Institution: University of Portsmouth

Unit of Assessment: 9 Physics

Title of case study: Impact of Galaxy Zoo and the Zooniverse on Public Engagement with Scientific Research

1. Summary of the impact

Galaxy Zoo (GZ) is among the most successful online citizen science project ever undertaken, relying on hundreds of thousands of volunteers to classify galaxy images. Since 2007, GZ has evolved into a "Zooniverse" of over 20 online projects, engaging nearly a million worldwide volunteers (from a range of ages, backgrounds and education) in scientific research. Most GZ volunteers report being motivated by a desire to contribute to real research, while 87% say their experience has changed their behaviour e.g. more museum visits (34%). For under-18s, 70% were encouraged to study a degree and 47% said GZ helped their schoolwork.

2. Underpinning research

A fundamental fact of the universe is that massive galaxies come in two basic shapes; "spiral" or "elliptical". Why and how these galaxies relate to each other remains a mystery. With the advent of large digital detectors in the 1990s, astronomers began surveying large areas of the sky, detecting millions of new galaxies, allowing them to examine the properties of galaxies to greater precision. For example, in 2011, the celebrated Sloan Digital Sky Survey (SDSS) released the largest image of the sky ever obtained: more than a trillion pixels containing 208 million galaxies[1]. Professor Bob Nichol has been a key member of the SDSS since 1993, first at the Universities of Chicago and Carnegie Mellon in the USA, then at the ICG, Portsmouth since 08/2004.

It is impossible to visually inspect each galaxy in massive digital imaging datasets like the SDSS, and modern, computer-based algorithms cannot yet unambiguously determine whether a galaxy is spiral or elliptical. This makes it difficult to uncover the true evolutionary history of galaxies, as such morphological information reveals the dynamical nature of galaxies e.g. merger of two smaller galaxies (elliptical) or a disk of stars made through the accretion of gas (spiral).

Galaxy Zoo was inspired by this limitation and was feasible only because of the easy access to SDSS images [1,2]. Samples of elliptical galaxies from the initial SDSS, by Bob Nichol and collaborators [3], relied on computer-based methods as such galaxies are often "red" (i.e., evolved) with no obvious star formation (a correlation that is not perfect, as shown by the first GZ results). To circumvent this challenge, Daniel Thomas, Claudia Maraston, and collaborators at Oxford University built a complete sample of elliptical galaxies based solely on their appearance. The team started by inspecting 50,000 SDSS galaxy images and ultimately created the MOrphologically Selected Ellipticals in SDSS (MOSES) sample: an order of magnitude larger than any visually inspected sample created at that time [4].

MOSES proved the need for dependable morphological classifications of SDSS galaxies, but it was unrealistic for a few researchers to scale MOSES to the level of the whole SDSS. Inspired by "Stardust@Home" (at Berkeley), a collaboration including several ICG researchers (Bob Nichol, Steven Bamford, Daniel Thomas), crowd-sourced the visual classification of the SDSS galaxies to the public via an online Web interface. On July 11, 2007, the GZ project was born [5]. Within twelve hours, GZ began receiving 20,000 classifications per hour (peaking at 70,000 per hour),

driven by a global media interest in the project. After 10 days, the public had submitted 8 million classifications; by early 2008, when the first GZ research papers were published, 100,000 volunteers had inspected more than 900,000 SDSS galaxies, each 38 times on average.

GZ data has enabled key new findings in the field of galaxy evolution, led by ICG scientists [6]. Now an internationally renowned research and public engagement project, GZ has been recognized for its innovative approach to the analysis of massive datasets and has spawned a "Zooniverse" of citizen science projects.

