’s Pro-Vice Chancellor for Education and meets jointly with the Management Board. Its membership also includes other senior members of the University such as the Dean of the Faculty of Science, representatives of key external stakeholders and senior members of partner organisations.

Administrative support for all Bristol ChemLabS activities is provided by a full-time secretarial appointment.
Professors Tim Gallagher and Nick Norman in one of the Teaching Laboratories
Teaching and Learning

Dr Paul Wyatt
Bristol ChemLabS Director

Introduction
In most traditional undergraduate teaching laboratories, students are expected to conduct experiments without necessarily having a thorough understanding of the chemistry and procedures involved before they arrive in the laboratory. In many cases, a cursory glance at the laboratory manual is all that occurs and it is only after the laboratory period, during (an often laborious) write-up, that the student gains some idea of what he or she has been doing during the practical.

The new approach adopted by Bristol ChemLabS, principally realised through the Dynamic Laboratory Manual (DLM), has been designed to ensure that the student has a thorough understanding of the reactions, apparatus and chemicals that are to be used before the laboratory begins. Students will therefore get far more benefit from their time in the laboratory as they will actually understand what it is that they are doing at the time.

Another fundamental change which has been developed is the way that assessment is carried out. Traditionally, assessment is done remotely from the laboratory based on a script handed in by the student. The approach adopted as part of the new ChemLabS laboratory experience is, as far as possible, to assess in the laboratory itself at the time the work is being done (in-lab assessment). This type of face-to-face contact with the student has many advantages. Thus, although assessment may be short, it is rich, individual and provides immediate, and therefore more useful, feedback to the student. It also provides a much more accurate degree of assessment and precludes plagiarism.

The Laboratory Working Party
The School of Chemistry established at the start of the CETL project a Working Party chaired by the Bristol ChemLabS Director that was charged with reviewing all aspects of the existing laboratory courses. Its remit was therefore wide ranging and offered the scope for the introduction of radical and innovative developments in practice. The membership of the Laboratory Working Party was chosen to represent key teaching (and research) interests from throughout the School of Chemistry and also included the two Teaching Laboratory Managers. The current membership is included as an appendix on the CD that accompanies this review. Through their regular and frequent meetings over the last two years, the members of the Laboratory Working Party have now considered all aspects of the Levels 1, 2 and 3 (first, second and third year) laboratories, including the development of new learning, teaching and assessment methods as well as the specific content of each course.

Although work is still in progress, considerable revision of each of the courses has already taken place. Much more emphasis has indeed been placed on assessed pre-laboratory work and in-lab assessment. As a result, students are no longer required to complete a large number of post-laboratory write-ups. Considerable thought has also gone into designing practical courses that allow students to develop key experimental skills as well as developing a better understanding of fundamental chemical concepts and learning about relevant applications. The Laboratory Working Party also considered how best to ensure that the students are fully aware of the safety implications of the work they carry out.

Skill Sets and Experiments
In designing a new laboratory, there is more than one way that the experiments and associated experience might be organised. It would be possible, for example, to have an experiment which illustrated an aspect of each lecture course. Unfortunately, there are problems in synchronising the lecture and practical timetables, so that some students perform the experiment before they have had the related lecture, whilst others perform it after. A broader (and superior) approach, however, was to decide upon a set of skills that would be expected of any chemist at the end of Levels 1, 2 and 3.

Naturally, the skills from Level 1 would be built upon in Level 2 and still further at Level 3. The experiments that would illustrate and teach these skills were then designed, and working from this skills foundation meant that broadly based chemistry experiments were developed instead of the more traditional organic, inorganic and physical experiments. Although, looking through a list of experiments, some can clearly be identified as being, for example, ‘an organic experiment’ there are many that transcend this structure.

Examples include the ‘superconductor experiment’, in which an inorganic technique is used to demonstrate a physical phenomenon; the ‘Wilkinson’s catalyst’ experiment, where an inorganic catalyst is prepared and then used to catalyse an organic reaction; the ‘cycloaddition reaction’ in which physical methods are used to follow the kinetics of an organic reaction.

This approach had already been adopted by the School of Chemistry in a comprehensive re-design of the Level 1 laboratory in 2002. Bristol ChemLabS provided an ideal opportunity to build on the proven success of this approach and do the same for the Level 2 and 3 laboratories. The Level 1 and 2 courses have already started, and a list of experiment titles for these laboratories is given as an appendix on the CD along with a table of the skills sets from which the experiments were designed. Work on the Level 3 laboratory continues with an interim course having been introduced in October 2007.

