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In less than two years in existence, the Liverpool Physics Outreach Group has developed and delivered physics workshops to over 3000 school pupils.

The physics outreach group: a how to guide

Abstract

In less than two years in existence, the Liverpool Physics Outreach Group has developed and delivered physics workshops to over 3000 school pupils. The Group is voluntary and non-credit bearing, meeting once per week to share good practice, develop new ideas and obtain feedback on their communications skills. Funding to run projects, such as Photons in the Classroom has been awarded from the Science and Technologies Funding Council, and the Institute of Physics. After some collaboration with Chemistry and Mathematics, we have put together a business case for a School of Physical Sciences Outreach Group.

Collaboration with other Departments has begun in which we introduce students who require an understanding of physics, but often have no background in the subject (e.g. Radiotherapy). By incorporating the hands-on 'fun' elements of outreach activities, these students have found physics more accessible, and a thorough evaluation of benefits to their learning is underway. The Ogden Trust have provided funding for a Women in Physics Outreach event which will be run by girls, for girls This approach is considered effective for the recruitment and retention of girls in physics and engineering in other countries (notably Germany)¹.

Benefits to our students involved include everything from a huge increase in confidence to an improvement in their motivation to learn physics. The schools involved and the Physics Department benefit from opening the lines of communication. Evaluation indicated that the pupils in all schools visited thoroughly enjoyed the sessions and have an improved attitude toward science, and in particular, physics. The uptake of Triple (separate) Science in all schools visited has increased since our visits began. We would like to share our experience of setting up and running so many successful events on order that other departments might develop their own without having to re-invent the wheel.

Introduction

The Physics Outreach Group was set up on a trial basis in May 2009, and expanded rapidly both from the perspective of student/staff participation and school interest/events which indicates a market/need for such activities. In this paper I will attempt to summarise the key considerations when setting up such a group to highlight some of the successes possible and potential pitfalls to be avoided. The approach is to look at Who? Where? When? and How? followed by Why? and What?

Who?

The potential audiences for outreach are mainly school groups on and off campus, and the general public. These can be more easily discussed in terms of where the event takes place, as the environment will influence the design of the event.

Where?

Schools

Schools are an obvious potential audience for outreach. Teachers and Heads of Physics/Science are usually amenable to 'enhancement' activities, particularly if it links well to the National Curriculum for that level. A session will usually correspond to the duration of a lesson ~1 hour, although the teacher may wish for only part of the lesson to be used if it is the only science lesson for that class that week. The school may be willing to run a morning or afternoon of science, either for their top set in a year group or the Gifted and Talented cohort. Some schools have lessons up to 1 hour and 20 minutes long, so it is vital to confirm this before any detailed planning. If you plan to visit the same class more than once it is worth noting that school sometimes run on a 2 week, rather than weekly, timetable.

Individual classes vary in size but year 7-9 classes tend to be 25-30 pupils, while GCSE and A-level may have 15 or less. Schools are sometimes willing to group 2 or more classes together giving a larger audience of 60-100 for lectures in a school hall type setting, particularly for Science Week in March or their local 'Enhancement Week.'

On Campus

Events on campus include anything from a class visit (usually A-level), which will involve interested and highly-motivated students, usually accompanied by a teacher who organised the event, to a family day on a Saturday where all age groups drift in with no idea what to expect. Such A-level visitors expect an experience that they cannot obtain at school, and so some time spent in the undergraduate teaching laboratories working on an experiment, demonstrated by physics students they can chat to and a tour to look at any specialised equipment in the Department are ideal.

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Younger class groups (year 7 – GCSE) tend to be bigger with more mixed views; some may be certain they do or do not wish to engage further with science, while most will be uncertain. Aim Higher and Widening Participation activities (usually this age range) have the aim of helping the pupils/students to become familiar with and comfortable in a university environment and so usually show them the Halls of Residence, the Student Guild and a lecture in a formal lecture theatre. Some organisers avoid science (in particular physics) in these types of visits as the group will have mixed interests. However science is exciting, and can be controversial, which are ideal components to develop a workshop (rather than a lecture), which, when delivered by young, enthusiastic outreach group members can have a real impact.

Museums/Public Events

Local museums are often happy to have activities delivered at their venue. Science Week weekends in March, half term breaks and the summer are the ideal times, though will involve some Saturdays and Sundays. Similar to family events on campus, a lecture should have elements to keep the parents entertained as well, but you will often find that a good explanation can be taken in by those at different levels in their own way.

