Institution: University of Oxford

Unit of Assessment: 9 - Physics

Title of case study: [1] The *Zooniverse* citizen science projects

1. Summary of the impact

The *Zooniverse* citizen science projects, including *Galaxy Zoo,* have engaged over 856,000 members of the public from 100 countries with astronomy and other areas of research such as nature, health and the humanities. The impacts include increased public awareness and understanding of science and research methods, changes in the attitudes of school children and adults, and benefits to teaching and learning. The *Zooniverse* engages with large numbers of people through the internet; additional benefits are also delivered through adaptations of the projects for interactive museum exhibits and classroom education. Further impacts include benefits to Cancer Research UK and commercial uptake by Microsoft and the BBC.

2. Underpinning research

The original research aim that led to the *Zooniverse* was to investigate star formation in as wide a variety of galaxies as possible. Under Professor Joe Silk, postdoctoral researcher Dr Chris Lintott (appointed to Oxford in 2006) began investigations into the astrochemical properties of a small proportion of local elliptical galaxies that showed signs of recent star formation but he required a larger sample of such systems. Ground and space-based platforms such as the Sloan Digital Sky Survey and the Hubble Space Telescope have produced large numbers (typically millions) of images featuring galaxies and other astronomical objects of interest. Previous work [1] had demonstrated that such samples were best assembled through visual inspection, a PhD student at Oxford, Kevin Schawinski, having classified 50,000 galaxies by eye. To find a sustainable solution, the Oxford team developed software that could be scaled to handle the size of modern datasets to crowdsource the problem.

In 2008, using the newly developed software, Lintott demonstrated that it was possible to train members of the public to classify galaxies with sufficient accuracy that, when cross-referenced with each other, the data could be used in scientific research [2]. Gathering several independent classifications for each galaxy, and quantitative estimates of error in the classification, was critical to the system. Using the public as a resource for classification meant that vast data sets could be analysed. The public online interface with the classification software was named *Galaxy Zoo* and within its first year of operation was able to collect 50 million classifications. With multiple classifications used for each galaxy, this resulted in the first data release of morphological classifications for nearly 900,000 galaxies [3]. *Galaxy Zoo* is a collaboration between Oxford, Portsmouth and Nottingham universities. Portsmouth and Nottingham each provided science team members who assisted with the analysis of *Galaxy Zoo* data. The scientific direction, project development, and operation were led by Oxford.

Having demonstrated the effectiveness of this form of citizen science, the Oxford team developed the *Zooniverse* platform capable of supporting the widest possible range of projects. This new platform was first used to re-launch *Galaxy Zoo* and now supports 17 live projects in a range of subject areas, collectively known as the *Zooniverse*. In 2009, Lintott was appointed to a permanent position in the department.

The power of this platform, coupled with scientific insights into the kinds of problems that could be tackled, has enabled some remarkable discoveries in astrophysics that would not have been possible without effective analysis of large data sets. These include the discovery of a quasar-scale light-echo [4], the first planet in a four star system [5] and a sophisticated measurement of the dust distribution in the Earth's orbit [6].

3. References to the research (<u>Oxford</u> authors, * denotes best indicators of quality)

[1] <u>Schawinski K</u>, <u>Thomas D</u>, <u>Sarzi M</u>, <u>Maraston C</u>, <u>Kaviraj S</u>, Joo S-J, Yi SK, <u>Silk J</u>, (2007), Observational evidence for AGN feedback in early-type galaxies, *Monthly Notices of the Royal Astronomical Society*, 382 (4), 1415-1431, doi: 10.1111/j.1365-2966.2007.12487.x, citations: 204 (WoS).