The Level 2 Laboratory
There are 24 teaching weeks in the School of Chemistry and 24 experiments to be carried out in the Level 2 laboratory (the same is true at Level 1). This requires that each experiment must be able to be started and finished in one day, but for many of the existing experiments, this was not possible using procedures from the literature in which, for example, a reaction might need to be stirred for 16 hours. Thus the experiments needed to be developed and modified and even those experiments which were found in the literature and appeared to be ideal needed to be tested. A number of chemistry undergraduates, both from the University of Bristol and other institutions, were therefore employed over the summer of 2006 to work on these experiments and to modify and develop them in a way that met with the new requirements. Additionally, some third-year project students were given, as a 9-week project starting in October 2006, the task of experiment development. For example, one student was told to find a way of getting a 16-hour experiment completed in 6 hours; in fact, he succeeded in finding a way of getting three 16-hour experiments completed in 6 hours!
Summer Laboratories
In order to help make up the time that would be lost because of the closure of the teaching laboratories for refurbishment, an intensive laboratory course was introduced for Level 1 students in the final two weeks of the summer term following examinations. Although taken by Level 1 students, the material covered was actually intended to replace that which would be missed at Level 2. Students performed eight experiments during the two-week period, one every day that the laboratories were open. The course therefore marked a change both in the level and intensity of experience and quickly became known as the ‘bootcamp’.

It was realised that with such an intensive course, it was not reasonable to ask students to submit a detailed post-laboratory write-up for an experiment. Instead, students were assessed in the laboratory, filling in a pro forma which provided a structure for their oral assessment.

The bootcamp proved highly effective and was well received by both students and staff. It was therefore agreed to hold similar courses in subsequent years. Intensive laboratory courses offer a number of advantages. Students clearly benefited from spending sustained periods working in the practical laboratory. They became familiar with both the laboratory environment and more confident about the equipment and techniques that they were using. Freedom from other teaching meant that students were also able to focus completely on their practical work.

However, it is not appropriate to deliver entire practical courses in such an intensive way. Many first-year students have had very little practical experience at school or college and introducing them to the laboratory gradually through the usual timetable is a necessary primer before any intensive period of laboratory work. The best time to have the bootcamp was thus determined to be at the end of the first year.

The Level 1 practical course is intended as an introduction to experimental techniques and methods in chemistry and is taken by a significant number of students following courses such as Biochemistry and Pharmacology. The bootcamp laboratories mark the transition to Level 2 and are therefore designed only for those first-year students who will be going on to do chemistry the following year. In designing experiments for the bootcamp there were two criteria. Firstly, it should introduce students to techniques they will encounter in the main Level 2 laboratory. Secondly, the experience should be fun and help to motivate students, making them look forward to the practical work to come in their second year. The intention is that chemistry students at Bristol University should end their first year on a high.

The Dynamic Laboratory Manual
The innovative Dynamic Laboratory Manual, developed in collaboration with Learning Science Ltd, is an essential element of the new laboratory courses. It incorporates several key features that are intended to help students prepare thoroughly for the time that they spend in the practical laboratory. As well as containing rich media such as video and animation, the Dynamic Laboratory Manual also provides the means to assess the students on their understanding and provides them with immediate feedback.

Background material and references are included for each experiment whilst formative self tests help students develop their understanding. Summative multiple-choice questions are also included, enabling both students and staff to identify areas where more support is needed. These tests also help to ensure that students take advantage of the preparatory material included in the Dynamic Laboratory Manual. Both the formative and summative tests are assessed online with associated feedback designed to help promote student understanding. Multiple-choice and multiple-completion safety assessment is also included to provide scenario-based safety training. Also integrated into the Dynamic Laboratory Manual are interactive virtual instruments and equipment, together with video clips of key practical techniques to help students gain confidence in various techniques and methods before they enter the laboratory. These elements combine to form a techniques manual that will be available as a resource throughout a student’s undergraduate career and beyond. The Dynamic Laboratory Manual is also able to function, in part, as an electronic laboratory notebook, and can be personalised to include a student’s individual data.

The Dynamic Laboratory Manual therefore provides the student with everything they need to know about a practical experiment before they enter the laboratory. Access to the Dynamic Laboratory Manual can be gained from any Internet connection. It is anticipated that students will typically access the resource from computers in their own rooms as they prepare for their practical work. It will, however, also be accessible from the computers at each bench in the laboratory so that students can follow the instructions and resources that accompany each assignment as they perform the experiment.

The Dynamic Laboratory Manual became available for Level 1 students in February 2007 when they entered the new laboratories and has been available for Level 2 students from October 2007. The Level 3 version will follow in October 2008. A demonstrator version will also be produced to assist postgraduate and staff demonstrators with in-laboratory assessment.

A more detailed description of the Dynamic Laboratory Manual that includes images of some of the learning features is included on the CD that accompanies this report. Also included is a link to the interactive demonstration version of the Dynamic Laboratory Manual on the Bristol ChemLabS website.