Museums also like stalls/stands at which small hands-on experiments (ideally supported by posters) attract passersby and you have a minute to grab their attention with something interesting and answer their questions before they move on. This also works for Careers Fairs and local Festivals which you may get invited to as your reputation grows.

Other Departments

Physics is an essential element of a degree in radiotherapy, but the students on the programme often do not have an A-level in physics, but at most a GCSE Double Science Award. In collaboration with the Radiotherapy Department, the Physics Outreach Group ran a pilot event in 2010/11 in which radiotherapy students participated in 3 non-credit bearing 2 hour workshops. Their attitude toward physics improved dramatically, and although their perception was that their understanding did not improve significantly, the results of tests (in the form of worksheets) completed individually at the end of the workshops shows marked improvement in understanding. Further the level of questions asked and their ability to reason through problems gradually increased over the course of the workshops. As failure in the physics exam in year 1 is the main reason for leaving the course, we are anxious to continue with and improve on this, and disseminate what works best.

When?

The school year runs alongside the university semesters and events can be run at any time if there is some basic consultation with the schools (to ensure not to clash with exams) and there is sufficient lead time for the schools. While a school visit can be arranged at relatively short notice (within a week, but ideally about a month in advance), many schools need sufficiently longer to ok the risk assessment, organise permission slips from parents and arrange a bus and cover (which are the most expensive parts of the exercise) for a campus visit.

The summer term from the half term in May until mid July can be a good time, but year 11 and A2 students will have left most schools. In terms of presenters, you may lose those who do not live near the university, but when the pressure of term and exams is removed, more students will often volunteer their time, encouraged by seeing their fellow students engage during term.

Who's going to deliver your outreach?

Undergraduate Students

I was concerned about using undergraduate students to deliver outreach on the basis that it would put a lot of pressure on them. However, as a voluntary project, it works quite well, as, from the students' perspective the benefits far outweigh the effort. Formally the students gain experience, which they can put on their CV while they get to know the workings of the department (familiarity with lab equipment, technicians, stores, etc.) However, they also get workshops on how to communicate their subject, practice with immediate formative feedback from staff and more experienced students, and an increase in confidence. As this is not limited to any year group the students also gain valuable experience of working in a team and acquaintance or even friendship with students in other years. From this they gain a valuable insight into what's ahead of them which can increase their motivation to master some difficult concept/skill or perspective on how much their

own understanding and skills have developed in a few short years. Through working closely with students in their final year or postgraduates, the students usually become more responsible and learn to think on their feet. However the reason they do it is usually because they really enjoy the experience and seeing the response of the pupils.

The disadvantages are that physics undergraduates are tied into timetables with high contact hours which overlaps significantly with the school term. This is also a problem for the students as their motivation can wane if they are prepared to visit a school, but their timetable constantly clashes. This can be overcome by allowing them to assist with on campus visits, even if they are only available for 1 hour between lectures. They are often happy to be involved in the preparations as well before their lectures start or in advance.

Benefits to Students

A bespoke questionnaire with open questions was completed by the initial 15 members (all undergraduates) which indicated their experience of working with the Physics Outreach Group after 1 year:

- Significantly increased confidence & experience (also useful for CV/PGCE application).
- Offered a useful opportunity to see if they would enjoy teaching.
- Inspired students to read and learn about physics other than 'for exams.'

Postgraduate Students/Postdoctoral Researchers

Postgraduate research students and postdoctoral researchers become involved for similar reasons. Their skills can be particularly well employed in running laboratory sessions for A-level master classes or recruitment sessions. Some plan to add this as their 'teaching experience' when applying for lecturing posts in the future. (Note: Taught postgraduate programmes are usually too tight for time for significant involvement.)

The advantages and disadvantages are similar to those for undergraduates, but sometimes there are less problems with availability so long as the group is not reliant on asking any one student to do too much. On the other hand sometimes it is worse, as students disappear to work on an experiment abroad for weeks or months at a time. Many universities now encourage their postgraduates to engage with the Researchers in Residence programme <www.researchersinresidence.ac.uk/cms/> in which structured sessions spent in schools contributes to their credits for a transferable skills/employability module which is a requirement of their PhD programme.

Staff

Staff involvement in outreach can be in any of a huge variety of formats. A simple approach to engage staff is to invite them to give a short talk at A-level master classes or other school event on campus, thus minimising the initial time commitment. If the person has little experience they are best steered toward A-level students as they will likely have some exposure to year one students. It is important to emphasise that these students will have less knowledge (on average) than year 1 students, and perhaps indicate that a good way to avoid patronising them as an audience, while lowering the level, is to link to the applications/experiments they might be aware of

in the media and to the A-level curriculum. A few minutes spent investigating and guiding them to those links with their research can be invaluable. However the catch is that as the A-level is not consistent from school to school due to different examining boards (an alien notion to many of us foreigners, so it is also worth pointing out to all staff); similar modules are sometimes taken in AS-level in one examining board while in A2-level in another.

