Institution: The University of Nottingham

Unit of Assessment: 9

Title of case study: Communicating Research to the Public through YouTube

1. Summary of the impact

In collaboration with film-maker Brady Haran we have developed the YouTube channel *Sixty Symbols* to present topics related to research in physics to the wider public. Since the 2009 launch of *Sixty Symbols* we have posted 212 videos, which have amassed 21.2M views, over 200k comments, over 266k subscribers and a content approval rating of 99.4%, placing *Sixty Symbols* in the top 0.01% of all YouTube channels. The success of *Sixty Symbols* led to commissions from Google and STFC for the launch of additional science-focused YouTube channels, and to the formation of the company *Periodic Videos Ltd* by Brady Haran (2011). Quantitative evidence gathered by management consultants, O'Herlihy & Co, demonstrates *Sixty Symbols'* global reach, and significant impact on the attitudes, scientific understanding and career aspirations of its audience. Overall the impact has been on society, culture and creativity through the promotion of public engagement and discourse on science and engineering, and through educational use in schools.

2. Underpinning research

The primary motivation within the School for the establishment of *Sixty Symbols* was to provide a new vehicle for the dissemination of our research using social media, specifically YouTube videos, in order to reach a much wider audience (demographically and geographically) than is possible using conventional approaches to outreach.

Videos have now been delivered by 15 different researchers, including academic staff, postdoctoral research assistants (PDRA) and PhD students, who span all of the research groups within the School:

Astronomy: *Almaini*, *Gray*, *Merrifield*, *Bauer* (*PDRA*)
Cold Atoms & Quantum Optics: *Krüger*
Condensed Matter Theory: *Clewett* (*PhD*/*PDRA*), *Bowley* (*Emeritus Professor*), *Fromhold*
Experimental Condensed Matter and Nanoscience: *Eaves*, *Hill*, *Moriarty*
Magnetic Resonance Imaging: *Bowtell*, *Glover*
Particle Theory: *Copeland*, *Padilla*

Accordingly, research across all areas within the School underpins *Sixty Symbols*, and the videos derive their authority from the expertise of the featured researchers. The topics covered in many of the early videos provide the context for our research activities, and built an audience through the release of videos tackling problems of topical interest and scientific curiosities. This platform has subsequently been used to introduce videos that focus upon specific results arising from research within the School. In particular, videos focusing on specific research outputs in the areas of nanoscience [1], galactic astronomy [2], magnetoscience [3], soft matter [4,5] and theoretical particle physics [6] have been produced. To illustrate our approach, we describe below two areas of research which have been successfully translated into series of *Sixty Symbols* videos.

2.1 Scanning probe microscopy: In a series of papers dating back to 1995, *Moriarty* has investigated the use of scanning probes to manipulate and image single molecules and atoms on silicon surfaces. The initial focus was on the use of a scanning tunnelling microscope (STM) to position single C_{60} molecules on silicon surfaces at room temperature. Following the purchase of a SRIF3-funded low temperature, ultra-high vacuum atomic force microscope (AFM) in 2008, *Moriarty* subsequently used AFM to toggle the state of Si dimers [1] and image molecular orbitals of fullerene molecules (with support from EPSRC [i]). This work has been translated to the *Sixty Symbols* project through the initial posting of videos on background material in condensed matter and surface physics: the video *Gold Nanoparticles* provides an introduction to crystal structure, electron microscopy and nanoparticles; *Electrons* introduces the wave nature of particles, including electron diffraction from a silicon surface; *Nano* provides an introduction to STM and nanoscience; *Wave Function* provides background information on probability amplitude and describes the molecular orbitals of C_{60}; *Vacuum Cannon* introduces vacuum technology. These videos contain many references to, and explanations of, relevant experimental techniques and provide contextual information for videos which focus on specific research outputs, such as the AFM manipulation of

Si atoms discussed in [1] and the video *Atomic Switch (manipulating a single atom).*