The Staff–Student Interface
The Dynamic Laboratory Manual operates via two pieces of sophisticated software: the freely available virtual learning environment ‘Moodle’ and a bespoke School of Chemistry system called ‘Marks & Absences’. Using free software such as Moodle as a platform should ensure that the Dynamic Laboratory Manual can be readily adopted by other departments or universities. Marks & Absences is extremely powerful largely because the database can be interrogated in so many different ways; a given student can see exactly what experiments were (or will be) done on a particular day and all the associated marks, whereas a member of staff (or postgraduate demonstrator) can see exactly which students he or she needs to assess. The two pieces of software work seamlessly so that, through the visual interface of the Dynamic Laboratory Manual, a student would be unaware that there were two independent programmes. A student who starts to work through pre-laboratory work has several things to achieve. The first of these is to work through the experiment information which is structured and may include videos or a simulation of the apparatus that is to be used. The student then has two assessments to undertake. The first of these, a pre-lab test, is an online assessment to determine how well
the student has understood the work. The questions asked are "banked" so that another student doing the same experiment will be asked a different set of questions. The pre-lab assessment counts towards the final mark for a given practical but the weighting will vary depending on the nature of the work. The student must also undertake an online safety and risk assessment dealing with the safety issues relating to each experiment. Students have two attempts to pass this test. A different set of questions will be used for the second attempt and, again, a different student will be asked different questions to minimise collusion.

A staff member (or postgraduate demonstrator) will have a page in their version of the Dynamic Laboratory Manual with a list of the students undertaking a particular set of experiments. A pass from a student gives rise to a green flag next to his or her name whereas a fail generates a red flag. It is easy to see at a glance if anyone has failed the test. A student who fails must speak about the safety issues to a member of staff, who must then be satisfied that the student understands these issues before allowing them to start in the laboratory. It was felt that human intervention if a student had failed twice was a better solution than allowing a student endless attempts at getting it right.

**Level 3 Experiments**

Both Level 2 and Level 3 experiments were identified in the early stages of the working party so that the course was designed across years as well as between Sections. Once this was done, the Level 2 experiments were worked out in detail. A similar procedure is being adopted for Level 3.

It was envisaged from the very start of ChemLabS that the benefits of the project would extend far beyond the School of Chemistry at Bristol. Those of us from other UK universities, who have been watching ChemLabS develop, are excited by the educational innovations that the project is bringing to practical chemistry. Although we may all be aware of recent advances in e-learning and information technology, many chemistry departments still have traditional paper-based laboratory manuals and laboratory reports. It is not surprising therefore, that we look with envy at the new online interactive laboratory guide known as the Dynamic Laboratory Manual, DLM, that has been developed in Bristol. This interactive resource mixes virtual experiments with video clips and detailed background material and allows in-lab assessments to be carried out. Having seen the DLM in action I am in no doubt that it represents a step-jump in the quality of the student's experience of practical chemistry. Clearly we would want this enhancement of practical chemistry to be disseminated as widely as possible and it is pleasing, therefore, that one of the aims of the Centre for Excellence is to ensure that practices can be shared with others. Indeed the ChemLabS Advisory Board has already discussed this issue and suggested possible mechanisms for efficient dissemination. It is good to know that a demonstration version of the DLM is now available to the wider community and that the benefits of ChemLabS will be presented at the next Heads of Chemistry UK meeting in late 2007. I have no doubt that the ChemLabS project is setting a new benchmark in the teaching of practical chemistry and it is fantastic that all other UK chemistry departments will be able to benefit from its success.

**Professor Steve Chapman, Chairman, Heads of Chemistry UK**
The capital part of the Bristol ChemLabS project began during the summer of 2005 when the University approached architects and city planners regarding possible changes to the external appearance of the School of Chemistry. It was recognised that the need for fume hoods on Floors 5 and 6 of the West Block, which houses the undergraduate teaching laboratories, would require considerable extra equipment on the roof. The University appointed architects and engineers to draw up preliminary plans around this time. Architects from Kendall Kingscott produced preliminary drawings of the existing and planned laboratories, while engineers from Silcock Dawson estimated the extent of the requirement for air-handling equipment, and an overall budget for the project was drawn up. Capita Symonds were appointed to manage the project on behalf of the University.

During the autumn of 2005 consultations with the School of Chemistry took place and small groups of chemistry staff were formed as the main contact points for the architects and engineers, although most communication was via the University Capital Projects Office. The City Council granted planning permission during late autumn 2005.

The first work carried out was the construction of scaffolding around the outside of West Block. West Floors 5 and 6 were officially cleared and vacated by the School of Chemistry in mid-December 2005, and in early January 2006 a specialist contractor was appointed to strip out the interior. At the same time, the University appointed Cowlin as the main contractor for the construction work and the primary Cowlin site was constructed in the School of Chemistry rear car park. During the early part of 2006 consultations continued about the fixtures and fittings in the laboratories, and the University issued outcome specifications for items such as fume hoods, benches, lighting and other services. In collaboration with School of Chemistry staff, architects and engineers, these were modified and finalised. School of Chemistry staff traveled to several other university chemistry laboratories and manufacturers in order to ensure that best practice was followed.

Cowlin started the construction phase of the project during spring 2006. This involved the removal of all windows from West Block and their replacement, the construction of a seventh floor to the building to contain all the air-moving equipment, and the installation of the services for the teaching and research laboratories: power, gases, and air-supply and extraction. Cowlin appointed Network Solutions as their sub-contractor to build the benches, and Mach-Aire to supply and fit the fume hoods.

During the summer of 2006, meetings began to coordinate the activities of Network and Mach-Aire, along with other contractors, to ensure that all of the sub-components of the laboratories worked well together and met the agreed specifications. Both companies worked well together and met the sub-components of the laboratories.”

