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Bright Lights: Big Experiments!

A Public Engagement Activity for International Year of Light

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Abstract

The Bright Lights: Big Experiments! public engagement project enabled high school students (Y2 Scotland) to prepare a short, five-minute video using their own words and in their own style to present a scientific experiment on the theme of light to their contemporaries *via* YouTube. This paper describes the various experiments that we chose to deliver and our experiences in delivering them to our partner schools. The results of pre- and post-activity surveys of both the pupils and teachers are presented in an effort to understand the impact of the project on the students, staff and their schools. The quality of the final product (here a video) is shown to be a key factor, increasing the pupil's likelihood of pursuing science courses and participating in further science engagement activities. Analysis of the evaluation methods used indicate the need for more sensitive tools to provide further insight into the impact of this type of engagement activity.

1. Introduction

In late 2013, the UN declared 2015 to be *International Year of Light and Light-based Technologies* (IYL) [1]. In doing so, the UN sought to raise global awareness of light, its properties and manipulation; and to highlight a number of important anniversaries of relevance: 1000 years since the first modern studies of optics and 100 years from Einstein's General Theory of Relativity. IYL strove to explain how technologies based on light provide solutions to global challenges in energy, education, agriculture and health. IYL recognised the crosscutting nature of light in science and the vital role light plays in our daily lives. It explained how our knowledge and ability to manipulate light has revolutionized medicine, opened up international communication *via* the Internet, and helped link the culture, politics and economy of our global society.

As an opportunity for public engagement, IYL provided a firm foundation on which to promote science to the public. Many simple, yet fascinating, experiments illustrate the behaviour and application of light. In developing the “Bright Lights: Big Experiments!” Project, we credit our choice of delivery medium to the extensive library of high quality chemical demonstration videos embedded in the YouTube Periodic Table developed by Professor Martyn Poliakoff and his colleagues at the University of Nottingham [2]. However, the “Bright Lights: Big Experiments!” Project sought to move away from traditional educator-centric delivery of ideas, though highly entertaining and erudite, to a more student-centric approach. Our team of mentors (senior undergraduate students, graduate students and post-doctoral research assistants) worked with teachers and small groups of S2 (equivalent of Y13 in England and Wales) pupils in a number of secondary schools across East Central Scotland. Their role was to enable the students to prepare a short, five-minute video using their own words and in their own style to present their assigned experiment to their contemporaries *via* YouTube. The videos were then to be professionally edited and delivered *via* a YouTube channel [3]. Professional transcription and translation of the videos into Chinese, Arabic, and British Sign Language is underway with the goal of widening access to the videos beyond the English-speaking world. In addition, all the student groups were expected to attend and demonstrate their experiments at the national closing event for IYL in Scotland, “IllumiNations”, in the presence of Professor Jim Al-Khalili, their contemporaries and the public.

This short paper will describe the various experiments that we chose to deliver and our experiences in delivering them to our partner schools. We will also present the results of pre- and post-activity surveys of both the pupils and teachers in an effort to understand the impact of the project on the students, staff and their schools.

2. Project Description

2.1 Pupil and Mentor Participation

The project engaged with 12 schools (11 state-funded and 1 fee-paying) in Central and South East Scotland. The schools were chosen following an email advertisement campaign managed by our colleagues in Heriot-Watt University Recruitment and Admissions Service. Each school was asked to select 5 - 6 pupils from their second year science classes to participate in the project. The pupil recruitment process was left entirely up to the school. Consequently, methods of selection varied from pupil volunteering to positive selection of participating pupils by teachers. In total, the project involved 70 pupils overall.

The mentor volunteers for this project were undergraduate students (1), PhD students (6) and post-doctoral early career researchers (5) from Heriot-Watt University. The mentors attended an introductory meeting to provide a project overview and a training session to give guidance on working with schoolchildren. Each mentor attended at least two meetings with the project experimental coordinator (JM) to finalise the experimental setups and to learn how to use the equipment.

