# Open Universe

## Bringing astronomical research and exploration into the classroom

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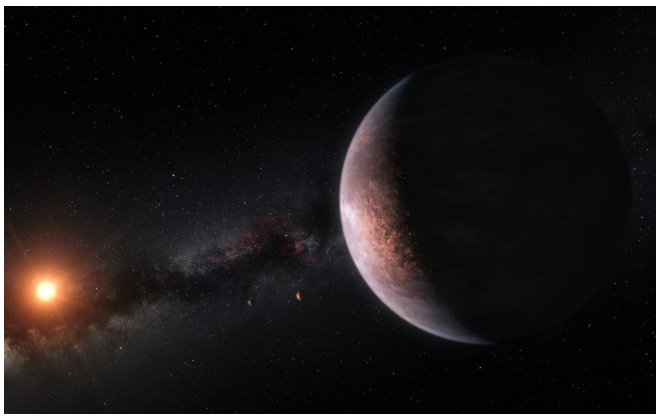
*A spiral galaxy known as NGC 7331, located about 45 million light-years away in the constellation of Pegasus (The Winged Horse). Image credit: ESA/Hubble & NASA/D. Milisavljevic (Purdue University)*

### Prelude

Looking at the night sky, one is drawn to the beauty and mystery of what lies beyond the blue marble we inhabit. For millennia, generations of scientists, philosophers and artists have asked fundamental questions about the Universe. Over time each generation has managed to piece together another part of the puzzle that is our Universe. These advances have been made possible using data generated by observations – from the unaided eye to state-of-the-art instrumentation.

Over the past couple of decades, leaps in technology have heralded the era of "Big Data" or, as some call it, the Data Deluge. While this applies to a variety of fields, astronomy is unique in that we truly have "astronomical" amounts of data! The Square Kilometre Array (SKA) is currently under construction in both Australia and South Africa. It will be the largest radio telescope in the world generating in the order of 160 Terabytes of data every second. This is equivalent to streaming Spotify non-stop for 457 years (that's starting to listen 46 years prior to Galileo pointing the first telescope at the night sky in 1609!), or binging on Netflix for 18 years non-stop[1]!

Considering the number of projects that are already collecting data (GAIA[2], ASKAP[3], MeerKAT[4], SDSS[5], SkyMapper to name a few), coupled with all those that will soon come online (SKA, Vera C. Rubin - LSST[6]), astronomers will have access to more data than they can ever analyse on their own. This data holds the key to unravelling some of the most fundamental mysteries of the Universe, from the nature of Dark Energy and Dark Matter, to understanding how galaxies form and grow, to probing the structure of our own Milky Way, and even piecing together the evolutionary history of the entire Universe, to name but a few. What is even more exciting is that this data will raise still more questions and discover new mysteries to solve, which is what astronomers secretly look forward to most!



*This artist's impression shows several of the planets orbiting the ultra-cool red dwarf star TRAPPIST-1. Image credit: ESO/M. Kornmesser*

## Citizen Science

Citizen Science is defined as scientific research undertaken by non-professionals who are members of the general public. It builds on the philosophy of "Open Science", where the aim is to remove the barriers to the sharing of research and discovery by making scientific exploration accessible by everyone. In the context of Citizen Science, projects can take various manifestations including crowdsourcing the collection of data in the field, observation with pre-existing data, low-level preprocessing or even high-level analysis of cleaned data, and everything in between, all of which contribute directly to research outcomes.

Citizen Science is not new, there are notable examples from astronomy (Transit of Venus, 1874), biodiversity (Great Christmas Bird Count, 1900), and environmental studies (Smithsonian weather project, 1847). Historically, and to this day, astronomers – professional and amateur – have actively collaborated. This collaboration, interaction, communication, and scientific exploration has been revolutionised in the digital age. Coupled with the public's growing interest to be actively involved in science, and being part of a community whose efforts can lead to vital change.