The remit that they spread the good news to other chemistry departments. This has started to happen and it is very good news.

The two most important factors are (i) the radically new approach to practical work involving an obligatory virtual run-through on each experiment with a quiz that must be answered successfully before the student is allowed to carry out any practical work and (ii) the enthusiasm, dedication and unity of the staff and the demonstrators making the new scheme work. In many departments, staff members who work on practical courses are regarded as the lowest of the low, but at Bristol everyone from the Head of Department to research students is involved. This is partly because of the way the department operates but also because the novelty and transparent effectiveness of the new approach appeals to everyone.

A separate but important aspect is the quality of the new laboratories. They have been designed and built to the highest standard with their role in student practical work being the point of judgement at each step. As a result the students greatly enjoy working in them and both staff and students find it natural to work together.
An Overview of Outreach Activities
During the first two years of Bristol ChemLabS a considerable number of Outreach activities have been undertaken, engaging people from 4 to 84 years of age. These activities encompass four main areas namely primary schools, secondary schools, teachers and the wider community. Full details of all the many activities and events (past, present and future) are available in the Outreach section of the ChemLabS website at http://www.chemlabs.bristol.ac.uk/outreach/. The considerable increase in all aspects of Outreach activity has been facilitated by the appointment of the School Teacher Fellow for the duration of the CETL programme following an initial one-year secondment from his school since it was quickly evident that this was the best way to make full use of the available resources rather than to have a series of seconded teachers. The advantages of having a School Teacher Fellow have been reported in a preliminary paper and will be evaluated again during the CETL period.

Working with Primary Schools
This activity constitutes a more unusual venture by an HEI science department, but one which has proved very successful both through engagement in competitions such as Chem@rt and online quizzes or through visits to schools. The primary schools visit programme involves taking around £4,000 worth of equipment and two or three postgraduate chemists, converting a classroom into a makeshift laboratory for the day and running a circus of practical experiments with the pupils and staff. The running costs are about £680 to engage the entire school via a science assembly and around 65 Years 5 and 6 pupils for a day. Around 25 visits have been undertaken to date, ranging from the South West to London and Kent and with bookings up to 16 months in advance now being made. A list of these and other Outreach events are presented in the tables in the appendix on the accompanying CD.

Working with Secondary Schools
The work with secondary schools had and continues to include many school conferences, spectroscopy tours, lecture demonstrations, practical workshops, summer schools and competitions which have engaged many thousands of students. ChemLabS has organised events from Wales to Central China and is currently working with the City of Bristol Local Authority as part of the RSC Chemistry for our Future project to increase science uptake by inner city school students.

Working with Teachers
Bristol ChemLabS has engaged in a number of teacher training activities ranging from those within the School of Chemistry to working in partnership with several Regional Science Learning Centres, the National Science Learning Centre and the Pan-European Science on Stage international science teachers’ conference in Grenoble. These courses range from work on climate change and solar cells to teaching practical chemistry work to non-chemist chemistry teachers. Teachers accompanying school students at events also get a form of CPD by diffusion!

Professor Dudley Shallcross, Bristol ChemLabS Outreach Director
Mr Tim Harrison, Bristol ChemLabS School Teacher Fellow


After a troubled few years, the prospects for chemistry in UK universities are starting to look brighter. The number of students applying to study chemistry degrees has been increasing in recent years and several universities are now looking to reopen chemistry departments and restart their chemistry degree programmes in order to accommodate this demand.

Yet in spite of these recent successes and its position as a strategically important academic discipline, chemistry remains vulnerable. The number of students studying chemistry may be increasing, but is still nowhere near its highest point. Unfortunately, chemistry is still perceived as being hard. Many of the country’s most promising students are therefore drawn into other subject areas even though they offer neither the intellectual nor the financial rewards that are available from a career in science.

As a society we need to recruit and train the large numbers of well-qualified chemistry graduates that are required by employers in both the scientific and non-scientific sectors.

One of the reasons for the recent upturn in the fortunes of chemistry has been the collaboration between schools, universities, industry and professional bodies, such as the Royal Society of Chemistry, in offering coordinated outreach programmes that demonstrate the opportunities and rewards that come from studying chemistry at university. It is vital that such activities continue. Also central to the ambition for continued future growth is the need for chemistry departments to develop innovative teaching methods that are relevant to the way today’s students learn, so that universities can offer stimulating and attractive degree programmes that will appeal to a wide cross section of young (and in some cases, older!) people.

The Bristol ChemLabS project addresses each of these issues. Its extensive outreach programme has been an incredible success. The appointment of a School Teacher Fellow has proved to be such an effective model for promoting engagement with students of all ages that it has been adopted by the Royal Society of Chemistry as one of the core initiatives of its HEFCE-funded Chemistry for our Future project. The developments in the teaching and learning of practical chemistry set a new standard for laboratory science. Innovations such as the Dynamic Laboratory Manual and the use of new assessment methods offer students an unparalleled opportunity to develop key practical skills, as well as enhance their knowledge and understanding. The standard of the teaching laboratories is exceptional and the level of equipment would not be out of place in a research environment.