2.2 School Sessions

The mentors attended their assigned school for three sessions with roughly a fortnight between each session. Each session lasted for 1 - 2 hours, depending on the timetable and availability of the school pupils. The goal of the first session was to introduce the mentor and project to pupils and to provide the pupils with the opportunity to feedback their own creative ideas into the experimental design. The timeframe between sessions allowed for some of the pupil's ideas to be incorporated into the experimental setups. The focus of the second session was to introduce the experimental apparatus to the pupils and to come up with a script and running order for the video. The final session was dedicated to recording the videos. Two sets of video recording equipment were shared between the 12 pupil groups. Each set consisted of an HD camcorder (Sony PJ240E) and tripod. The video scripts were prepared jointly between the school pupils and their mentor. Furthermore, the direction and filming of the videos was carried out by the school pupils, with assistance provided by their mentor where required. Professional editing of the video footage was provided by a third party (Nick Callaghan Photography), allowing for a consistent, high quality final product. This included the incorporation of a ubiquitous introduction, format and background music for all of the videos. Mentors had the opportunity to arrange further sessions with the school on their own accord.

2.3 Experimental Design

Twelve experiments focusing on the theme of light and chemistry were prepared for the purpose of this project. Each experiment was designed to introduce a single scientific idea to the pupils in a fun and engaging way. The experiments and the associated scientific concepts are detailed in **Table 1.** The equipment used for this project was sourced from a range of technical and educational suppliers including Thorlabs [4], RS [5] and Timstar [6]. Further details of two of the experiments, “What are Optical Fibres?” and “How do we make White Light?” are presented below to give an overview of the nature and scope of the experiments. A Link to the complete set of videos produced by the pupils is provided as electronic supplementary information.

What Are Optical Fibres?

The goal of this experiment was to provide understanding of total internal reflection through learning about optical fibres. To aid this understanding, an experiment was devised that showed the concept of an optical fibre in the form of visible laser light travelling through the curved path of a jet of water. The scattering of the visible light as it travelled through the water allowed the path of the light to be clearly seen, including the total internal reflections at the water-air boundaries. Screenshots from the final video on Optical Fibres by Bathgate Academy are shown in **Figure 1**.

How Do We Make White Light?

The goal of this experiment was to investigate the wavelength dependence of light and in so doing understand that white light can be made up of many different colours. The experiment comprised two distinct parts: splitting up the light of a broadband white light source using a prism to view a continuous spectrum; and combining red, green and blue to form white light using variable intensity LEDs. Screenshots from the final video on Optical Fibres by Selkirk High School are shown in **Figure 2**.

2.4 Public Demonstration of Experiments

Each participating school group was invited to attend the “IllumiNations” event, which closed the International Year of Light in Scotland. Held at Heriot-Watt University, the pupils had the opportunity to demonstrate their experiments and present their videos to their contemporaries, teachers, students and staff of Heriot-Watt University and the public in general. All 12 teams attended and presented their work to 450 fellow school students during the science exhibition component of the closing ceremony. The awarding of prizes for the winning videos took place at the “Illuminations” closing ceremony. The videos were ranked by a panel of Heriot-Watt academics according to the criteria of “Communication of Science”, “Creativity of the Video” and “How Inspiring is the Video?”.

3. Understanding our Impact

3.1 Methodology

In seeking to understand and evaluate the impact of this project and the factors behind this impact, the priority was to gather as wide a range of views as possible from both pupils and teachers. For this reason, paper and online surveys were chosen. Three different surveys were carried out.

A pre-project survey was distributed to students during the first visit from the mentors. The aim of this survey was to map initial interest in science and to understand some of the basic characteristics of those who were taking part in the project. This survey was carried out entirely on paper and the decision was made to ensure that the entire survey took up a single sheet of A4 paper to attempt to minimise the time required to fill it in and hence encourage higher response rates (*cf.* [7, 8]). Of the 72 pre-project surveys known to be distributed, 16 were returned, giving a response rate of 22%. These 16 returns came from 4 of the 12 schools.

Analysis of the pre-project student surveys gives a useful overview of the prior engagement of the students in science-related activities. Since the aim of gathering this data is to provide an initial picture of interest in science, analysis here takes the form of a descriptive account of the responses given.

At the end of the project, during the IYL closing ceremony, paper post-project surveys were given out to pupils and a follow-up visit with each school was organised. Returns were a little lower for the post-project surveys, with 13 surveys returned out of the 66 distributed, giving a return rate of 20%.

While the scales used in the multiple-choice items on the pupil surveys varied in accordance with the questions asked, those used in the teacher surveys were standard 5 item likert scales. This was done as it was felt that the constructs used in the pupil surveys did not lend themselves to standardised scaling and in an attempt to privilege readability. An attempt was made, however, to maintain the kind of discrete yet evenly-spaced scaling found in likert items. Neutral responses were allowed for every item and responses were turned into numeric data for analysis. Conversely, the underlying constructs used in the teacher survey were deemed to be more amenable to likert scales.