2.2 Galactic Astronomy: *Merrifield* has been studying the rates at which patterns rotate in galaxies since 1995, and this work has resulted in 7 refereed publications to date, including [2], with support from STFC [ii]. Measurements of this wave phenomenon have significant implications for the way in which galaxies evolve and may even provide new insight into the distribution of dark matter in galaxies. *Merrifield* described many of the properties of galaxies in the videos *Plus or Minus* (looking at the distance scale in the Milky Way), *Redshift* (Milky Way merger with Andromeda), *Dark Matter* (looking at the existence and distribution of dark matter in the Universe) and *Milky Way's Twin* (spiral structure, etc. in a galaxy very like our own), as well as in videos on the sister *Deep Sky Videos* channel (see Section 4). This allowed us to present his recent work [2] on measuring pattern speeds and their variation with radius in spiral galaxies, as well as galaxy bar pattern speeds, in the video *Spiral Galaxies.*

In addition, we have released background videos related to cold atoms, magnetic levitation, graphene, magnetic resonance imaging and semiconductor physics which will provide the relevant background physics for a further phase of videos focusing on specific research results.

3. References to the research (*denotes paper which best highlights the quality of the research)

1) ***A. Sweetman, S. Jarvis, R. Danza, J. Bamidele, S. Gangopadhyay, G.A. Shaw, L. Kantorovich, P. Moriarty** '*Toggling Bistable Atoms via Mechanical Switching of Bond Angle',* Phys. Rev. Lett. **106**, 136101 (2011).
Listed in REF2; DOI: 10.1103/PhysRevLett.106.136101

2) ***S.E. Meidt, R.J. Rand, M.R. Merrifield** '*Uncovering the Origins of Spiral Structure by Measuring Radial Variation in Pattern Speeds',* Astrophysical Journal **702**, 277 (2009).
Listed in REF2; DOI:10.1088/0004-637X/702/1/277

3) ***R.J.A. Hill and L. Eaves, '***Nonaxisymmetric Shapes of a Magnetically Levitated and Spinning Water Droplet',* Phys. Rev. Lett. **101**, 234501 (2008).
Listed in REF2; DOI: 10.1103/PhysRevLett.101.234501

4) **K. Roeller, J.P.D. Clewett, R.M. Bowley, S. Herminghaus, M.R. Swift**, *'Liquid-Gas Phase Separation in Confined Vibrated Dry Granular Matter'*, Phys. Rev. Lett. **107**, 048002 (2011).
Listed in REF2; DOI: 10.1103/PhysRevLett.107.048002

5) **J.P.D. Clewett, K. Roeller, R.M. Bowley, S. Herminghaus, M.R. Swift, '***Emergent Surface Tension in Vibrated, Noncohesive Granular Media***'**, Phys. Rev. Lett. **109**, 228002 (2012).
Listed in REF2; DOI: 10.1103/PhysRevLett.109.228002

6) **A. Avgoustidis, E.J. Copeland, A. Moss, L. Pogosian, A. Pourtsidou, D.A. Steer,** *'Constraints on the Fundamental String Coupling from B-Mode Experiments'*, Phys. Rev. Lett. **107**, 121301 (2011).
Listed in REF2; DOI: 10.1103/PhysRevLett.107.121301

Funding

i. 'Digital Matter: towards mechanised mechanosynthesis', PI: Moriarty, EPSRC Leadership Fellowship EP/G007837/1, (Nov 2008 – Mar 2014), £1,730,559

ii. 'Nottingham astronomy rolling grant', PI: Merrifield, STFC, (Apr 2008 – Mar 2011), £1,846,070

4. Details of the impact

In 2007 the School started to collaborate with Brady Haran, then a freelance BBC journalist, who had worked previously with the Nottingham School of Chemistry on the production of short videos on the chemical elements. This initiative arose from interest within the School to engage with the wide and diverse audiences which can be accessed through new forms of social media and mobile technology. Following the success of a pilot phase in which several Physics-focused videos were featured on Haran's *Test Tube* YouTube channel, which is aimed at a general science audience, a decision was taken to launch the *Sixty Symbols* YouTube channel (http://www.youtube.com/user/sixtysymbols) and website (www.sixtysymbols.com), devoted entirely to physics-related topics. This activity serves the strategic aim of providing a route through which the public can become engaged with our research.

