Institution:
University of Cambridge

Unit of Assessment:
UoA9

Title of case study:
Physics at work

1. Summary of the impact (indicative maximum 100 words)

Between January 2008 and July 2013, over 10,000 key stage 4 school students and their teachers directly engaged with active research of the Cavendish Laboratory, Department of Physics, University of Cambridge through an annual interactive 3 day exhibition, titled "Physics at Work". In 2012 the event attracted 31 non-selective state schools and 17 selective/independent schools, 23 of which had visited the exhibition 3 or more times previously- a testament to its success. Building on the enthusiasm that the students showed during their participation in the event, teachers noted an increase in the number opting to study A-level physics and stated that those previously with no interest left with a very positive image of the subject.

2. Underpinning research (indicative maximum 500 words)

The research underpinning two specific presentations at the Physics at Work exhibition, selected from among the groups **within the Cavendish Laboratory,** is described here as a sample of the ~23 exhibits on display each year throughout 2008 to 2013.

The body of research described in the interactive presentation of the **Biological and soft systems sector (BSS)** featured their current research in soft matter as recently published in PNAS[i] and Nature letters[ii]. The first example cited in the 2012 (BSS) presentation drew upon the wide variety of potential applications of biocompatible, and biomimicking, hydrogels in biotechnology and medicine.

Research into the rational design of self-assembling hydrogels was published in June 2009 by Athene Donald (lecturer 1985 and Professor of Experimental Physics since 1998) as part of a wider collaboration which included academic and corporate researchers in Bristol, Sussex and Unilever, Bedford[i]. Within this collaboration Prof. Donald co-supervised the research in cell biology and rheology. The key findings of this research were that hydrogelating self-assembling fibres (hSAFs) gel at a concentration which is >99% water and that changing the nature of the inter-fibril interactions enables temperature responsive hydrogel properties to be engineered. This published work supports the use of these specific hydrogels as a new substrate for the growth of cells to enable novel cell differentiation during growth and confirms that such substrates would provide unprecedented control on design.

Also underpinning the BSS presentation is the work of Erika Eiser (appointed Lecturer in 2007 and Reader in 2012) who published collaborative work with researchers in the Ecole de Lausanne, Switzerland, on colloidal gels and the previously unexplored class of materials – bigels in November 2012[ii]. Erika Eiser was instrumental in all aspects of the work pertaining to this publication, designing the experiments undertaking the experimental research and co-authoring the final paper. The key finding of the research was a new proposed mechanism for creating bigels through the arrested demixing of 2 component mixtures to form gel-like structures. One possible application of this outcome is the mimicking of structural colour in natural materials such as the blue butterfly wings or some blue bird feathers. Structural colours are due to refraction of light from a high refactive index material with a specific order; this order needs to be of the length scale of a couple of hundred nanometers, which can be achieved with these colloidal bigels.

The Cavendish **surface physics group** developed a novel helium scattering technique for studying the dynamics of atoms and molecules on surfaces on nanometre length-scales and pico-second timescales. The specific research underpinning the group's contribution to Physics at Work was performed by staff members Holly Hedgeland (Research Associate 2006 to 2011), Andrew Jardine (Royal Society Research Fellow 2005 to present), Gill Alexandrowicz (Research Fellow 2006 to 2008), William Allison (first academic appointment 1983, promoted to Reader from 2002 to present) and John Ellis (Assistant Director of Research 2000, promoted to Reader from 2010 to present). Collaboration with Peter Fouquet (previous Cavendish member) at the ILL, Grenoble facilitated complimentary neutron scattering measurements. The focus of the

underpinning research, conducted from 2005 to 2009 and published in Nature Physics[iii], was to understand the nature of the motion of a typical molecule, like benzene, on a graphite surface. The key finding of this research was a novel frictional regime in which single molecules of benzene move with Brownian motion over a corrugated graphite surface. This regime was previously undiscovered and a much lower friction hopping mechanism of motion would intuitively be expected.

3. References to the research (indicative maximum of six references)

Biological & Soft Systems Sector peer-reviewed Journal references

i) Eleanor F. Banwell, Edgardo S. Abelardo, Dave J. Adams, Martin A. Birchall, Adam Corrigan, **Athene M. Donald**, Mark Kirkland, Louise C. Serpell, Michael F. Butler and Derek N.Woolfson, ***Rational design and application of responsive alpha-helical peptide hydrogels,*** Nature Materials Letters, Vol. **8**, July 2009, DOI: 10.1038/nmat2479.

ii) Francesco Varrato, **Lorenzo Di Michele**, Maxim Belushkin, Nicolas Dorsaz, **Simon H. Nathan**, **Erika Eiser**, and Giuseppe Foffi - ***Arrested demixing opens route to bigels*** **-** PNAS, Vol. **109,** No. **47,** 20 November 2012, DOI: 10.1073/pnas.1214971109

SMF: Surface Physics Group peer-reviewed journal references

iii) **H. Hedgeland,** P. Fouquet, **A. P. Jardine, G. Alexandrowicz, W. Allison** and **J. Ellis**, ***Measurement of single-molecule frictional dissipation in a prototypical nanoscale system,*** Nature Physics Letters, Vol. **5**, July 2009 - pp561 – 564, DOI: 10.1038/nphys1335)

4. Details of the impact (indicative maximum 750 words)

Physics at Work is a 3 day event centred on ~25 exhibits with capacity for 2300 students and the aims of stimulating interest, widening participation and raising aspirations of students aged 14-16 from all over the UK. The exhibition is specifically designed to promote interactions between cutting-edge researchers, school students and teachers – helping to spread the excitement of modern physics to students who will soon be making important examination and career choices.