Bristol ChemLabS and the Royal Society of Chemistry are committed to engaging with partners and stakeholders to ensure that as many students as possible can benefit from the results of this success.
Bristol ChemLabS, AIMS and Outreach

ChemLabS and AIMS (Applied and Integrated Medical Sciences) are the 2 HEFCE-funded Centres for Excellence in Teaching and Learning in the University of Bristol.

Outreach was an important theme in both CETL bids, which included initiatives designed to build on an already firm foundation. The CETL awards allowed the respective departments (Chemistry – ChemLabS; Anatomy & Physiology – AIMS) to invest in outreach, providing funding for both staff and facilities.

ChemLabS funded a School Teacher Fellowship, in the person of Tim Harrison, while Professor Dudley Shallcross, with a distinguished track record in schools outreach and CPD, became Director of Outreach. Tim Harrison, an experienced science teacher, provides a link between chemistry at university and in schools, and has set up summer schools, A-Level practicals, science workshops and conferences, for both students and teachers.

The CETL projects have facilitated a collaboration between departments in two different faculties, coming together to provide a wider perspective on science outreach. In practice, AIMS has been able to draw on the repository of experience, expertise and the links with local schools that ChemLabS have built up. ChemLabS/AIMS outreach has been supported by Widening Participation, attracting initiative bid funding for pilot visits to schools. In 2007, the CETL-funded Mobile Teaching Unit has started to be used for joint ChemLabS/AIMS visits to local schools, and to the Cheltenham Festival of Science.

Public engagement, including schools outreach and CPD as well as dialogues with the public about academic research, is important to the University, bringing benefits to the wider community as well as enhancing the experience of staff and students. Other bodies, such as the Royal Society, echo these sentiments and promote relationships between academia and schools; to quote from their website: ‘Real-life professionals are the best advertisements for careers in science, engineering and technology’.

Dr Alice Roberts, Lecturer, Department of Anatomy, University of Bristol

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Dr Alice Roberts, Lecturer, Department of Anatomy, University of Bristol
**Working with Others**

A range of additional activities undertaken is listed below:

(i) The RSC consulted with Bristol ChemLabS in preparation for the appointment of four School Teacher Fellows to be spread across England and Bristol ChemLabS was involved in their appointment and training. Bristol ChemLabS is also working on a number of strands of the HEFCE-funded, RSC administered Chemistry for Our Future project, including the strand which involves Better Use of Labs; a comparison of ChemLabS use with that of the purpose-built laboratory created at Sheffield.

(ii) In the spirit of cooperation, a cluster of the Outreach workers in the Chemistry Departments at the Universities of Bristol, Warwick, Manchester, Southampton and Nottingham has been formed to share good practice. Cooperation with staff at the Universities of Cardiff, Plymouth and Brunel also exists.

(iii) Internationally, a joint summer school has taken place with Trinity College Dublin and chemistry promotion has been discussed with the National University of Singapore and Wuhan University, China. Universities in Slovenia, Turkey, The Netherlands and Hungary are applying for funding for joint Outreach work with Bristol, and ChemLabS has begun to work with representatives of the Ministry of Education in Brunei and expect to run teacher training courses in practical chemistry later this year as a prelude to much greater involvement in chemistry outreach.

(iv) Along with the AIMS CETL, ChemLabS has worked together to pilot the use of the Mobile Teaching Unit in schools' Outreach. In its first pilot, over 750 students and around 20 teachers were engaged by three University of Bristol staff members in one day.

(v) Several articles have been published or are in print that publicise the Outreach work at primary or secondary level in UK and international journals. These are listed as an appendix on the CD.

An unforeseen success of the Outreach work has been that over 100 postgraduate (PG) chemists from the School of Chemistry have been available for working with school students. They report very positively on their experiences and several overseas postgraduates are considering carrying on such work when they take up postdoctoral or other positions in their countries of origin. All postgraduate chemists have been trained through the Science and Engineering Ambassador Scheme (SEAS). Evaluation of the Outreach work (see also Section 7) is undertaken using several methods. In-house and external (e.g. Aim Higher) questionnaires with students and/or teachers have been used on a number of occasions.

Unsolicited complimentary e-mails, conversations with teachers, technicians, participating students and others contribute to the drive to increase further the quality of experience. For example, several schools have reported a doubling of A-Level Chemistry uptake by students having had experience of Bristol ChemLabS. Requests for repeat events and invitations to national events such as science festivals also reflect prior appraisal by organisers. Appraisal of some teacher training activity has been done by RCUK (via an Ofsted Inspector) and by Professor John Holman (‘Science Tsar’). The time put aside for regular reflection has been highlighted by Professor Kathy Sykes, Kohn Award winner in 2006. Further evaluation by others resulted in Dudley Shallcross and Tim Harrison being presented with the inaugural University of Bristol Science Faculty Engagement Award in 2007.