These results were once again turned into numeric data for analysis, following standard procedure. No reverse items were used in either survey.

Given the small number of returns of the post-project surveys, it was decided to focus analysis on the correlations between the different survey responses. Focussing on correlations and thus concentrating on analysis of the relationship between different variables, such as views of the final product of the project, and pupils' self-reported likelihood of taking one or more sciences as they progress through school, was expected to lead to more theoretically and practically useful insights. In theoretical terms, this represents a very early stage in the process of building relational models of ongoing pupil engagement with science, akin to those used to measure university students' attitude to chemistry [9]. In practical terms, knowledge of such relationships will be vital for future practitioners wishing to find innovative yet reliable means to increase pupil engagement with science. This paper therefore represents a step in the process of being able to trace the effects of such work on later study and career choices.

Correlations were measured using Pearson's Product Moment Correlation Coefficient (also known as Pearson's r), which is a measure of the linear correlation of two variables. In this case, the norms of social science were observed where values above 0.5 were deemed large (see, p. 88 of Hancock, G. R. and Mueller, R. O. (2010) The Reviewer's Guide to Quantitative Methods in the Social Sciences. Routledge.). This is especially appropriate for exploratory work such as this project. In addition, the statistical significance of these correlations were calculated. This represents the likelihood of these correlations being present where there is no actual relationship between the variables. This is represented in the results by values of "p" and values lower than 0.05 were deemed admissible. This represents a 5% chance of the correlations appearing even though there was no relationship between the variables.

While there have been prior investigations into student engagement in scientific reasoning (*e.g.* [10]) and in student attitudes to science in general (*e.g.* [9]), there seems to be scant literature on the effect of projects of the type covered in this paper. Bridle *et al.* provided an evaluation of the design of a problem-based learning public engagement activity in the field of microfluidics, sharing their best practise [11]. However, the data gathered as part of this project aims to provide an initial, exploratory picture of the outcome of the project and of the factors behind this outcome.

In addition, and given the important role they play in student outcomes [12, 13], the views of teachers on the outcomes and usefulness of the project were deemed important. In this case, online surveys were used two months after the end of the project to allow its medium-term impact to be ascertained. In this case, response rates here high with 7 of the 11 teachers who were sent a survey responding (a response rate of >63%).

The pre-project pupil survey and the post-project teacher survey contained multiple-choice and free text items. The emphasis in this report is on the correlational data from the pupils' surveys and on the descriptive numerical data from the teacher surveys, as this data gives the clearest picture of the impact of the project and the factors behind this.

3.2 Results and Discussion

The pre-project surveys painted a picture of a group of pupils who were already largely excited about and engaged with science. When asked about their prior interest in science, 13 of the 16 respondents answered that they “enjoyed it a lot” with three answering that they “kind of enjoyed it”. The relationship between this interest level and intention to take science later seems rather complicated, however, with 10 of the 16 respondents intending to take more than one science at the next stage of their schooling and 6 showing an interest in taking one. While this does demonstrate a continued willingness to engage with science, it also suggests that for 3 respondents, their enjoyment is not sufficient for them to allow science to take up a major part of their curriculum.

Where there was greatest variation was in their prior involvement in science activities outside of school. Levels of participation varied from taking part in no other science activities (1 respondent) to having watched science on TV and tried some experiments at home (9 respondents), with the remaining pupils having watched some science programmes on television or having done the same and read some books (2 and 4 respondents respectively). This level of interest seems to be a driving force behind the fact that all the students who returned their surveys self-reported an intention of taking a science course when they chose their subject at the end of the academic year, with 6 of the 16 respondents reporting an intention to take two sciences. It is likely, however, that participation in the project was an indicator of a high-level of initial science interest, with responding to the survey being an indicator of high levels of interest among an already engaged sub-group.

Analysis of the post-project survey responses offers a more fine-grained, albeit still limited, view. Opinions of the final videos correlated highly with many of the other questions. Responses to the question “how happy are you with the final video” ranged from “it was alright” (7 respondents) to “it was great” (2 responses), with 4 respondents rating it as “pretty good”.