During the period of 1 January 2008 to 31 July 2013 exhibitions directly reached over 10,000 students and their teachers, with each exhibitor interacting with ~650 visitors. The 2012 event continued to attract new schools but also retained a high return rate, clear evidence of its sustainability, demand and quality: Of the 48 attending schools, 4 were new while 6 had visited more than 5 times before.

2009 saw the first exhibition from SMF: Surface Physics Group while in 2012 the Biological and Soft Systems sector secured, for the second time, the event's "*Schools' Exhibitor of the Year"* trophy for their particularly interactive and cutting-edge, research specific presentation.

From 2009 **the BSS presentation** was coordinated and delivered by Dr Erika Eiser (previously in 2008 by postdoctoral researcher Deborah Waller). Through the employment of biopolymers such as DNA and proteins they discussed their underpinning research on polymeric structures and how this novel work leads to mimicking biological systems and building new materials.

The presentation included many demonstrations and experiments describing their published work. Students watched the formation of a physical biogel with weakly cross-linked chains by adding borax to a solution of PVA (poly vinyl alcohol dissolved in water), demonstrating the binding of >90% water using very little polymer typical of gels that we would find in the body as lubricants

This work contained a deliberate emphasis on the link between the use of proteins in the underpinning research and the human body as there are many medical examples of the importance of understanding the aggregation of proteins and peptides that would resonate with the students, for example, cataracts and Alzheimer's disease.

In Dr Eiser's underpinning work the preparation of samples and the ability to extract long chains of DNA was an important part of the experimental procedure and students were able to watch, live, the extraction of DNA from strawberries. From here students learned about the significance of being able to create specifically designed biological structures as described in the PNAS paper, citing natural world examples of where these structures exists, for example, in butterfly wings and opals, and the possible technological applications as biosensors and electrical batteries.

The members of Cavendish Staff coordinating the **Surface Physics Group** presentation were Dr Andrew Jardine and Dr William Allison. The specific graphite system published in (iii) was chosen

as both topical and accessible to presentation through the ability to demonstrate the surface structurelive. Live STM images enabled students to visualise and appreciate the breadth of processes on the atomic scale that featured in this research that they would otherwise find unimaginable.

The chosen surface was polycrystalline, highly oriented pyrolytic graphite (HOPG) – one of the only materials that can be resolved at atomic resolution in air and the surface on which the underpinning research was conducted. The live STM demonstration included the preparation of the scanning tip and sample, identical to that required for the sample preparation in the published experiment.

Having enabled the students to observe live, a technique for viewing the atomic surface of graphite, the presenters moved on to discuss the role of surface structure and the motion of atoms and molecules on surfaces in a variety of processes, such as chemical reactions. Particular emphasis was given as to how the frictional regime between adsorbed atoms or molecules and the graphite surface contribute to processes such as catalytic reactivity, once again linking directly to the focus of the underpinning research.

Teachers attending the 2012 exhibit quoted a variety of impacts on their students that they had noted as a consequence of their visit to Physics at Work.

"Their [students'] interest in science and physics in particular has increased," Lealands High School, Luton.

"Pupils now see physics as a vocational choice as well as an academic one," Oaks Park High School, Ilford.

"Yes, more students study A-level physics" Harlington Upper School, Luton.

"Even the students with no interest in Physics come away with a positive image of the subject." Norwich High School for Girls.

The exhibition provided additional impact through staff and graduate student development both within the department and industry. Rolls-Royce Plc. has exhibited at every Physics at Work event throughout the impact period and has consequently raised its profile in schools and the community, in the meantime providing its own-funded graduate students with training in public engagement and communication. Similarly since 2009 the Atomic Weapons Establishment (AWE) has been a regular exhibitor – raising their own profile to schools and teachers. AWE and the SMF: Surface Physics Group are just two examples of the how the fluidity of the programme is maintained and demonstrate its success in continuing to evolve mechanisms through which to best present current research and develop further impacts and collaborations. Links with industry are an integral part of the exhibition structure and include both local (e.g. the Technology Partnership and ThermoFisher Scientific) and worldwide (e.g. the Mathworks) companies.

Physics at Work has also achieved secondary impact through media coverage of the event, particularly over the last 4 years. 2009 marked the event's 25th anniversary and the exhibition was supported enthusiastically by comedian and physicist Dara O'Briain, thus gaining invaluable local TV and print media coverage. In 2012, Physics at Work featured in Athene Donald's Guardian blog with many hits on social media sites subsequently.

5. Sources to corroborate the impact (indicative maximum of 10 references)

Physics at Work booklet 2008 – 2013
Education Manager, Rolls-Royce Plc
Statement from AWE Deputy Chief Scientist
Schools to corroborate impact: Questionnaires submitted as part of the 2012 event