Since its launch in February 2009, *Sixty Symbols* has amassed 21.2M views and 266k subscribers and there are now 212 freely-available videos (all figures quoted are up to 31st July 2013), each of

which consists of a commentary on a particular scientific topic by a researcher from the School. *Sixty Symbols* was designed to present the workings of a research-led physics department in a manner that engages the viewer by giving them a sense of membership through the development of themes, familiar faces, and a common informal style. This feeling of community is reflected by the rapid growth in the number of *Sixty Symbols'* subscribers and the high proportion of returning viewers, evidenced by large numbers of comments and channel subscriptions. *Sixty Symbols* is now ranked within the top 0.01% of the tens of millions of YouTube channels by number of views. For comparison, the viewing statistics for *Sixty Symbols* compare favourably with the highly acclaimed *CERNTV,* the YouTube channel of CERN, a major international organisation which attracts wide media interest: *CERNTV* has attracted 3.3M views and 36k subscribers to 179 uploaded videos since its launch in 2007.

The *Sixty Symbols* videos and viewing figures (31st July 2013) related to the topics discussed in detail under the research section on scanning probe microscopy (Section 2.1) are: *Gold Nanoparticles* (72,627), *Electrons* (74,842), *Nano* (41,082), *Wavefunction* (111,012), *Vacuum Cannon* (87,785), and *Atomic Switch* (49,608). Those related to Galactic Astronomy (Section 2.2) are *Plus or Minus* (54,451), *Milky Way's Twin* (41,370), *Redshift* (47,248), *Dark Matter* (142,422) and *Spiral Galaxies* (52,040). The videos may be readily accessed through an internet search on 'Sixty Symbols *Videoname*' and the viewing figures confirm the effectiveness of this dissemination route for our research.

To assess further the impact of the *Sixty Symbols* project, the School commissioned an independent evaluation by management consultants O'Herlihy & Co [A] which was completed in 2013. This report is used extensively below to provide supporting statistics and analysis of audience interaction with *Sixty Symbols*. The report is based on: data extracted from viewing statistics, audience comments appended to each video [B], social media conversations, newspaper reports, stakeholder interviews, teaching resources, and a student survey. The report confirms the viewing figures above and makes the following additional points,

- 99.4% positive feedback, quantified by viewers 'liking' (positively rating) the video content.
- Geographical analysis of viewer statistics shows that *Sixty Symbols* reaches a global audience across all continents with a particular concentration in Australia, North America and Europe.
- Prior to university study, 1st year undergraduates reported that *Sixty Symbols* significantly raised their interest in Physics (74%) and also raised their understanding of Physics (77%).
- The large number of comments (over 7000 for some videos) provides clear evidence of debate between the public and the researchers themselves (including 100s of direct emails). Scientific debates arising from *Sixty Symbols* videos are often followed up through other social media sites such as Facebook (https://www.facebook.com/sixtysymbols) and Twitter.
- *Sixty Symbols* has been used as a formal educational resource, positively referenced by numerous teachers' support networks including; Times Educational Supplement (TES), the California Learning Resource Network and the Northern Illinois University [A].

For a specific example of inclusion in core teaching material, see reference [C] from a UK teacher in a secondary school who highlights the importance of the link with research (in this case the topic of scanning probe microscopy discussed in Section 2.1) in stating:

"….greatly enjoyed throughout our student population, around 130 at A level studying for Physics. A key element of Sixty Symbols is the symbiotic content of real research carried out with a physics department, such as nanoscale microscopy, supported by discussion of the underlying physics."