*[2] <u>Lintott CJ</u>, <u>Schawinski K</u>, <u>Slosar A</u>, <u>Land K</u>, Bamford S, Thomas D, Raddick MJ, Nichol RC, Szalay A, Andreescu D, Murray P and Vanderberg J, (2008), Galaxy Zoo: morphologies derived

from visual inspection, *Monthly Notices of the Royal Astronomical Society*, 389 (3), 1179-1189. doi 10.1111/j.1365-2966.2008.13689.x, citations: 175 (WoS). *This paper introduces the Galaxy Zoo project and finds that Galaxy Zoo results are comparable with classifications by professional astronomers.*

*[3] Lintott CJ, Schawinski K, Bamford S, Slosar A, Land K, Thomas D, Edmondson E, Masters K, Nichol RC, Raddick MJ, Szalay A, Andreescu D, Murray P and Vanderberg J, (2011), Galaxy Zoo 1: data release of morphological classifications for nearly 900 000 galaxies, *Monthly Notices of the Royal Astronomical Society*, 410 (1), 166-178, doi: 10.1111/j.1365-2966.2010.17432.x, citations: 67 (WoS)

*[4] Lintott CJ, Schawinski K and 19 other co-authors, (2009), Hanny's Voorwerp, a quasar light echo, *Monthly Notices of the Royal Astronomical Society*, 399 (1), 129-140, doi: 10.1111/j.1365-2966.2009.15299.x, citations: 19 (WoS). *This paper gives an example of a serendipitous discovery made possible using Galaxy Zoo.*

[5] Schwamb ME, Orosz JA, Carter JA, Welsh WF, Fischer DA, Torres G, Howard AW, Crepp JR, Keel WC, Lintott CJ, Kaib NA, Terrell D, Gagliano R, Jek KJ, Parrish M, Smith AM, Lynn S, Simpson RJ, Giguere MJ, Schawinski K, (2013), Planet Hunters: A Transiting Circumbinary Planet in a Quadruple Star System, *The Astrophysical Journal*, 768, 21, doi: 10.1088/0004-637X/768/2/127, citations: 1 (WoS).

[6] Davis CJ, Davies JA, St Cyr OC, Campbell-Brown M, Skelt A, Kaiser M, Meyer-Vernet N, Crothers S, Lintott C, Smith A, Bamford S, Baeten EML, (2012), The distribution of interplanetary dust between 0.96 and 1.04 au as inferred from impacts on the STEREO spacecraft observed by the heliospheric imagers, *Monthly Notices of the Royal Astronomical Society*, 420, 1355, doi: 10.1111/j.1365-2966.2011.20125.x, citations: 4 (WoS).

4. Details of the impact

Here we detail the impact of the entire suite of 17 *Zooniverse* projects, all of which have been launched and sustained in the REF period. Many of these projects involve researchers and datasets from other institutions, but the underpinning research and expertise in citizen science as a scientific tool, along with the leadership of development and implementation, is an Oxford-led endeavour. The *Zooniverse* includes 7 astronomy projects (the first being *Galaxy Zoo,* launched 2009) and 9 projects beyond astronomy, for example in climate, nature, health and the humanities. In November 2012 the users of *Zooniverse* were surveyed to determine the nature, reach and significance of the impacts. The survey received over 2000 responses [A], primarily from users of astronomy projects *Galaxy Zoo* and *Planet Hunters.*

Impacts on the users of the *Zooniverse*: The *Zooniverse* is distinguished by its broad reach, with more than 856,000 people engaging directly as a result of signing up to one or more of the projects and taking part. Roughly one third of these volunteers are from the UK, one third are from the US and one third are from over 100 other countries. Translations into languages including Polish, German and Czech further widen the *Zooniverse's* reach. 85% of survey respondents were not already amateur astronomers prior to engaging with *Zooniverse.*

88% of respondents agreed that the *Zooniverse* had increased their understanding of how modern scientific research is carried out. In addition to citing specific research methods they have learned about, users say that working with real data has enhanced their understanding of the research process. Comments include: *"working with real data […] gives me a better feel for the connection between data scientists deal with and the conclusions they develop from it"* and *"by participating in the research, I have appreciated more what researchers have to check for, cross referencing their data, and analysing the results"*. Comments also indicate a better understanding of scientific consensus: *"a thing isn't true just because one person says or believes it is, a thing is true because it can be shown to be by observations and measurements which are not dependent upon one's personal bias and/or belief structure."*