3. References to the research

*[1] Aihara H, et al. "The Eighth Data Release of the Sloan Digital Sky Survey: First Data from SDSS-III". 2011. *Astrophysical Journal Supplements,* 193, 29. (167 authors, including Bob Nichol, Will Percival, Karen Masters, Daniel Thomas, Claudia Maraston, Ashley Ross, and Rita Tojeiro from the ICG). DOI: 10.1088/0067-0049/193/2/29 (288 citations on Thomson Web of Knowledge)

*[2] Adelman-McCarthy, J., et al. "The Sixth Data Release of the Sloan Digital Sky Survey", 2008, *Astrophysical Journal Supplements,* 175, 297 (132 authors including Bob Nichol who contributed to paper while at ICG) DOI: 10.1086/524984 (806 citations on Thomson Web of Knowledge)

[3] Bernardi M, Nichol R. C, Sheth R. K, Miller C. J, and Brinkmann J. "Evolution and Environment of Early-Type Galaxies." 2006. *Astronomical Journal*, 131: 1288. DOI: 10.1086/499522 (106 citations on Thomson Web of Knowledge)

*[4] Schawinski K, Thomas D, Sarzi M, Maraston C, Kaviraj S, Joo S. J, Yi S. K, and Silk J. "Observational evidence for AGN feedback in early-type galaxies." 2007. *MNRAS*, 382: 1415. DOI: 10.1111/j.1365-2966.2007.12487.x (209 citations on Thomson Web of Knowledge)

[5] Original (archived) GZ site: http://zoo1.galaxyzoo.org. Current active site is www.galaxyzoo.org which hosts the "Galaxy Zoo: Hubble" project

[6] Fortson L, Masters K, and Nichol R. C, et al. Table 1, "Galaxy Zoo: Morphological Classification and Citizen Science." 2011. *In:* Advances in Machine Learning and Data Mining for Astronomy. Available at: http://arxiv.org/abs/1104.5513.

ICG researchers are underlined and asterisk highlights the three references for assessing the quality of the underlying research.

4. Details of the impact

Galaxy Zoo (GZ) is one of the most successful "citizen science" projects ever undertaken, i.e., the engagement of the public in the collection and interpretation of scientific data. From the beginning of GZ, it was clear the volunteers wanted to do more than simply contribute their visual classifications. Within two weeks of the GZ launch, the team was swamped with thousands of e-mails requesting information or reporting interesting objects. The volunteers' overwhelming desire to communicate inspired the creation of the GZ internet forum[1], which encouraged users to communicate with each other, thus allowing many of their basic queries to be answered by other, more experienced, volunteers, and also allowed the volunteers to share their thoughts.

Through the forum, several rare classes of object were discovered by the public, of which *"Hanny's Voorwerp"* is the most famous. Hanny, a Dutch school teacher, discovered a strangely coloured outflow from a nearby galaxy, which appears to be the light echo from a supermassive black hole. Her object is now the focus of significant research (24 publications to date) and was memorialized

in a popular comic book[2]. Hanny is outspoken about the impact of GZ on her life, giving invited talks and TV appearances about her experience, and she serves as an excellent role model for volunteers (especially young women) interested in astronomy and citizen science.

In addition, several volunteers have organized science projects of their own making. The largest such project is the search for irregular galaxies that do not fit currently recognized classification schemes, while other volunteers have been inspired to start research careers e.g. Alice Shephard, a forum moderator, is studying a masters degree in Astronomy at QMW. Galaxy Zoo is also a valuable educational tool (e.g. integrated into the curricula at the Royal Observatory, Greenwich) and is part of "Zooteach" where educators share teaching plans and resources [3].

The GZ forum boasts more than half a million postings on nearly 18,000 topics (as of April 2013) making it similar in size to the largest football fan forums. In addition to the forum, the GZ blog has become the main mechanism by which scientists communicate with volunteers to provide updates on the academic research being done with their classifications. The GZ blog presently has hundreds of articles, and ICG member Karen Masters is a frequent contributor. Over the last year (2012-13), the Zooniverse blogs have attracted 86,000 unique viewings.