The educational influence of *Sixty Symbols* has also steered other organisations in their approach to outreach and investment in new media. In 2010, STFC commissioned a series of videos under the title of *Backstage Science* (http://www.backstagescience.com) to present their facilities using an approach similar to the *Sixty Symbols* format. The open call for an STFC contract to shoot these videos was won by a consortium headed by *Merrifield* (£70.5k, 2010), with further support (£18k) in 2012. These videos have had over 0.5M views, and the *Backstage Science* channel has 24,000 subscribers. STFC have estimated that this channel has been used by 3,000 teachers [A; see page 19].

The success of *Sixty Symbols* in delivering videos of high quality and with educational value has been recognised by the invitation to *Merrifield* to speak at the *BrainSTEM* 'unconference' on

YouTube science held at the Perimeter Institute in 2012. Recognition has also come from Google: *"Sixty Symbols provides quality educational content on YouTube. The videos have theories in physics and astronomy put forth so passionately by experts in the fields, they serve as a very effective way to propagate this knowledge."* Global Head of Education Partnerships, Google [D]

In an initiative to raise the quality of content on YouTube, Google [E] funded Brady Haran to establish several new YouTube channels including *Numberphile* related to mathematics and, in collaboration with the astronomy researchers in the School, *Deep Sky Videos*. These new channels, which build directly on the success of the *Sixty Symbols* project, have already attracted over 30M views and 400k subscribers. To support this additional activity, Brady Haran has recently formed "*Periodic Videos Ltd*" (2011), securing the future for this style of disseminating scientific research. Haran himself [E] notes the importance of the role of research in the success of the videos:

"I believe this "real life researcher" discussion is what makes Sixty Symbols so successful. The people in these films are "the real deal" at the cutting edge of research - and viewers respond to that!"

4.1 Comments and critical review by leading scientific communicators

Physics World [F]
"This is what online physics should look like…..professional but not too slick…explained thoughtfully. The scientists skilfully avoid either confusing or patronizing their audience".

Henry Reich, Perimeter Institute (producer of Minute Physics) [G]
"..Sixty Symbols is a particularly important channel because it shares the real "on the ground" stories….increase public awareness and understanding, but also to make science a more approachable and desirable path for young students around the world."

Simon Singh (science writer) [H]
"*Sixty Symbols is an excellent example of science engagement, reaching large number so people (sic), using the internet in an effective manner, and working within a modest budget. Others should pay attention and learn from this model. With millions of videos viewed and over 100,000 comments, the project speaks for itself. Part of the reason for its success is that the people behind Sixty Symbols regularly update with fresh material, thus bringing cutting edge research direct to the public. Perhaps the site's greatest achievement, after sheer volume of traffic, is its ability to strike the right balance between serious content and a flair for entertainment*"

- **Audience comments**

Comments uploaded by the audience reveal inspiration, and motivation to study physics. The Word Cloud (right) summarising over 220k comments, indicates the frequency of keywords. Specific comments [B] include:

"convinced me of studying physics at university"
"I want to be a physicist"
"inspiring me in the sciences"
"go back to school and finish my undergraduate in physics"

5. Sources to corroborate the impact (available on request)

A. *Evaluation of the Sixty Symbols Video Series*, O'Herlihy & Co. Ltd. Management Consultants.
B. A sample of comments from the *Sixty Symbols* YouTube channel; additional comments for each video may be accessed through the *Sixty Symbols* YouTube channel.
C. Letter from a secondary school teacher at Queen Mary's College, Basingstoke.
D. YouTube Partnerships Manager for Education, Europe, Middle East and Africa, Google.
E. Letter from Brady Haran.
F. Physics world "Web life: Sixty Symbols", 2nd September 2009, (Institute of Physics).
G. Email from Henry Reich producer of Minute Physics.
H. Letter from independent science writer Simon Singh.