85% agreed that the *Zooniverse* had increased their understanding of astronomy and physics. Again users list specific scientific concepts they now understand, for example gravitational lensing and morphological classification of galaxies. Comments include: *"with every Zooniverse project I've participated in my knowledge of that subject has increased substantially."* 78% of under-18s said they were more encouraged to study physics or astronomy at a higher level as a result of the *Zooniverse.* 39% of all respondents said they were more likely to take up a scientific career as a

consequence of their experiences with the *Zooniverse.*

Over half of respondents have changed their astronomical observing behaviour as a result of the Zooniverse including 19% who observed the night sky for the first time. Many note that they have bought their own telescopes and now observe as a family activity. In all, 87% of respondents reported at least one increase in engagement with science as a result of the *Zooniverse,* including those who read more about science (68%), studied more formally (34%), carried out their own research (12%), attended lectures or events (19%), and/or visited museums and planetariums (33%).

The highly accessible nature of the *Zooniverse* is an important factor in enabling these impacts. Users comment that *"these projects have allowed me to feel less removed from the daily application of science and more knowledgeable about astronomy, something I've always had an interest in but have been too intimidated to pursue seriously"* and *"what was once seemed [sic] distant, lofty, and inaccessible to many people is now right at their fingertips."*

Teaching: Further reach is achieved through formal and informal teaching. Teachers use the *Zooniverse* site directly to support classroom learning and comments suggest that this *"has opened their curiosity in a whole new way"* and changed some students' preconception that *"science was hard or boring."* Another teacher comments that *"the feedback from students suggests that they learn about physics/astronomy but also get a better understanding of what scientists actually do."* In recognition that impact through teachers is an important pathway, the *Zooniverse* has produced resources for teachers directly. A series of workshops, using *Galaxy Zoo* data, were organised in Oxford and following their success the *Zooteach* tools were launched in 2011. These resources include 38 lesson-plans categorised by subject and age, and have received almost 14,000 page views between 1st January 2013 and 30th July 2013.

Many survey respondents note that they participate in *Zooniverse* projects with their families in an informal learning environment. A user said *"the combination of tutorials and extensive community discussion about the data are an invaluable part of increasing mine and my family's scientific literacy."* 47% of under-18s said that the *Zooniverse* had helped with their school work. Parents find the *Zooniverse* beneficial to support their children; for example one commented that *"I have a better understanding of physics, so much so I can help my son in his school work."*

Media: Many of the *Zooniverse* projects have enjoyed a high media profile, both on launch and during their operation. UK broadcast examples included BBC Radio 4's Today Programme (6 appearances) and PM (1 appearance), BBC Breakfast (1 appearance), Bang Goes the Theory (2 appearances). Lintott is co-presenter of Sky at Night (viewership 1 million) where *Galaxy Zoo* was featured and other projects mentioned. Stargazing Live (viewership 4 million) also featured two projects on episodes of the show. *Galaxy Zoo* was reviewed in the *Guardian* [B] which concluded that there was *"no surer way to engage the public than to involve people in the research itself."* *Planet Hunters* is showcased in the *Economist* [C].

Museums: Museums have also made use of the underlying *Zooniverse* software leading to a wider audience than just the primary users of the online projects. *Zooniverse* project *Solar Stormwatch* has been at the heart of programmes for schools and visitors run by the Royal Observatory Greenwich. This won 'Best Innovative Site' at the 2010 'Museums and the Web' awards [D]. The Public Astronomer at the Royal Observatory Greenwich said, *Solar Stormwatch* has *"certainly had a very positive impact on the content of our public programme, as well as the Observatory's online and media profile. We regularly run solar viewing sessions […] and Solar Stormwatch has been the springboard for several of these"* [E]. US museums, including the Adler Planetarium in Chicago (500,000 visitors per year), have also featured *Zooniverse* projects prominently in floor displays and in public programs. The President of the Adler Planetarium said: *"Our partnership with Oxford University on the Zooniverse citizen science effort is a critical component of our success in inspiring the next generation of explorer. The Zooniverse permeates our operation, and allows us to offer all visitors meaningful opportunities to engage in frontier science"* [F].