**Future Plans for Outreach**

Plans include the commercialisation of many outreach activities particularly with regard to long-term sustainability. This includes the use of the undergraduate laboratories on Wednesdays throughout the year for A-Level and GCSE practicals and workshops, as well as week-long Chemistry Programmes for international students in schools from China, Singapore, Australia, India and the USA. These will sit alongside other University-desirable activities. In 2008 it is hoped to have developed holidays for alumni and other members of the wider public who would come into the laboratories for weekend activities. Bristol ChemLabS also featured in Bristol's Engaged Universities Beacon application. A financial model has been devised that will allow all of these activities to be properly costed, ensuring that the costs to Bristol ChemLabS, or in the longer term, the School of Chemistry, can be recovered. The level of activity projected has resulted in a business plan being drawn up to ensure that funding for a School Teacher Fellow and others continues after the end of CETL funding.
Dissemination and Publicity

Dr David Smith
Bristol ChemLabS Manager

Effective dissemination of all the work carried out by Bristol ChemLabS is essential in order to ensure the success of each of the elements of the ChemLabS project. Thus Bristol ChemLabS is affiliated with a number of other organisations and groupings, providing efficient routes for dissemination. Within the higher education community, these partnerships include the Physical Sciences Subject Centre of the Higher Education Academy, as well as individuals at other universities across the UK. Links with professional bodies such as the Royal Society of Chemistry, the Association of British Pharmaceutical Industry and the Society of Chemical Industry (all of which have membership on the Advisory Board) provide further routes for dissemination.

In addition to the strong collaboration with organisations such as the Science Learning Centre and Bristol City Council, Bristol ChemLabS plays an active role in the Royal Society of Chemistry’s Chemistry for our Future Project, providing a coordinated focus for dissemination of Outreach activities.

Bristol ChemLabS has also been working closely with the AIMS CETL at the University of Bristol in order to maximise the opportunities for dissemination of activities both within the University of Bristol and further afield. A joint opening event is to be held in November 2007, with facilities in both CETLs formally launched by Professor David Eastwood, the new chairman of HEFCE. Bristol ChemLabS, along with AIMS, is also a member of the South West CETL cluster, facilitating dissemination to those outside the scientific community. Bristol ChemLabS and AIMS have also placed a joint advertisement in the House of Commons magazine in an attempt to raise the profile of both CETLs’ activities to a wider audience of potential decision makers.

Key stakeholders have also been invited to visit Bristol ChemLabS, either as part of the first Stakeholders’ Conference held in May 2005, or through a programme of individual visits. The opening of the new laboratory facilities will provide many further opportunities for dissemination and a further Stakeholder’s Conference is planned for 2008.

Details of the many meetings, conferences, seminars and publications that have highlighted the activities of the Bristol ChemLabS team are given in the appendices on the CD that accompany this review.

Professor Kathy Sykes, Collier Professor of Public Engagement in Science and Engineering, University of Bristol

Hands-on experience is an essential ingredient of a proper education in science. The chance to perform real experiments engages and excites. It leads to a better understanding of both fundamental concepts and applications and helps in the development of technical and transferable skills. As an academic community we need to be able to offer proper opportunities for our young people to perform real experiments — whether it be pupils in primary schools who are just starting out on their formal education or secondary students seeking the qualifications and skills to prepare them for higher education or careers in the outside world. It is essential that as professional scientists and educators we offer a genuine and stimulating experience of practical science. Only in this way will we ensure that future generations have the scientific knowledge and understanding necessary for our ongoing development as a society.

The Bristol ChemLabS Centre for Excellence in Teaching and Learning has already made a significant contribution to this effort. Through its extensive outreach programme, Bristol ChemLabS has engaged with many thousands of students of all ages and experiences, visiting primary and secondary schools and colleges in both the state and independent sectors, as well as hosting events designed to inspire and raise aspirations and to provide curriculum support. Its work in offering continuing professional development for teachers and its collaborations with other organisations will ensure that the impact of Bristol ChemLabS will be both long lasting and widespread. It acts not only as a beacon for outreach within the University of Bristol but also across the wider higher education sector.
Evaluation Strategy

Dr David Smith
Bristol ChemLabS Manager

Effective evaluation of all of the activities associated with the Bristol ChemLabS CETL project is both necessary and desirable. HEFCE and the Higher Education Academy have both identified a number of important reasons for such evaluation, and on-going evaluation provides important information for continuous development and improvement, ensuring that the project can build upon both expected and unexpected outcomes. Evaluation is also important in assessing the achievements and impact of the ChemLabS project, so enhancing knowledge and informing future developments in teaching and learning both within the University of Bristol and the wider higher education community. This evidence is useful for the further development of both the teaching of practical chemistry in particular and education in general. Evaluation is also essential to ensure accountability and to demonstrate to both HEFCE and the University of Bristol, as well as other stakeholders in the wider community, that the investment has been both worthwhile and effective.

A framework has therefore been devised to ensure the effective evaluation of all aspects of the Bristol ChemLabS project. The framework addresses each of the themes that must be addressed in the two-year Interim Self-Evaluation Report that is required by HEFCE and includes strategies for the evaluation of all aspects of the project, from experience of the new teaching laboratories to the effectiveness of Outreach activities. It includes the use of both qualitative and quantitative data and will draw upon information and experience from before and after the establishment of Bristol ChemLabS. The implementation and on-going development of the framework is overseen by the Evaluation Working Party whose membership is listed as an appendix to the Interim Self-Evaluation Report.

