Institution: University of Sussex

Unit of Assessment: UoA 9 Physics

Title of case study: Using fundamental physics to improve physics teaching and up-take at A-levels and at university

1. Summary of the impact

Over a four-year period, teachers and around 16,000 pupils from all over the UK have benefited from engagement with Sussex physics research. Outcomes include enhanced science teaching in schools, an increased interest of school children in science and scientists' work, and a greater ability of school children to understand and reflect on science, leading to better-informed study choices. The UG physics population across the South East has roughly doubled over the REF period (based on numbers at the SEPnet partners), which is an important contribution to alleviating the problem of a scarcity of STEM graduates.

2. Underpinning research

The Department has a strong focus on basic research. We communicate this directly to school teachers and children through a variety of events. For the purposes of this case study, we focus on three examples of research that underpins our impact.

The Higgs boson and supersymmetry

The ATLAS experiment at CERN operates at the high-energy frontier of physics. Since 2009, Sussex researchers Prof. Antonella de Santo and Dr Fabrizio Salvatore have participated in the discovery and characterisation of a new particle, consistent with the Standard Model Higgs boson [see Section 3, R1]. They lead the ATLAS search for charginos and neutralinos, particles predicted in supersymmetric models, through the tri-lepton signature [R2], and the search for strongly interacting supersymmetric particles in events with final-state taus [R3]. These examples were covered in Master Classes and our Schools Lab, where it stimulated great and sustained interest among students and teachers.

Physics of single photons

[The late] Prof. Wolfgang Lange and Dr Matthias Keller, together with members of their research team, have performed world-leading research into single photons and their interactions with ion-trap cavities since 2004. A novel single-photon source was described in [R4]. These investigations may be crucial for quantum technological applications. This research underpinned various outreach talks, such as Dr Keller's contribution to a teachers' CPD event, described below.

Herschel Space Observatory

Prof. Seb Oliver was Instrument Control Centre Scientist (1999–2009) and a founding Associate Investigator on the ESA's Herschel SPIRE Instrument [R5], designing and producing software for the instrument data-analysis pipeline (1998–2013). He has been at Sussex since 2000.

3. References to the research

R1 ATLAS Collaboration (Aad G., *et al*.) (2012) 'Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC', *Physics Letters B*, 716(1): 1–29.

R2 ATLAS Collaboration (Aad *G., et al*.) [lead author Prof. Antonella de Santo] (2012) 'Search for supersymmetry in events with three leptons and missing transverse momentum in sqrt(s) = 7 TeV pp collisions with the ATLAS detector', *Physical Review Letters*, 108(26): 1–18.

R3 ATLAS Collaboration (Aad G., *et al*.) [lead author Dr Fabrizio Salvatore] (2012) 'Search for events with large missing transverse momentum, jets, and at least two tau leptons in 7 TeV proton-proton collision data with the ATLAS detector', *Physics Letters B*, 714(2–5): 180–196.

R4 Takahashi, H., et al, (inc. Seymour-Smith, N., Keller, M, and Lange, W.) (2013) 'An integrated fiber trap for single-ion photonics', *New Journal of Physics*, 15: 1–10.

R5 Griffin, M., *et al*. (inc. Oliver, S., Roseboom, I., Savage, R., Smith, A. and Ward, R.) (2010) 'The Herschel-SPIRE instrument and its in-flight performance', *Astronomy and Astrophysics*, 518: L3.

Outputs R1, R2, R5 best indicate the quality of the underpinning research.
Outputs can be supplied by the University on request.

4. Details of the impact

As described in the impact template, a sustained central pillar of our impact strategy is a comprehensive engagement programme for school teachers and children at all levels of education (including primary, secondary, A-level and adult education). Here we describe in detail how and with what aims we engage school children and teachers directly with our research [see Section 3, R1–R5] and how this impacts on both groups.

Physicists have a particular skill set that is in short supply in the UK economy, as recognised by the government and by HEFCE. A survey by the IOP and STFC [C1: p.14] of 800 undergraduate students found that the most popular subject areas cited by first-year undergraduates were particles (72 per cent), nuclear physics (63 per cent) and astronomy (53 per cent), all within the domain of fundamental research as tackled by Sussex researchers; hence our strategy to base our school engagement in these areas [R1–R5]. The aim is both to improve teaching and to raise pupils' interest directly. The means by which this is achieved is through talks at schools, bringing pupils into the University, and through the continuing professional development of teachers. These activities have grown significantly over the current REF period, in conjunction with the Department's membership of SEPnet, a HEFCE-supported consortium of physics departments in South-East England. Since January 2009, we have employed a dedicated PhD-educated outreach officer, astrophysicist Dr Darren Baskill. We take feedback for all types of outreach activities, both quantitative and qualitative. There is tangible evidence of enhanced engagement with science through feedback from students and teachers [C2, C3] as well as increased physics up-take in the region (see below).