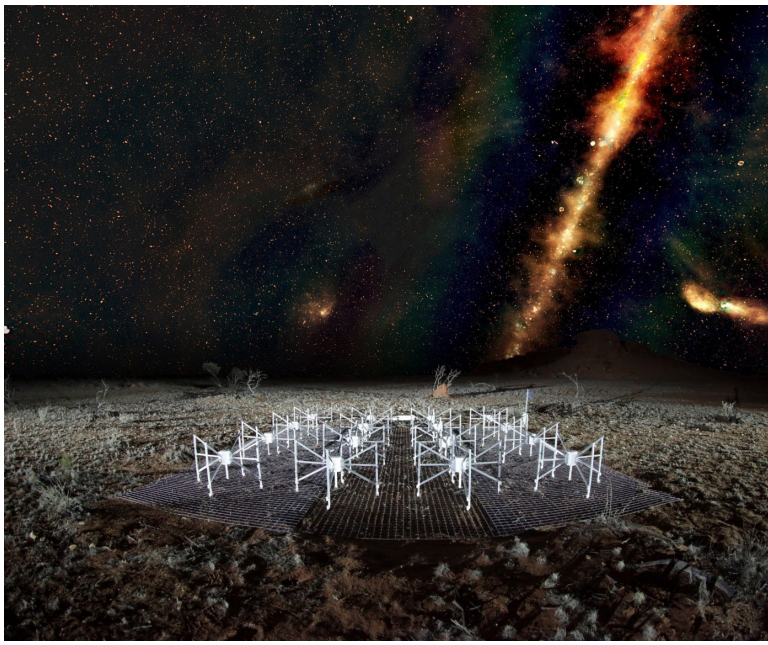
One of the earliest online Citizen Science projects in astronomy – SETI@home (1999), used internet-connected computers to analyse radio signals collected from radio telescopes to search for signs of Extraterrestrial Intelligence. Users simply downloaded a program that would run when their computer was not being used. After 21 years of successful operations, SETI@home announced it will no longer be sending requests to users' computers, as the project has now accumulated a vast amount of data that needs focused analysis. Citizen Science projects of the @home variety, which included in Australia TheSkyNet[7], are designed to make use of connected computers, rather than citizens being "directly" involved in the project. Given that there is more data than can be analysed by the professional astronomy community we have seen a shift towards involving the public actively into the analysis of the data. This changing landscape has created fertile ground and a strong potential to engage students in authentic scientific exploration, whilst teaching them skills that will serve them well into the future.

Citizen Science has received significant attention, as it is seen to be a cost-effective way to analyse large datasets, act as the bridge between scientists and the layperson, and most importantly bring "real" science to the public. Citizen Science can be described as symbiotic, as both scientists and volunteers benefit from the experience.

The benefit to volunteers is in the form of a learning experience and contribution to real science (which comes in the form of being published in peer-reviewed journals). The scientists benefit from the extra help that contributes to their research, which they could not manage alone.

Citizen Science projects have resulted in discoveries by members of the public[8], especially in astronomy, for example, the discovery of an exoplanetary system with five planets (K2-138), the discovery of a new class of galaxies affectionately called "Green peas", the discovery of a rare type of astronomical object called a quasar ionization echo, called Hanny's Voorwerp, and many more.

A more recent development in the realm of Citizen Science is the gamification of research projects like FoldIT[9], which helps scientists with understanding and designing proteins. These Citizen Science efforts take advantage of the puzzle-solving abilities of the public to address scientific issues using a competitive game platform. From an educational perspective, this project draws on the research regarding game-based learning.



*A 'radio colour' view of the sky above a 'tile' of the Murchison Widefield Array radio telescope, located in outback Western Australia. The Milky Way is visible as a band across the sky and the dots beyond are some of the 300,000 galaxies observed by the telescope for the GLEAM survey. Credit: Radio image by Natasha Hurley-Walker (ICRAR/Curtin) and the GLEAM Team. MWA tile and landscape by Dr John Goldsmith / Celestial Visions*

## Bringing Citizen Science into the classroom

Many studies over the past few years have highlighted declining student engagement in science at various education levels, and across the world. There have been calls to reform the current pedagogical practices to better engage students in science, whilst giving them valuable and authentic experiences in scientific inquiry, critical thinking, and problem-solving.