Central to the strategy is the involvement of undergraduate and postgraduate students, as well as members of staff from across the School of Chemistry. Focus groups have been established for each year group of undergraduate students and the views of these focus groups have been especially useful in informing the team working on the development of the Dynamic Laboratory Manual. Separate groups of postgraduate students and staff from outside the direct ChemLabS team are shortly to be convened now that the teaching laboratories have reopened. In future, it is expected that a focus group of employer stakeholders will also be established in order to evaluate the effectiveness of the Bristol ChemLabS project on improving the practical skills of graduate chemists from the University of Bristol. Meetings of the focus groups are coordinated by external facilitators in order to ensure that members feel able to provide honest and critically constructive views of the project.

Spot interviews have also been conducted with undergraduate students working in the new laboratories. Performing such interviews on a regular basis will allow an assessment of how students’ impressions and experiences change with time as the new teaching laboratory course becomes embedded into the curriculum.

Student questionnaires have long played an important part in the evaluation of the effectiveness of teaching and learning across the School of Chemistry, and those for the practical course will form an important source of information for the evaluation process. A comparison of student achievement will also provide quantitative information about the impact of the Bristol ChemLabS developments on undergraduate teaching. It is not anticipated that the overall level of achievement, as measured by the marks obtained by students, will necessarily change, even though the nature of the assessment in the new laboratory course is now significantly different to what has gone before. It will nevertheless be important to consider the effect of the developments on the motivation and therefore attendance and participation of students.

The impact on the wider University of the developments in both the Bristol ChemLabS and AIMS CETLs will be evaluated by textual analysis of individual activities. Interviews between staff involved in each CETL and with senior University staff such as Faculty Education Directors will also allow an evaluation of how much other subject areas have been able to learn from the activities of each CETL. In addition, the interviews will demonstrate whether the CETLs have caused a change in University policy and practice and raised the profile of teaching-related activities in reward, recognition and promotion. In each case, the involvement of both CETLs in these activities will provide an invaluable comparison of methods and impact.

An important element of the evaluation strategy is the appointment and involvement of Dr Stuart Warren, of the Department of Chemistry at the University of Cambridge, to act as an External Evaluator. The role of the External Evaluator is to provide informed and unbiased comment on all aspects of the project, including the aims and objectives, the process and structure, the educational developments and the academic standards achieved. Dr Warren will therefore have responsibilities in each of the areas highlighted by HEFCE and the Higher Education Academy. He will be expected to perform independent and impartial evaluation, as well as helping the ChemLabS team in its own evaluation. It is not intended that Dr Warren be involved specifically in the initial development but will instead help in evaluation at various intermediate stages throughout the project and at the end of the formal period of CETL funding. As a senior academic chemist, Dr Warren has significant experience, and will therefore be in a strong position to compare subject-specific practice and achievement within the ChemLabS with that at other higher education institutions both in the UK and worldwide. He is well qualiﬁed to consider the content and delivery of the practical courses and understands the challenges involved in engaging future generations of chemists through outreach activities.

HEFCE Interim Evaluation

In July 2007, the University of Bristol submitted to HEFCE a joint interim self-evaluation report for both the Bristol ChemLabS and AIMS CETLs. The two CETLs focus on innovation in the different academic disciplines of Chemistry and Medical Sciences. Nevertheless, there are many parallels between the activities of the two CETLs. Some of the challenges faced are common to both projects and there are also some areas of joint activity, such as the operation of a mobile teaching laboratory for outreach events. Producing a combined self-evaluation report allowed comparisons to be made between the two projects, enabling the CETLs to learn from the experiences of each other.
The self-evaluation report is included on the CD that accompanies this review. It includes a section describing the effect that the two CETL projects have together had on learning and teaching within the University of Bristol as a whole, as well as an analysis of the impact of the projects on the University’s reward and recognition processes. The report also contained separate sections reflecting upon the activities of the individual CETLs. These individual sections focused on the particular themes of student experience, connections with external partners and the internal strategic impact, together with a critical analysis of the lessons learned so far and the unintended consequences.

**Educational Research**

In addition to the pedagogic research that forms part of the inherent evaluation of the core activities of the project, members of the Bristol ChemLabS team are also engaged in wider ranging educational research projects. Some of these, including those focusing on the role of the School Teacher Fellow, have already been published. The Bristol ChemLabS team is also developing partnerships with both internal and external researchers, including members of staff from the Graduate School of Education at the University of Bristol and the Centre for Excellence in Experiential Learning in Natural and Environmental Sciences at the University of Plymouth.
Fundraising and Commercial Activities

Professor Nick Norman
Chief Executive, Bristol ChemLabS

An important part of both the Stage 1 and Stage 2 bids to HEFCE to become a CETL was to demonstrate that consideration had been given to long-term sustainability. Thus, whilst the HEFCE (and University of Bristol) capital and recurrent funding would provide the initial investment for Bristol ChemLabS over the five-year time frame of the CETL programme, its financial viability beyond that time was important to demonstrate.

