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Authentic Biology: Student-led research and discovery in schools

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Abstract

Conducting cutting-edge biomedical research in schools and further education college laboratories has its challenges, but these are not insurmountable. In 2008, we established a successful cutting-edge research project into a debilitating human disease, in a secondary school environment. Here we provide a narrative describing the process behind the project, and then reflect not only on the process, but also on the benefits for school students, teachers and university researchers from engagement in such a collaborative project. We describe how, with significant financial input from a major biomedical charity, we were able to expand the initial project into Authentic Biology, a national programme of research in schools across the UK. Authentic Biology has resulted in six schools establishing their own novel research projects, mainly relating to human disease, and working in collaboration with their local university. Authentic Biology is a model for long-term school/college/university collaboration that is highly effective, productive and measurable through outcome. The challenge ahead is how to sustain the technical and financial support for such programmes.

Keywords: school; university; biomedical research; collaboration; post-16; A-level

Key messages

- With the support and backing of university research staff and students, it is possible for A-level students to carry out novel biomedical research in a school environment.
- Universities and schools both benefit from such research-led collaborations in a wide range of school settings.
- School students gain important insights into biomedical research, strengthen their university applications and broaden their understanding of biology; teachers gain valuable continuing professional development and reignite their passion for practical science; university researchers gain valuable experience in communicating science to the next generation of researchers.

Introduction

Bringing meaningful, cutting-edge biomedical research into school laboratories presents a number of challenges – financial, regulatory, technical and conceptual. Yet these challenges can be met and, by so doing, motivate the next generation of

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biomedical researchers who can tackle emerging issues in human health and welfare. In this article, we report on the initiation of a novel biomedical research project launched in the teaching laboratories of the Simon Langton Grammar School for Boys (www.thelangton.org.uk). This is a school of over 1,300 students and staff, located on the outskirts of Canterbury in the UK, which has a mixed gender group in Years 12 and 13 and holds both foundation and grammar school status. The project we describe has been realized with the support and guidance of university-based research students and staff from the nearby School of Biosciences at the University of Kent in Canterbury. In order to inform and guide similar future ventures, we describe how we set up this novel project and, with the financial backing of the Wellcome Trust (www.wellcome.ac.uk), how we launched Authentic Biology (www.researchinschools.org/Biology/home.html), a nationwide programme of such school–university research collaborations.

Figure 1: The class of 2012, with University of Kent staff in the foreground

Credit: Terry Connolly

One of the authors (Colthurst) was a biology teacher in a successful state secondary school in Canterbury when his wife was diagnosed with multiple sclerosis (MS). With 12 years' experience as a research biochemist in academia (having gained a PhD in the laboratory of the co-author, Tuite) and in the pharmaceutical sector (with GlaxoSmithKline), followed by a further 12 years of teaching experience, DRC was ideally placed to bring together these experiences to drive a project aimed at contributing to our understanding of the molecular events that lead to MS. The challenge was to carry out this research in a school environment, thereby also providing a unique experience for Year 12 and Year 13 students to discover just how modern biomolecular research works and how it can contribute to the long-term improvement of human health.

The search for funding

Biomedical research is not cheap, both in terms of equipment and consumable costs, and also in support-staff costs. All of these expenses are beyond a normal school budget, so the first step was to devise a research plan that would allow us to seek funding to launch the initiative.

An initial review of the available research literature on MS through Google Scholar (this was nine years ago, when open-access publications were few and far between), identified myelin basic protein (MBP) as an interesting target for our students to study. MBP is an intrinsically unstable protein with no tertiary structure and is subject to a myriad of post-translational modifications. Although the protein has been extensively studied in the past, this has typically been done using extracts from human or animal brain or spinal cord material, all non-starters for a school laboratory-based project. For this reason, we decided to study the human MBP protein by expressing the gene in the 'bakers' yeast' *Saccharomyces cerevisiae*, and the Myelin Basic Protein Project (MBP^2) was born. Yeast is a tractable and – importantly – a safe organism for a school laboratory to work with, and one of us (Tuite) has spent the last 40 years using this organism to explore aspects of protein synthesis and folding. Furthermore, as the project required the generation of a genetically modified microorganism (GMO), it was necessary to apply for a Home Office Licence and, in so doing, become the first school in the UK to obtain a GMO licence. The literature search also revealed that there had been no published work on the expression of MBP in yeast, so we had the necessary novel project to support our search for funding.

With the research plan in place, the next step was to identify a potential financial backer. After unsuccessful attempts to persuade the research councils and various learned societies, the Wellcome Trust appeared to be the most likely source of support through their People Awards Public Engagement Grants. This led to an application for £30,000 to establish and run the project for two years under the initial title 'Investigation into phosphorylation of human myelin basic protein in *Saccharomyces cerevisiae*'. This application was successful, and the project was launched in September 2008. The funding allowed for two days per week teacher release, an initial sum to buy basic laboratory equipment and a small consumables budget, thus providing the stable financial foundation needed.