The relationship between research and interest/effort is perhaps best represented by Luisa Rebull's Funnel of Interest (Fig.1)

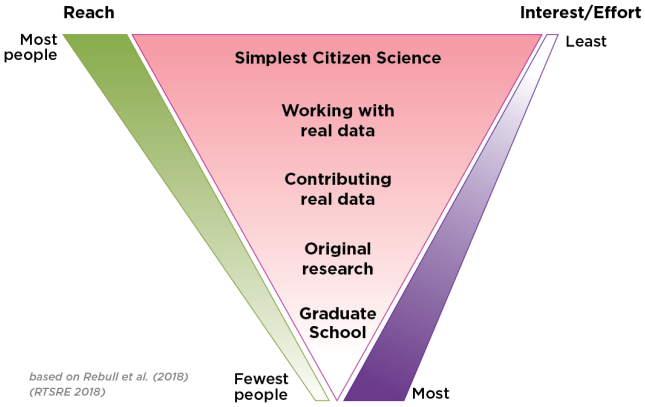



*Figure.1: Funnel of Interest ecosystem (modified from Rebull et al., 2018)*

Citizen Science is primarily designed to be a way to undertake authentic research using human input where it is needed the most and where computers are not particularly useful. It is generally considered by the project investigators as a subset of their science but we are also seeing a broad appreciation of Citizen Science as a form of education and outreach. This is perhaps based on the perspective that individuals participating in Citizen Science will inevitably have to understand something about the science they are doing. This has led to Citizen Science often being promoted as a form of informal science learning and engagement.

Projects that are authentic and address questions at the forefront of research are more appealing and engaging to many students, especially when compared with traditional school experiments. Students are able to feel that they are contributing to actual science, and not doing an experiment just for the sake of it, or to fulfil an assessment task. Citizen Science, or more broadly authentic research, also addresses broader key science competencies and skills which are part of curricula around the world.

Incorporating Citizen Science into your classroom might be daunting at first, this could be driven by lack of confidence in the background knowledge, the challenges of finding projects, issues in connecting a Citizen Science project to the curriculum goals, and especially time. It might be best to consider instead the broad skills and competencies that can be taught using a Citizen Science education model as the specific content knowledge can always be delivered in the context of a Citizen Science project.

The first step is to find projects that are available. One of them is SciStarter[10], which allows people to search for Citizen Science projects. In Australia, the Australian Citizen Science Association maintains a database of Citizen Science projects[11]. In the context of game-based learning, *ScienceatHome*[12] provides a range of game-based Citizen Science projects. However, the most well-known portal with access to a range of Citizen Science projects is Zooniverse[13].

Teachers may find it challenging to develop connections between a Citizen Science project and the curriculum. This could be a potential deterring factor, based on our discussions with teachers. The Royal Institution of Australia's education arm[14] creates lesson plan material based on the latest discoveries, all aligned to the Australian Curriculum. In general, the Australian Curriculum provides enough flexibility for teachers to implement Citizen Science modality into their units.

Astronomy is an example of the topic most suited to Citizen Science, particularly in teaching the Earth and Space Science curriculum. The various astronomy Citizen Science projects provide the background knowledge required for the complete beginner to participate in real science whilst learning about the astronomy content. Furthermore, projects like GalaxyZoo have blogs and forums where citizen scientists can ask questions directly to the research team. This could be very empowering and could tap into the Nature of Science, or Science as Human Endeavour aspects of the curriculum. In addition, many Citizen Science projects do provide lesson plans, and these can be used as a guide when developing a unit of work. The California Academy of Sciences produced a toolkit for teaching science using Citizen Science[15].

In order to provide teachers with a starting guide, we provide some key considerations:

- The most effective implementation of Citizen Science in the classroom is to incorporate it as part of a larger unit of work, for example, a unit about light.
- Keeping the overarching theme both broad and fundamental provides flexibility to draw on various Citizen Science projects.
- Focus on depth, rather than breadth.
- Consider the science capabilities you want students to learn, for example, interpreting data/graphs.

## Future implications

Citizen Science has far-reaching implications for the education community. It provides a mechanism for connecting scientists to students and teachers. This allows authentic science to become more tangible in the classroom, especially when the project is centred within the community. Citizen Science also provides an efficient model for increasing content knowledge, occurring as a result of this interaction with scientists and through the process of learning by doing. The interactions and participations are authentic and practical, while providing students and teachers with real-world context. Rather than science merely being a subject they study at school they now have a role to play in the creation of new knowledge. Citizen Science in the classroom provides students with opportunities for awareness, critical thinking, and problem-solving. They can also gain insights into an aspect of research, and what researchers actually do. All of this together has the potential to change attitudes towards science in the broader community.