As described in the preceding sections, the primary focus of Bristol ChemLabS is to provide an excellent environment for the teaching and learning of laboratory-based practical chemistry for undergraduates. It is the responsibility of the School of Chemistry to provide and maintain the best possible environment. However, the level of initial investment in the construction and, in particular, the equipping of the new teaching laboratories has been to such a degree that additional sources of income will be needed to maintain the operation at its starting level. It is in this regard, and indeed with regard to enhancing further the laboratory experience, that additional financial support is being sought.

A key concept in seeking external support is that of ‘added value’. Thus as stated above, it is the responsibility of the School of Chemistry to maintain a well-found laboratory in which to educate undergraduate students and it is important that this message is clear to potential donors. Nevertheless, the reality of the situation is that the level of initial investment in new laboratory equipment and instrumentation has been to such a degree that the School will only be able to maintain a certain, albeit high, level of provision without long-term external support. Added value goes beyond mere maintenance of provision, however. Additional resources will enable even more ambitious activities to be undertaken which will enhance the student experience still further. To date, a number of carefully selected potential commercial supporters (stakeholders who have a key interest in the training of undergraduates to the highest possible standards) have been invited to visit Bristol ChemLabS and during their visit, they have received presentations from senior ChemLabS staff and discussions have taken place about how relationships with companies can be developed for mutual benefit. These discussions have ranged widely and the types of support which have been considered include not only cash donations but also equipment/instrumentation purchase by the company and provision of an income stream through commercial use of the teaching laboratories for industrial training and Outreach activities. Furthermore, the fundraising has been linked to the University of Bristol 2009 Centenary Campaign (ChemLabS is one of around 20 University projects highlighted in the Campaign). Efforts are therefore coordinated with the University of Bristol Campaigns and Alumni Relations Team, including approaching individuals such as alumni for financial support. It is important to recognise that sponsorship is not a one-way street and that whilst the benefits of sponsorship are clear for ChemLabS, the benefit to the sponsor is just as crucial. With this in mind, a gift recognition list has been drawn up which clearly states what benefits accrue to the sponsor for a given level of investment.

In addition to the use of the teaching laboratories for School of Chemistry undergraduates, it is planned that the laboratories will be used for a broad range of Outreach and public engagement events. These activities are described in detail in the section on Outreach but it is important that in the long term, all Outreach/Engagement becomes financially self-sustaining. A detailed Outreach business plan has therefore been prepared in which all activities are fully costed and priced. It is expected that by the end of the initial five-year CETL period, Outreach/Engagement will not only be self-sustaining but will provide an income stream to support other ChemLabS activities.

Commercial opportunities for Bristol ChemLabS are also being considered. One aspect focuses on the wider use of the teaching laboratories, as highlighted earlier, in terms of potential industrial use (for training and other activities) and use for Outreach/Engagement activities. Indeed, a pilot training course for GSK industrial placement students has already taken place. The laboratory equipment is occupied by Bristol undergraduates for 26 weeks of the year and even during this time, they are not used on Wednesdays; to do nothing with the laboratories for what amounts to half a year is a waste of resource. In addition to laboratory usage, there are a number of other possibilities being considered for future commercial development. Primary amongst these at present is the potential to develop a version of the Dynamic Laboratory Manual for A-Level practical courses and discussions are underway with the A-Level exam boards, Learning Science Ltd and the University of Bristol Research, Enterprise and Development (RED) office. Bristol ChemLabS is already a registered Trademark.

Dr David Lathbury
AstraZeneca

It is a pleasure for me to support such an exciting initiative as the Bristol ChemLabS project as a member of its Advisory Board. At AstraZeneca, and within the wider pharmaceutical industry, we have significant interest in the capability of UK universities to produce chemistry graduates with a high level of practical skills. The new facilities at Bristol coupled with the quality of the experiments that will be carried out in them is a great step in the right direction. It’s good to see that the strong links that the department have with industry in general have been used to very good effect in both the design of the facility and the course content.

This collaboration with industry will be very important in sustaining this initiative which will I believe play a major role in both educating and inspiring our future generations of scientists. The use of the facility in enhancing outreach provision is both creative and very welcome. It is vital that chemistry capture its fair share of able students from all socio-economic backgrounds, and this facility should play a key role in the South West region in reaching out to future chemists on whom we will all so heavily depend.
I am very impressed with the investment from both HEFCE and the University of Bristol in the Bristol ChemLabS CETL. Shimadzu is delighted to be associated with such an important venture which I am sure will have a huge impact on the teaching and learning of practical chemistry in higher education and beyond.

Colin Jump, Managing Director, Shimadzu UK
All the documents on this CD are in PDF or HTML format. You will need a Web Browser such as Internet Explorer and Adobe Reader to open them. If you do not have Adobe Reader, you can visit http://www.adobe.com/products/acrobat/readstep2.html to download and install it.

The DLM demo will necessitate a Web browser with Flash plug-in.