GZ has clearly had a major impact on public engagement in science. An early quantitative survey (2008) of GZ volunteers [4] found they come from a range of educations and ages, and have an evenly distributed gender balance. According to this survey, the major motivation for volunteering was a desire to contribute to scientific research (40%). In a more recent (2012) online survey of over 2000 GZ volunteers [5], 87% confirmed GZ had changed their behaviour in at least one of: (i) more visits to museums and planetariums (34%); (ii) read more about science (68%); (iii) study more formally (34%), and (iv) carry out their own research (12%). For under-18s, 70% were encouraged to study a degree and 47% said GZ helped their schoolwork. Overall, 39% of GZ volunteers said they had done more astronomy (e.g. amateur observations) since starting GZ, and 75% would recommend GZ to others. Finally, quantitative learning assessments given to GZ participants indicate the volunteers do perform better at correctly answering conceptually challenging questions on the astrophysics of galaxies. Two studies show that, on average, the most experienced GZ participants outperform their novice counterparts by as much as a full letter grade (10%) [6]

The success of GZ inspired the creation of several follow-on projects, e.g. a Google-funded project at Portsmouth asked the public to draw on SDSS images in "Google Sky" to help measure the size and orientation of galactic bars[7]. Moreover, there now exists an array of different "zoos" that span diverse disciplines and are organized under the common banner of the "Zooniverse" [8], hosted and led by Oxford University. The Zooniverse now has more than 20 projects running simultaneously, from climate change to cancer research, with over 850,000 worldwide volunteers (08/2013). The GZ methodology has inspired the "Citizen Science Alliance," which holds regular calls for proposals of science projects that would benefit from citizen science involvement. In August 2013, the University of Portsmouth officially joined the CSA, based on our long-term association with GZ, and will embark on new Portsmouth-specific Zoo projects.

Galaxy Zoo has emphatically demonstrated the power of citizen science, and has inspired new and exciting projects. There are now several commercially-orientated citizen science projects including "DIYgenomics", a mobile phone app to look for variations in genes, and "Crowdflower", which provides businesses assess to citizen scientist volunteers [9]. Also, Zooniverse projects like "Seafloor Explorer" have commercial partners. These projects clearly illustrate the potential economic impacts of citizen science and Portsmouth scientists Joe Cox and Karen Masters have a

funded EPSRC Digital Economy grant to research such potential further [10].

5. Sources to corroborate the impact

[1] http://www.galaxyzooforum.org (postings from 2007 until 2013)

[2] http://hannysvoorwerp.zooniverse.org/ (Hanny's Voorwerp was first seen August 2007, but its impact was only appreciated from early 2008)

[3] Education Section of the GZ Forum (http://www.galaxyzooforum.org/index.php?board=29.0) and the teachers resource page of the Solar Stormwatch Project, hosted by The Royal Observatory Greenwich (http://www.solarstormwatch.com/teachers), and http://zooteach.org run by the Zooniverse Educational Team.

[4] Raddick J, et al. 2010. *Astronomy Education Review*. 9: 010103. DOI: 10.3847/AER2009036. Available at: http://arxiv.org/abs/0909.2925

[5] Private communication from PI of Zooniverse, Senior Lecturer, University of Oxford

[6] Based partly on results from *"Measuring the Conceptual Understandings of Citizen Scientists Participating in Zooniverse Projects: A First Approach"* by Prather et al. 2013, Astronomy Education Review, Volume 12 (DOI: http://dx.doi.org/10.3847/AER2013002) and private communication from Executive Director of the Center of Astronomy Education (CAE) at the University of Arizona.

[7] See http://www.icg.port.ac.uk/~hoyleb/bars/ for the google website for volunteers to draw on SDSS images (no longer collecting data).

[8] http://www.zooniverse.org/

[9] http://www.diygenomics.org/ which is a non-profit organization but their findings will be essential for new drug development. Also see http://crowdflower.com/

[10] Funded EPSRC grant as part of the "New Economic Models in the Digital Economy" scheme. Project is for 3 years (2013-16) for £750,000 entitled *"The wonders of the Zooniverse: Modelling and optimising volunteer participation in online citizen science*" PI: Joe Cox (Portsmouth)