Engaging pupils with science

Table 1. Pupils participating in Sussex events, broken down by stage

	Primary	Pre-GCSE	GCSE	A-level	TOTAL
01/08/09–31/07/10	370	788	1,029	340	2,527
01/08/10–31/07/11	402	972	1,744	933	4,051
01/08/11–31/07/12	964	1,292	1,819	949	5,024
01/08/12–31/07/13	901	1,770	1,807	499	4,977
All years	2,637	4,822	6,399	2,721	**16,579**

Since we began collecting data in 2009, we have worked with 16,579 students at all levels, using a variety of methods to engage them with the research. For example, in the academic year 2011/12 we worked with 5,024 students (see Table 1). They engaged with departmental research through physics days, master classes, research talks, schools lab days and lectures, both on and off the University campus.

We offer a wide selection of talks [C4] covering all our research areas, and given by staff visiting schools and colleges. We also run regular physics days on campus throughout the year, including master classes in particle physics (an astronomy master class is currently under development), both for GCSE and for A-level students. These include a research talk, lab tours, live video links to Sussex PhD students at CERN working on the ATLAS experiment, and other hands-on physics activities. During 2011/12 alone, members of the Department talked about their research to groups at or from about 100 schools [C5].

Schools lab days

During the school terms, we run a weekly Schools Lab day in our dedicated Schools Lab facility, where GCSE, AS- and A2-level students visit us for a full day of experimental physics. As part of the day, the students, together with their teacher or teachers, attend a research talk where a different researcher describes her/his work each week.

On a recent Schools Lab day (17 May 2013), a group of GCSE students from Dorothy Stringer School

in Brighton, together with their physics teacher, Andy Latham, attended a talk about the principles of the Standard Model and the story of the ATLAS discovery of the Higgs boson through H→ZZ and H→γγ. The group, which consisted of eight female and two male students, subsequently reflected on the topic during their classes. In a snap poll at the event, 80 per cent stated their intention to continue to A-level physics. Feedback from Mr Latham submitted in June [C6] states:

> Not only was the lecture informative for the students but it sparked a significant amount of debate about the standard model and its development as a theory. From that discussion we are now looking into taking a group of students next year to CERN and possibly holding master classes for KS4 students here in experimental and theoretical physics, such was the interest from students. The number of female students was accidental but incredibly encouraging. We at Stringer strive to increase the number of female students taking up further education in Physics and it's days such as this that make our job easier.

Enhancing science teaching in schools

We regularly host teacher-training events such as the recent 'Physics Update' course. Key decision-points for students are not only when they apply for university, but also at the transition from GCSE to A-levels. This is where the 'bottleneck' of STEM undergraduates is formed. The science teachers at GCSE and A-levels hence play a pivotal role in addressing this societal challenge. We run continuing professional development events for teachers several times a year, informing them about the findings of our current research through talks by faculty members, answering their questions, and giving them ideas, as well as materials, that they can use in the classroom.

In March 2013, we organised and ran the Institute of Physics 'Physics Update' 3-day international conference, which was attended by 34 teachers from across the UK. Follow-up demonstrated that this conference has had a real impact in the classroom – for example, Claire Aspinal [C7] says that at her school in Cheshire they have:

> …discussed new developments with pupils e.g. Quantum computing to help them understand where a career in physics could take them. […] [We] purchased the particle zoo to help pupils understand fundamentals particles better. We are taking 30 AS/A level students to CERN in December.

Justin Walker [C8] said

> My department has decided to buy a [Geiger-Mueller Tube] like the one you demonstrated […] I used photos from the ion isolation qubit storage lab in lessons on atomic theory and digital data transmission.

Each summer, we hold an evening event for local teachers, giving them the opportunity to explore the Department, to see our latest offerings, and to network with other teachers in the region. This event has an attendance of approximately 45 teachers each year. During the 2011 event, Prof. Wolfgange Lange gave tours of our AMO research laboratories, prompting the following unsolicited feedback: 'Faculty members such as Dr Lange [were] engaging in making physics understandable and accessible for a relative "newbie" (read "chemist"!) like me' – Jason O'Grady, Hove Park School, July 2011 [C6].