Establishing the MBP^2 project

The overall aim of MBP^2 was to establish how the MS-associated protein MBP is chemically modified by cells, and thus provide new insights into the role played by MBP in this debilitating disease. To achieve this aim, at the outset the students were set several clear objectives: to clone the human gene for MBP into an expression plasmid in the bacterium *Escherichia coli*, to introduce the resulting plasmid DNA into yeast, to purify the engineered MBP protein from yeast and finally to identify any chemical modifications that the protein was subjected to in yeast, in particular the addition of phosphates.

The project represented a huge challenge to sixth-form biology students, and to expect them to be able to learn and understand a wide range of molecular biology and protein-handling techniques was unrealistic. For this reason, an early decision was taken to establish six 'research teams' within the project, with each team being set a particular task that aligned to the main objectives – a protein-purification team, a DNA-analysis team, and so on. One of the teams was responsible for the 'bioinformatics' element of the project, carrying out the underpinning computer analysis that informed the laboratory experiments by, for example, designing synthetic DNA sequences to facilitate gene cloning using the polymerase chain reaction (PCR). One of the challenges faced by the students was what to do when an experiment did not produce the expected outcomes, and important lessons were learnt both in terms of the importance of attention to detail in the design and execution of experiments, and also in terms of how to 'troubleshoot' an experiment.

Each team was led by a Year 13 student along with a specific biology teacher or technician. Each team deliberately contained both Year 12 and Year 13 students so that there would be continuity from one year to the next when the Year 13 students left for university. Students were allowed to choose which team they wanted to join. At this point, the Year 13 team leaders were invited to the research laboratories of Professor Martin Warren in the nearby School of Biosciences at the University of Kent to learn some of the basic techniques, for example pouring and running polyacrylamide gels for protein analysis, preparing DNA from *E. coli* and its subsequent analysis using agarose gel electrophoresis, the techniques that still underpin the increasingly sophisticated world of modern molecular biology.

By December 2008, we were ready to launch MBP² – the Myelin Basic Protein Project (www.mbp-squared.org). We had 50 students split across the six teams and we were joined by a dozen willing helpers from the School of Biosciences at the University of Kent, ranging from postgraduate students through to professors. The university students and staff acted as demonstrators, teachers and guides, helping the school students using micropipettes, handling potentially toxic substances safely and working under sterile conditions. This level of input was essential if we were to expose the students to the realities of the day-to-day life of a researcher in a biomedical research laboratory.

Figure 2: Students at work

Credit: Wellcome Images

The first 'MBP² Day' was a resounding success, and the students came away from this inaugural session highly motivated by being able to carry out such complex and challenging practical techniques. The university staff worked hard to ensure that the students understood the reason for every step of the practical work, very often having to go back to some very basic (for them) biology concepts to explain the theory behind the experiments. This also provided the university contributors with a chance to hone their wider communication skills. The school teachers and technician were also able to share the experience of learning new techniques and to make more sense of some of the newer molecular techniques, which had not existed when they had graduated.

The first MBP² Day set the theme for the rest of the project, and we now run three such research days each academic year, involving both school and university staff and students. These sessions are supported by a regular Wednesday afternoon timetabled lesson for Year 12 students where they continue the project and are able to learn different techniques from other teams. Students are also encouraged to come into the school laboratory on days when it is staffed, to help carry on the practical work.

Figure 3: Students learn how to load a gel

Credit: Wellcome Images

Expanding the concept, and the birth of Authentic Biology

Once the MBP² project was up and running, the next challenge was to sustain the increasing level of interest from the students at the school and allow them to push forward with the research objectives we had set for the project. Naturally, the first port of call was the Wellcome Trust, and we were delighted when they provided an additional £30,000 to support the project through a second People Award. This allowed us to continue MBP² for a third year. By maintaining a dialogue with the Wellcome Trust and engaging with them through the MBP² Days, we were soon encouraged by them to apply for a much larger award to replicate our successful concept in other schools across the UK. This led to an application for one of their Society Awards.

We identified four other universities to be involved in this expansion: Bristol, Sheffield, Southampton and Queen Mary University of London (QMUL). These four were selected because we had direct contacts to researchers in each of their respective bioscience-related departments, through our networking and through Martin Warren and our other University of Kent collaborators. These links provided an important 'foot in the door'. The decision on which school to work with was left for each university to make, and what research project they would conduct was agreed in consultation with their partner school. All universities had active outreach programmes in place and good working relationships with a range of their local schools.