Staff may become more involved after some positive experiences or due to interest in contributing to the enhancement of science in their child's school. Resources such as the IOP's Physicists in Primary Schools <www.iop.org/activity/outreach/resources/pips/index.html> are very useful as the links to the National Curriculum at each level have been clearly identified and the PowerPoint presentations and ideas for demonstrations are provided with clear guidance and timings for the inexperienced. However sending a student with them for their first session can be beneficial.

Verdict

Having a variety of providers available would be the ideal; school pupils can often associate with the students and see them as role models within reach, while staff, particularly those who work with ESA or CERN, have the 'wow' factor. A weekly meeting open to all, at which ideas are shared and students practice delivering presentations, running workshops activities and organising a group activity is important to develop a confidence in their skills and sense of community. Allowing the students to design a t-shirt which the Department then provides for each member of the group is also an effective method creating a cohesive group.

How?

Security Clearance – the CRB

Obtaining security clearance is not as complicated as it sounds. Usually the host institution will have some facilities through those who already work with schools such as the Recruitment Office, Aim Higher or Widening Participation. However the Criminal Records Bureau check, referred to simply as the CRB, can be obtained through the local STEMNET office (Science, Technology, Engineering, and Mathematics Network), and is transferable when someone moves about within the UK <www.stemnet.org.uk/>. The STEMNET ambassador registration and online application for CRB is short and straight forward, and they usually come to the students (preferably a group altogether) to check their documents. The first CRB can take up to 3 months to come through, although is usually significantly shorter. After that a second CRB (needed if someone has had a CRB while working for a different institution, if not a STEMNET ambassador) can take as little as 10 days (usually 2 weeks). Contrary to rumour it is a simple matter for international students (and foreign staff no matter how long or short they have lived in the UK) to have a CRB check; they are required to have the same documents confirming identity and current address as all applicants. This document is required to gain access to most schools, although you will never be alone with the pupils, and is at the discretion of the school rather than a legal issue at the moment. It is simplest to get the CRB and advise all students to carry it to all schools with them.

STEMNET

STEMNET provide a resource for schools to contact those who offer outreach or are willing to support enhancement activities organised by the school. They send regular e-mails asking for assistants or talks on particular topics for schools. This can be an advantage if undergraduates are becoming frustrated that the schools always want visits during their lengthy laboratory sessions, as some of these events are in the evenings or on Saturdays. Ambassadors commit to participating in one event per year to maintain their ambassador status, and this is recorded in the STEMNET database. STEMNET North West have consented to accept Physics Outreach Group (at the University of Liverpool) events as recordable STEMNET events so that our members can record their high level of activity. As STEMNET is a nationally recognised body, this increases the profile of their efforts on their cv. STEMNET have been very helpful, and they provide their own introductory training for all, so if there are no communications workshops available in your institution for your students, they can learn a lot from these.

Funding

A comprehensive guide on funding would fill a book, and then immediately be out of date. The following is a short summary to get you started.

HE STEM

The HE STEM programme <www.hestem.ac.uk> provides access to materials and funding to run events based on events which have been successfully run as part of pilot projects across the UK in all 4 areas. There are a of events for each subject and support is provided from them and the professional bodies; the Institute of Physics, Royal Society of Chemistry, the Royal Academy of Engineering and the Institute of Mathematics and its Applications. The call for bids to win funding to run events has been twice per year to date since launch at the end of 2010.

The Science and Technologies Funding Council (STFC) offers the *Small Award Scheme* <www.stfc.ac.uk/Public+and+Schools/1396.aspx> and the Institute of Physics the *University Schools Links Scheme* <www.iop.org/about/grants/university_school/page_38821.html> twice per year. Their websites contain clear criteria and summaries of previously successful awards from which ideas of what works and contacts can be obtained.

There are charities and other organisations out there such as the Ogden Trust <www.ogdentrust.com/> and the Science Enhancement Programme <www.sep.org.uk/> which will provide funding or support (ideas and people) to get events off the ground. However they usually expect the institution involved (the university rather than the schools) to contribute and/or funding to be sought elsewhere in the future as they have contributed to the starting up costs. Companies from international to local small business can be approached for a contribution to an established event and can be supportive, though this is time consuming.