The UK Herschel outreach project has also produced many educational resources based, in particular, on the Herschel SPIRE instrument: http://herschel.cf.ac.uk/education. These resources have been very well received by teachers and used to improve their teaching in the classroom. Dr Keith Moseley (Head of Physics, Monmouth School) says, 'The standard approach to teaching the electromagnetic spectrum is significantly enhanced by showing, through the resources associated with the Herschel Telescope, the multi-wavelength universe' [C9]. David Grace, (PGCE teacher), said 'I have used [Herschel educational resources] myself with Year 9 and Year 12 pupils in school... I know that some of this year's students also used them in school on their practices and found them appropriate and very useful' [C10]. In addition Sophie Allan, who is the National Space Academy physics teacher engaged in developing and teaching physics programmes for the Academy, as well as running CPD, said

> I have used the Herschel resources with both student and teacher groups…The resources worked very well…They really brought multiwavelength astronomy to life in a manner that

was relevant to the curriculum, time saving and gave a fantastic modern context to the topic. I have also introduced many other teachers to the resources through CPD sessions that I have been leading, and they have all been thoroughly impressed!' [C11].

Evolution of UG student uptake in the region

Strong evidence of the impact on pupils comes from the rise in UG student uptake not only at our institution, but across the South East (the main reach of our, and our SEPnet partners', outreach activities). One teacher commented "we have seen an increasing number of students choosing Physics at Uni over the last few years, and we believe this is partly because of the positive experience they have had of Uni physics in the schools' lab" [C13]. Based on SEPnet data [C12], the overall SEPnet physics UG population has roughly doubled from 967 in 2007 to 1,813 in 2012/13, and the Sussex UG population from 131 to 229. This significantly outpaces the national growth of 34 per cent over the same period and goes some way to alleviate the societal problem of a lack of STEM graduates. The correlation with the onset of SEPnet and our enhanced outreach activities strongly suggests that it arises in part as a result of our research, as communicated through our engagement. It is to be expected, and our evidence from feedback [C6] confirms, that this very significant impact on the 'elite' subgroup of students who actually took up physics is accompanied by a more widespread, better appreciation of modern physics research, among both students and teachers.

SEPnet has had an extraordinary impact on recruitment to the Physics Department at Sussex University: at a time when it's of national importance to UK plc to increase STEM, and particularly physics recruitment, their outreach activity (drawing on their strengths in fundamental research) is changing the pattern of recruitment in the region, with more than twice the national average increase in undergraduate recruitment – Prof. Sir Peter Knight, FRS [C14].

5. Sources to corroborate the impact

C1 Institute of Physics (2007) *Particle Physics – It Matters*. London: Institute of Physics in partnership with the Science and Technology Facilities Council. Available for consultation.

C2 Feedback from Science Teacher, Hove Park School, Brighton available in dept records.

C3 Feedback from Science Teacher, Hove Park School, Brighton available in dept records.

C4 Listed on the Department's outreach page: www.sussex.ac.uk/physics/outreach

C5 Local records at the Department, kept by Outreach Officer. Feedback collected by the Institute of Physics.

C6 Local records at the Department.

C7 Feedback from Science Teacher, The King's School in Macclesfield.

C8 Feedback from The John Lyon School, Middle Road, Harrow on the Hill, Middlesex HA2 0HN.

C9 Email from Head of Physics, Monmouth School, Almshouse Street, Monmouth NP25 3XP.

C10 Email from PGCE Physics Tutor, School of Education and Lifelong Learning, Aberystwyth University, Penbryn 5, Penglais Campus, Aberystwyth, Ceredigion SY23 3UX.

C11 Email from National Space Academy Physics Teacher, National Space Centre, Leicester.

C12 Based on data from SEPnet annual report 2011–12, Available for audit.

C13 Email from Curriculum Leader for Science & Professional Tutor, Sackville School, Lewes Road, East Grinstead, West Sussex, RH19 3TY.

C14 Email from Professor Sir Peter Knight, Senior Research Investigator in the Physics Department at Imperial College and Senior Fellow in Residence at the Kavli Royal Society International Centre at Chicheley Hall. He retired in September 2010 as Deputy Rector (Research) at Imperial College. He was President of the Institute of Physics from 2011–2013.