Views of the video correlated very highly (r=0.841, P<0.05) with self-reported likelihood of recommending that friends get involved in similar projects and with the feeling that they were more likely to choose one or more sciences because of participation in the project (r=0.736, P<0.05). This would suggest that, if involvement in engagement activities is to spread throughout a school, the quality of the final product created in any engagement activity is critical. Further evidence of the potential ripple effect of successful engagement can be found in the significant correlation between self-reported change in interest in their science and their willingness to recommend participation in future similar projects to their friends (r=0.613, P<0.05)

The pupils’ willingness to be personally involved with similar projects in the future correlated significantly with a self-reported increase in interest in science because of the project (r=0.573, P<0.05). Therefore we believe that is essential for public engagement projects with school pupils to lead to a final product that the pupils are proud of if they are to be encouraged to take part in further science activities. This would suggest that repeated involvement in science projects acts as an indicator of increased interest in science. While this may seem obvious, the fact that this intention to take part in further activities correlated significantly with positive views of the final product (r=0.554, P<0.05) suggests it is possible that a poorly rated final product could reduce interest in science. However, evidence for this direct effect were not found in the survey, as the correlation between positive views of the final video and self-reported increase in interest in science were because of the project not significant (r=0.443, P>0.05).

There are three possible mechanisms behind this, both of which will need tested in further work. The first mechanism is simply that, since the pupils involved already had high interest levels in science, these had already reached a maximum point and so the project could do no more than direct these existing high levels of interest into decisions as to the subjects they would choose in the next year. This would accord with the aforementioned significant correlation between positive impressions of the final product and self-reported increase in intention to choose a science course in the next academic year and intention to be involved in further similar projects. If this hypothesis holds true then future engagement could either look to widen involvement among those who current have low interest in science or to target the decision-making of those who do.

A second possible explanatory mechanism for the low correlation between positive views of the final video and a self-reported increase in interest in science because of the project may be that, unlike the relationship between other pairs of questions, the relationship between these two is indirect. Evidence for this interpretation can be found in that fact that there was a significant correlation between positive views of the final product and willingness to be personally involved in similar activities ($r=0.554$, $P<0.05$) and between a self-reported increase in interest in science because of the project and willingness to be involved in similar activities ($r=0.573$, $P<0.05$). Thus, it may be that the relationship between the quality of the final product and increased interest in science is mediated by other variables. It should be noted that this mechanism is compatible with the idea of a maximum interest level, suggested above.

A third, much simpler, explanatory mechanism is simply that either the tool used was not powerful enough to provide an adequate picture of the relationship between these two variables or that there was a limit to the self-awareness of the pupils, given the timescale of the project. In both cases, we suggest that methodological refinements, notably further testing of survey tools and coupling them with other methods, such as interviews or longitudinal studies would be useful.

Overall, it would seem that impressions of the quality of the final product of the project were much stronger factors in willingness to get involved in more engagement activities and self-reported increases in interest in science. This suggests that, where projects have a defined end product, ensuring that this meets or exceed the expectations of pupils will be important in maximising the effects of the project in terms of increasing ongoing engagement with science and spreading this throughout a school. This latter aim is all the more important given the self-selected nature of the groups involved in this project. In short, if science engagement is to move from a select few, who are already interested, out to those students who may currently feel disengaged, creating products that pupils and schools can be proud of will be vital, perhaps even more important than the process itself.

In terms of teacher feedback, the small amount of returns and the fact that answers to 15 of the 22 multiple-choice questions asked showed no variation, mean that any findings must come with caveats. In addition, the responses from one teacher showed much more deviation than any of the others (SD=1.068 compared to the others who ranged from SD=0.417 to SD=0.686), which had a knock-on effect on the correlations between responses.

Taking that into account, as with the results from the pupil surveys, positive views of the quality of the final video were again seen to be a strong factor in perceptions of the project. Answers to this item correlated perfectly ($r=1$, $P<0.05$) with willingness to use the video produced in the school in future science lessons, the feeling that the project gave teachers good ideas for future science teaching, and confidence with the equipment. Confidence with the equipment and the feeling that the project offered good ideas for science teaching also correlated perfectly with a willingness to use the video produced in the school in future science lessons. In the same vein, the view that the project offered teachers good ideas for future science teaching correlated perfectly with confidence with using the equipment in future lessons.

With the above caveats in place, these perfect correlations suggest that the project tended to offer teachers equipment and ideas that could be easily transferred into future teaching, alongside a video exemplar. When this exemplar was deemed to be of good quality, it was viewed as a useful addition to future teaching.

As with the pupil surveys, the responses from teachers also seems to underline the importance of the quality of the final product produced. Indeed, for teachers, the educational value of the video and the experiment seems to be tied to their own confidence in being able to reproduce the experiment in the classroom.