When researchers apply for grants from STFC or Engineering and Physical Sciences Research Council (EPSRC) money can be requested in the public dissemination section to cover audiences from schools or the general public or both. An integrated approach to outreach within a department can strengthen the case for public dissemination funding.

Why

As a guide the aims of the Physics Outreach Group at Liverpool are:

- To deliver quality outreach to schools,
- To develop communication skills and confidence in students,
- To develop a resource for the department in terms of
 - A pool of trained and experienced students and
 - tested materials for and notes on how to run events,
- To increase the uptake of physics in the long-term.

It is particularly important for physicists to visit pupils in their classroom as that is where they spend the majority of their time in lessons² and only ~19% of the 30,000 science teachers in the UK have a qualification in physics, although not all of these will be required to teach physics³.

The Institute of Physics commissioned research which found that students pre-GCSE already have a negative attitude toward physics, believing that the only job prospects are research & teaching, that all scientists are genius-nerds, and that they should not continue with physics as they would not be able and would not enjoy it anyway. However the main problem is that pupils are not even certain what exactly physics is⁴. Other studies done have found that pupils view science as irrelevant in their lives, see no job prospects and are not clear on which elements of science constitute physics, therefore it is not surprising that more than half of pupils asked in the OCR examining board study said that science lessons were 'boring, confusing or difficult'⁵.

Even a fantastic outreach group in every city in the country could not solve these problems, but the following is an outline of some of the benefits a group can have for the schools and their host institution.

The schools have given unanimously positive response to Physics Outreach Group activities and regularly contact us asking for more sessions and recommend us to other schools.

- Trained students can visit the classes more than once, which is not really an option for staff (for younger classes in particular).
- Students are closer in age, which is particularly relevant for GCSE and AS-level students, to enable the pupils to better relate to the presenters, very important when visiting schools with a history of low university attendance.
- Many teachers are more comfortable using the National Schools Observatory software after the class spend a whole workshop working on it under our guidance.
- More on offer both on and off campus.
- The resources are available online from our website or on a DVD by post.
- Recognised Continuous Professional Development sessions for teachers are planned for 2010/11 (after successful pilot).

Feedback was obtained from approximately half the pupils involved in the *Photons in the Classroom: National Schools Observatory* set of 3 workshops (~300 pupils). Before the presentation ~26% claimed to be interested in physics. After the workshops, 61% claimed to have 'more of an interest' in physics, 32.8% indicated 'a little more interest,' and some of the negative responses pointed out the lack of change was because they already liked the subject. When asked if the workshops gave the pupils a 'better idea of what physics is', 71% said 'yes', while 25.7% said 'a little', again some of the pupils who gave a negative response pointed out that they 'already knew about physics.'

In this survey group, the pupils were if they wanted to study Double Science or Triple (separate) Science, but it must be noted that not all pupils understood the difference and in some of the schools, the top set will automatically take Triple Science. However 40.6% of the pupils expressed an interest in taking Triple Science, which is quite a large percentage when compared to the national average of 10% of pupils in comprehensive schools taking Triple Science,⁶ although the numbers have been gradually increasing since the entitlement to Triple Science took effect in 2008⁸.

The benefits to the Department of Physics, it:

- Can now offer a range of outreach activities at short notice.
- Can now accept more requests for University visits.
- Has help in the recruitment of new students e.g. AS-level talk has led to requests from schools to visit the Department for the first time, which we have been in a position to organise.
- Now has experienced students to help on UCAS days and at other events.
- Now has a resources of tried and tested materials and workshops available to staff and students wishing to become involved in outreach.
- Has led to setting up the first Undergraduate Ambassador Scheme module in the University.

In terms of recruitment, although only a portion of outreach is aimed at a sixth form, the last four intakes to the School of Physical Science were considered. Of these 298 schools who sent students to Liverpool, Maths Outreach have reached 30%, Chemistry have reached 15% and Physics 10%. In total 36% have been reached by 1 or more of the Outreach teams, while a further ten schools have been reached by all 3 teams.

What

In order to tackle these issues outlined above, we particularly set out to develop workshops, which would be interactive and enjoyable, highlighting the importance of scientific research to the pupils' lives in terms of new technology and medical techniques. The idea is to develop awareness of and get pupils thinking about the scientific developments all around them. Woolnought⁷ found that 'well planned visits and talks' are 'important in both encouraging pupils both to study science at school and to pursue careers in it.' This research also describes as 'likely to encourage pupils toward science' those activities which 'are both relevant to the students and intellectually stimulating.' This is achieved by using up-to-date examples from popular culture, and something familiar or local examples whenever possible (e.g. wind turbines which can be seen from the school).