Charity: *Cell Slider*, a *Zooniverse* project launched in 2012 in collaboration with Cancer Research UK (CRUK), is the first biomedical citizen science project in the world; its purpose is to accelerate cures for cancers by using citizen scientists to classify tumour samples. So far *Cell Slider* has

helped to reduce analysis time from 18 months to three months, and with accuracy that shows a high degree of agreement with expert pathologists. The Citizen Science Lead at CRUK said, *"in addition to significantly reducing research timeframes, CRUK recognise Zooniverse's impacts on their work as a charity. The Zooniverse has given us access to a community of people outside of the typical CRUK supporter base. Cell Slider is the first non-fundraising product CRUK have launched and the first time that CRUK cancer research data has been made publicly available for analysis. The Zooniverse has made an essential contribution to these developments."* [G]

Sustainability: There are many problems in science that cannot be dealt with by purely automated processes, and capability to crowdsource parts of the analysis is crucial. By pursuing these scientific problems through citizen science, the *Zooniverse* has created a virtuous circle where the scientific outcomes and the public both benefit. In only four years, this stream of citizen science has grown into a large activity measured by number of users and the diversity of projects: from January 2013 to July 2013, between 500 and 1000 new users signed up daily and 4 new *Zooniverse* projects were launched. On-going engagement is apparent through the *Zooteach* resources, discussion forums and special tools for advanced users.

Recognition: In 2011, Lintott won the Royal Society Kohn Award *"for his excellent engagement with society in matters of science and its social dimension"*. *Zooniverse* also won the President's Prize in the Institute of Physics web awards. *Zooniverse* was the People's Choice winner as well as the overall winner by the judges, who described it as *"a great site for non-professionals to take part in serious scientific discovery"* (Paul Millar); *"an engaging online experience that takes visitors beyond browsing and into genuine interaction"* (Sumit Paul-Choudhury); and *"a great way to harness collaboration, sense of participating and making a difference"* (Maggie Philbin). The *Old Weather* project, a collaboration with the Met Office, won the 2012 Royal Meteorological Society award for "Meteorological innovation that matters" – the certificate states that the success of *Old Weather "depended on the efforts of the Zooniverse team, who built the novel website interface which ultimately allowed the public to digitize the data with minimum effort"* [H].

Commercial uptake: In 2009, Microsoft licensed the *Zooniverse* framework in their development for NASA of *Be A Martian. Tiny Planets*, an educational website, also implemented a version of the *Zooniverse* project *Moon Zoo* adapted for children aged 4-7, into their online educational virtual world. *Scribe,* a generic package for crowdsourced transcription, was developed by the Oxford team as open-source software. The first third-party implementation of *Scribe* was in *What's the Score,* a partnership between the Bodleian Library and Google to digitize a collection of music manuscripts.

5. Sources to corroborate the impact

[A] *Zooniverse* survey results (data held on file) confirming the nature and significance of impacts on members of the public.

[B] "Galaxy Zoo and the dawn of citizen science", The *Guardian*, 18th March 2012
http://www.guardian.co.uk/science/2012/mar/18/galaxy-zoo-crowdsourcing-citizen-scientists

[C] "A new world in your bedroom", The *Economist*, 1st October 2011
http://www.economist.com/node/21530947

[D] *Solar Stormwatch* winner of the Best Innovative Site at the 2010 Museums and the Web awards http://www.museumsandtheweb.com/nominee/solar_stormwatch

[E] Letter from the Public Astronomer at the Royal Observatory Greenwich (held on file) confirming impacts on the Royal Observatory and their visitors.

[F] Letter from President of Adler Planetarium, Chicago (held on file) confirming impacts on Adler Planetarium and their visitors.

[G] Letter from Citizen Science Lead at Cancer Research UK (held on file) confirms reduction of analysis time and impacts on CRUK's work.

[H] *Old Weather* winner of 'Innovation that Matters' award from the Royal Meteorological Society 2012 http://oldweather.files.wordpress.com/2013/05/rmets_ibm_award_certificate.pdf