The Wellcome Trust Society Award application, called 'Authentic Biology', was successful, and a further £252,000 was made available for the proposed project expansion. These essential funds allowed each school to have a teacher and a technician released for half a day per week to run the project. Each school also received £6,300 for initial equipment costs and a £2,000 per year consumables budget. There were also funds for an annual research symposium to give the students the opportunity to present their research findings. The initial grant was for three years, but in fact the funding was stretched for a further six months.

A priority of the project was to ensure that each school was involved in the decision on what type of research it would carry out. For example, at St Paul's Way Trust School in Tower Hamlets, over 80 per cent of the students are of Bangladeshi origin, and they were determined to carry out a research project on diabetes, since it has a disproportionately high incidence among their own community. Both Tapton School in Sheffield and Cotham School in Bristol started working with zebra fish embryos, looking at heart disease and inflammation genes respectively. Peter Symonds College in Winchester is a very large sixth-form college with no spare capacity in their science laboratories, so they elected to carry out practical Extended Project Qualifications (EPQs) with their Year 12 students after the Year 13 students had left the college after their exams. In the current academic year (2016/17), there are some 230 Year 12 and Year 13 students across the UK benefiting from the Authentic Biology experience.

Various issues emerged in establishing the research projects in each of the schools. For example, for the diabetes project, St Paul's Way Trust School had to obtain ethical approval and then devise a way of anonymizing samples and data. This was necessary because the samples being used came from their local community and needed to be processed by QMUL before the students could use them. The schools using zebra fish embryos had to conform to Home Office regulations in their work, and this required careful planning and consultation with the Home Office. Thankfully, these and other issues were soon resolved, and the resulting projects were so successful that the Society Award was extended for a further two years. This also allowed us to include two further schools, Archbishop's School in Canterbury, working on bird heart myosin with researchers at the University of Kent, and Parkside Federation, working on the search and discovery of new bacteriophages with the Department of Biochemistry in Cambridge.

The annual Authentic Biology Research Symposium

Being involved in a research project necessitates timely communication of the outcomes of that research to your peers, typically by making oral or poster presentations at a scientific conference. Consequently, we established an annual symposium to serve just that purpose, and this has been a particularly successful aspect of the Authentic Biology programme. The first symposium was held at the People's Palace at QMUL, with Professor Robin Franklin from the University of Cambridge and Dr Anne-Lise Goddings from University College London (UCL) as keynote speakers. Students from each participating school gave a 15-minute oral presentation with slides, and also presented a poster about their work. The subsequent symposia were hosted by the Wellcome Trust at its headquarters in London, and have included a number of very influential keynote speakers, including Dr Jeremy Farrar (Director of the Wellcome Trust), Lord Robert Winston (Imperial College London) and Professor Wendy Barclay (UCL). The symposia have afforded the students with fantastic opportunities to sharpen their presentation skills, to find out about the other Authentic Biology projects and to hear from senior research scientists about their work.

Figure 4: Students from the Simon Langton School present their work at the third Authentic Biology symposium

Credit: Emma Colthurst

Figure 5: Poster session at the third Authentic Biology symposium

Credit: Emma Connolly

The impact of Authentic Biology on students and staff

In 2015, an independent survey commissioned by the Wellcome Trust (Finegold, 2015) of Year 12 and Year 13 students studying A-level biology in the partner schools in the Authentic Biology programme revealed the impact of the project on students and staff. For example, those school students engaged with the programme showed an increased sense of science as an approach or methodology, rather than as a body of knowledge. They were also more comfortable using practical and investigative methods to study, and had greater commitment to future bioscience study than those not carrying out the programme, with almost twice the percentage of Authentic Biology-engaged students considering careers in biological research compared with those who chose not to participate. For example, over the nine-year period, 65 per cent of the participants in MBP[2] at the Simon Langton School have gone on to study science, technology, engineeering or mathematics (STEM) courses, using their research experience to good effect at interview. Recognizing the value of being part of a team with a common goal is also seen as an important outcome for the students.

The impact that the programme has on teachers and university staff and postgraduate students is also evident, both from this survey and anecdotally. Importantly, teachers from all participating schools note a great improvement in student motivation, knowledge and understanding of the nature of the scientific research 'process'. There is also value to the university-based staff and postgraduate students, developing more effective methods of communicating their science to a less-knowledgeable audience and forming closer links with the local community. In many cases, the research that is being done will find its way into the public domain via peer-reviewed publications. We firmly believe that these are highly valued partnerships and are exemplars of how university–school collaboration can occur and benefit all parties.