Careers in physics are introduced by encouraging the pupils to think of themselves as the ones who could develop these new technologies in the future and be at the cutting edge in a challenging and important field, building on the impression, already present in younger year groups, that science offers reasonably high status, well paying jobs⁹.

In order to create a more positive image of science, POG students visit the schools in pairs, and use the banter during the presentation to demonstrate that physics is a collaborative subject, not something worked on alone, in a poorly lit laboratory (an impression given in several University prospectuses in a survey commissioned by the IOP in 2007⁴). This also gives the students confidence in their early presentations, and allows the more experienced to guide the newer members. Where possible, each class is visited 3 times, usually by the same 2 students, as it was found that the impact of single-visit events falls off rapidly¹⁰. By the third session there is always a big welcome as a relationship has been built up with the class.

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The 3 linked workshop structure means that you can introduce quite a lot of material, but there is time for absorption and in particular for hands-on activities. In the middle session of both strands of our *Photons in the Classroom* project we use no slides, but instead focus on using the National Schools Observatory software (free to schools) in one and experiments in the other. The pupils particularly enjoy these sessions and demonstrate an improvement in their understanding from their questions and responses in the final workshops. In younger classes (up to year 9, but based on the teacher's guidance) we complete the final workshop by asking the pupils to prepare a poster with the title 'What is Physics' in small groups (2-3). These have amazed us at the links they have made between the 3 workshops, with the school science or with their own lives. Ideally these are put on the walls of the classroom/science lab for a few weeks to remind them of what they have learnt.

Our own research has strongly indicated that in classes where science is not a popular subject, their science lessons usually consist of the teacher reading out material, possibly from slides, of which they are directed to write down appropriate sections for revision notes. In our experience this happens

with classes as early as year 8 and is sometimes linked to the teacher being a non-specialist in physics. Investigation has further led to the conclusion that secondary pupils' expectations at year 7 (possibly from experience at primary school or feeder school sessions) are that science will be an enjoyable, if challenging, subject with interesting lessons. They expect experiments and activities more than in other subjects and seem to be particularly disappointed when dictation is the norm. To combat this our workshops are designed to be as interactive as possible. Although we wish to provide information and visual representations (pictures, diagrams, graphs) through slides we take several steps to ensure engagement throughout the session and make even presentations more of a workshop than a lecture. It is important to bear in mind that 'teaching' them is not the role of outreach, there should be an element of fun or excitement with the aim of enthusing them about physics, which unfortunately is necessary even in early secondary school. Ideally we make the learning experience enjoyable and the pupils learn more. In our presentations:

- The slides are designed to be interesting with high quality images – lacklustre or poorly finished work is a big turn off to the internet savvy youth of today.
- Images are chosen to be of local/current interest where possible e.g. when discussing Google Earth, we always include an image of the school from the programme and ask the pupils if they recognise it.
 - The pupils are pleased we've done something specifically for them.
 - They will all recognise it, even if it takes a minute.
- The student presenters work in pairs to give it variety and introduce some banter.
- We ask the audience questions which we expect (and give them time to) respond to:
 - This breaks up the 'download' of information in one direction.
 - By varying the level of the questions, such that everyone is able to answer some of the questions, audience engagement is maintained.
 - The old adage 'Never underestimate the pleasure people get from being taught something they already know' applies to teenagers too.
- We bring props which we pass around to the entire class, e.g. in a section on space technologies we pass around a pillow made of memory foam; it is difficult to overstate the interest that this simple (inexpensive) object raises.
- We include demonstrations which involve movement of the presenters rather than just animated slides or videos. e.g. As an indicator of size in the Solar System, we have 2 balls representing the Earth and the Moon and get the pupils to guess their physical separation to scale based on the size of the balls. This is demonstrated physically and by using examples from the media such as 'Near Miss of Poisonous Comet' type headlines we can initiate a discussion of how physics is often misrepresented.
- Sections where the pupils' opinions are sought are fully integrated, with a supporting slide, where we ask the pupils to think up 3 examples of something e.g. problems facing the world. This is best done in small groups as otherwise the loudest/most confident pupils will respond quickest.
 - It is important to explain clearly what you want them to do and give them a time limit (a signal should appear on the slide to indicate the time is up), before asking them to work with the pupil beside them.
- Ideally questions are fielded whenever they arise as well as at the end, and the pupils' interests are followed to some extent, rather than sticking rigidly to the planned activity.

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