The lack of variability in teacher responses in so many of the survey questions can be read in two ways. It is possible that the project had such an overwhelmingly positive impact that any minor niggles could not be captured with multiple-choice questions. What is more likely, however, is that these lack of variability is an indicator that, alongside improvements in the development of engagement projects, there will need to be effort put into developing more sensitive tools to monitor and evaluate their impact.

4. Summary and Conclusions

This article has demonstrated that the delivery of science public engagement by enabling school pupils to demonstrate a scientific experiment through the medium of video and in person at a live event can be an inspirational and worthwhile activity for school pupils and their teachers alike. Pre- and post-survey analysis of participating school pupils and teachers provided the following key outcomes:

- The quality of the final product (here a science demonstration video) has been shown to be a key factor in the overall success of the project, increasing the pupils' likelihood of: choosing a science course in the next academic year; participating in future science engagement activities; and recommending that friends get involved in similar projects.
- The overall response from the teachers' survey provided a very positive review of the project, however the lack of variability indicates the need for more sensitive tools for monitoring and evaluating the impact of this type of project from the perspective of the teacher.

The analysis of this project is intended to be a stepping stone, to inspire organisers of other public engagement activities in the Physical Sciences to work together with Social Scientists to carry out further and more detailed analysis of their own projects. This article has provided an insight into some key factors influencing the success of the project, however highlights the need for more sensitive tools for evaluation. Heriot-Watt University will be investigating the tools required for evaluating public engagement activities through an upcoming PhD studentship.

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6. References

[1] http://www.light2015.org/Home.html

[2] http://www.periodicvideos.com/index.htm

[3] https://www.youtube.com/playlist?list=PLYmkj73NeZvIRUIg2wrXKbqIKgdCjycbF

[4] https://www.thorlabs.com

[5] http://www.uk.rs-online.com

[6] http://www.timstar.com

[7] C. Jepson, D. A. Asch, J. C. Hershey and P. A. Ubel, *J. Clin. Epidemiol.*, 2005, **58**, 103–105.

[8] M. Galesic and M. Bosnjak, *Public Opin. Q.*, 2009, **73**, 349–360.

[9] S. M. Villafañe and J. E. Lewis, *Chem. Educ. Res. Pract.*, 2016.

[10] A. Pabuccu and S. Erduran, *Chem. Educ. Res. Pract.*, 2016.

[11] H. Bridle, J. Morton, P. Cameron, M. P. Y. Desmulliez and M. Kersaudy-Kerhoas, *Microfluid. Nanofluid.*, 2016, **20**, 103.

[12] A. M. Klem and J. P. Connell, *J. Sch. Health*, 2004, **74**, 262–273.

[13] P. A. Jennings and M. T. Greenberg, *Rev. Educ. Res.*, 2009, **79**, 491–525.

Table 1: Titles of experiments developed and associated key scientific concepts.

Experiment	Associated Scientific Concepts
Is Light a Wave or a Particle?	– Diffraction of Light – Wave Particle Duality
What is the Photoelectric Effect?	– The Photoelectric Effect
What is the Speed of Light?	– Measuring the speed of light
How can we Count Photons?	– Wave Particle Duality – Concept of a Phonon – Wavelength Variation in Light
The Invisible Spectrum	– Invisible Wavelengths of Light
What are Optical Fibres?	– Total Internal Reflection
Why is the Sky Blue?	– Wavelength Variation of Light – Rayleigh Scattering
How do we make White Light?	– Wavelength Variation of Light – Colour Mixing – Diffraction of Light
Raspberry Pi - Lego Spectrometer: Atoms	– Wavelength Variation of Light – Colour Mixing
Raspberry Pi - Lego Spectrometer: Molecules	– Wavelength Variation of Light – Colour Mixing
Raspberry Pi - Lego Spectrometer: Fluorescence	– Wavelength Variation of Light – Colour Mixing – Fluorescence
What is Bioluminescence?	– Bioluminescence, Chemiluminescence

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Figure 1: The investigation of total internal reflection in fibre optics was carried out by Bathgate Academy. Screen shots of their video show how they explained the concept of total internal reflection using Perspex blocks, a ray box, a water jet and laser pens.

Figure 2: The investigation into white light was conducted by Selkirk High School. Screen shots of their video show how white light can be split up into its constituent colours using a prism, and then how white light can be synthesised using red, green and blue light.