All of the Authentic Biology projects have proved highly successful, demonstrating that our initial model of school students carrying out original research in their own school laboratories, with the support and encouragement of their local university, can be successfully migrated to a wide range of schools. All of the schools have seen increases in their A-level biology cohorts; they have also all reported a much higher level of engagement with biology as a taught subject. The longer-running projects have also seen a shift in destinations of students for their degree studies; instead of simply choosing between medicine, veterinary or dental studies, they are now applying for biochemistry, neurology, microbiology and biomedical science (among others). They are achieving places at high-ranking universities on popular courses, they are more confident at interview and they have developed greater skills in scientific presentation. Students have even co-authored published articles with their teachers (for example, Colthurst *et al.*, 2015).

Besides the clear benefits the project is having on the student researchers, the teaching and technical staff in schools are now more confident in exploring advanced methods for their practical classes. Many are using state-of-the-art laboratory techniques, which has reignited their enthusiasm and passion for science. They relish the opportunity to discuss their projects with university researchers and to develop their projects to the full. Similarly, the university staff and students actively involved in their respective projects have found the experience rewarding, being able to help train the next generation of biomedical researchers. This has also made us all realize what a positive impact such an early exposure to front-line research can have. Authentic Biology 'graduates' step into their first undergraduate laboratory classes with a confidence that belies their years, and already some of the first cohort of school students involved in this project are now well into PhDs and training to become medical doctors.

The future of Authentic Biology?

Having established the fact that a wide range of secondary schools can carry out novel, meaningful biomedical research with their students, how can we sustain such stimulating and challenging research opportunities for school students? The Wellcome Trust support for MBP[2]/Authentic Biology was seen by all parties as 'pump priming', with the expectation that longer-term financial support would come from local education authorities or direct from government itself. With the financial backing from the Wellcome Trust now finished, the Authentic Biology projects are all continuing, supported by the respective school – and in some cases university – budgets. Yet we must bear in mind that these schools already have the laboratory equipment in place for their projects. Our estimate is that the consumable costs to run the individual projects in the Authentic Biology programme is approximately £2,000 per annum.

Is Authentic Biology unique? There are a growing number of programmes around the world that aim to engage school students in research. For example, in Australia there is the STEM Professionals in Schools programme (www.scientistsinschools.edu.au), which involves partnerships between schools and industry with the focus on educating and inspiring the teacher. In the USA, the DNA Learning Centre at the Cold Spring Harbor Laboratory (www.dnalc.org) provides, among other things, summer camps for school-age students to learn about genetics and the underlying research. We believe that Authentic Biology is different from many of these other programmes in both the focus – bringing the experiments to the school laboratory – and in the approach – building a collaborative network of schools and universities across the UK.

The approach we have taken of giving students the chance to be actively involved in novel research projects prior to pursuing a university-level education has also recently led to the establishment of the Institute for Research in Schools (IRIS; www.researchinschools.org). Founded by its director, Becky Parker, who is also on the staff of the Simon Langton School for Boys, IRIS seeks to encourage and support schools in setting up their own research programmes and to collaborate in national 'big data' projects. To date, over 300 schools have registered with IRIS, emphasizing the very great demand for these types of activities from teachers and schools.

Working with IRIS will certainly allow provision of training and resources for teachers, technicians and university researchers to encourage a wider participation in such projects, and hence inspire the next generation of research scientists. Providing access to the necessary longer-term financial and technical support for such projects will ensure that the groundwork laid by Authentic Biology is built upon and that the UK is able to motivate a new population of highly skilled bioscientists able to meet the health, environmental and agricultural challenges we will face for the foreseeable future.

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Notes on the contributors

Dave Colthurst is a former research biochemist who turned to teaching 20 years ago. Having taught in a number of different schools across east Kent, he moved to the Simon Langton Grammar School for Boys 15 years ago. He has taught science to all ages of secondary school students, specializing in biology at advanced level, and is currently lead teacher and principal investigator on the Authentic Biology project.

Mick Tuite is Professor of Molecular Biology in the School of Biosciences at the University of Kent in Canterbury and a member of the Kent Fungal Group. His research exploits the yeast *Saccharomyces cerevisiae* as a model organism in which to explore how proteins are synthesized and folded. This has led to an interest in diseases associated with protein misfolding, and he is using yeast to explore how organisms cope with such potentially catastrophic molecular events.

References

Colthurst, D., Kent, M., Mauchaza, R., Senasinghe, T., Sparkes, G., Vasilijevic, F., Parker, B., Ireland, E., Bibb, S.J., Pomeroy, F., Evans, A., Cooke, C. and Gorecan, O. (2015) 'Research science in schools: An insight into the student experience in biomedical science and particle physics'. *School Science Review*, 97 (358), 44–51.

Finegold, P. (2015) Authentic Biology Evaluation Update. Powerpoint presentation available at www.authentic-biology.org.