If the goal of science education is to provide students with the opportunity to develop skills and knowledge that are authentic then Citizen Science offers immense potential. Science education research is exploring this mode of education by developing pedagogies and frameworks that teachers can use to bring Citizen Science into their classroom. As we traverse the era of Big Data, Citizen Science will become ever more prevalent and vital. This will be of fantastic benefit not just for scientists, or even teachers and students, but the entire community at large as new discoveries are made by all the public working together.

## References

[1] Based on 1 hour of Standard Definition Video uses up to 1 Gigabyte of data.
[2] Global Astrometric Interferometre for Astrophysics
[3] Australian Square Kilometre Array Pathfinder
[4] "More" of Karoo Array Telescope (KAT)
[5] Sloan Digital Sky Survey
[6] The Vera C. Rubin Observatory - Large Synoptic Survey Telescope
[7] TheSkyNet was the first Citizen Science project by the the International Centre for Radio Astronomy Research (ICRAR)
[8] https://www.zooniverse.org/about/publications
[9] https://fold.it
[10] https://scistarter.org
[11] https://citizenscience.org.au/ala-project-finder
[12] https://www.scienceathome.org
[13] https://www.zooniverse.org
[14] https://education.australiascience.tv
[15] https://bit.ly/2QYaaT8

## A selection of recommended Astronomy Citizen Science programs

### Agent Exoplanet

Study known exoplanets.

**Website:** agentexoplanet.lco.global/

### AstroQuest

Inspect and classify galaxies

**Website:** astroquest.net.au

### Einstein@Home

Use your computer's idle time in the search for gravity waves.

**Website:** einsteinathome.org

### Exoplanet Watch

Join the search for exoplanets

**Website:** exoplanets.nasa.gov/exoplanet-watch/

### Galaxy Cruise

Classify the shapes of interacting galaxies.

**Website:** galaxycruise.mtk.nao.ac.jp/en/

### Globe at Night

Measure the amount of light pollution at night and share your observations with people across the planet.

**Website:** www.globeatnight.org

### Gravity Spy

**Website:** www.zooniverse.org/projects/zooniverse/gravity-spy

### LIGO E-lab

**Website:** www.i2u2.org/elab/ligo/home/project.jsp

## A selection of recommended Astronomy Citizen Science programs (continued)

### MeteorCounter

Help forecast meteor show activity.

**Website:** www.nasa.gov/solve/feature/meteor-counter-app

### NASA Citizen Science projects

Such a range on offer – from air quality here on Earth to planet hunting in other solar systems.

**Website:** science.nasa.gov/citizenscience

### Planet Four Terrains

Help scientists map the surface of Mars.

**Website:** terrains.planetfour.org

### Planet Hunters

Join the search for exoplanets

**Website:** www.zooniverse.org/projects/nora-dot-eisner/planet-hunters-tess/about/research

### RadioJOVE

Become a radio-astronomer by creating your own radiotelescope.

**Website:** radiojove.gsfc.nasa.gov

### Rad@Home

Collaborate with astronomers in India.

**Website:** www.radathomeindia.org

### Scope

Classify stars according to their spectrum.

**Website:** scope.pari.edu

### The Great World-Wide Star Count

Record the brightness of stars in the night sky.

**Website:** www.windows2universe.org/starcount

### Zooniverse Astronomy Projects

Zooniverse is a go to site for links to people-powered research projects around the world that cover a range of disciplines, including the sciences.

**Website:** www.zooniverse.org/projects

**Student:** Jesse Kasehagen

**Teacher:** Holly Bosman

**School:** Immanuel College

**Date Taken:** 28 July 2018

200mm - ISO 5000 - F/6 – 1.3 sec

**Midway Eclipse**

As the Earth falls in between and in line with both its moon and the sun, the Earth casts shadows onto the moon and into space. The shadow the Earth creates has 3 different areas: the penumbra, the umbra, and the antumbra.

The penumbra is a half shadow made by the Earth where the light source, the sun, is only partly covered by the Earth. As the moon falls behind the Earth and into the penumbra, this is when we are able to see a penumbral lunar eclipse. If the moon travels behind the Earth into its umbra this is where we can see a total eclipse.

The umbra is the darkest part of the Earth's shadow where the sun is completely covered.

The antumbra is the shadow that appears beyond the umbra at a particular distance. The antumbra only exists if the light source, in this case the sun, has a larger diametre than the object creating the shadow, the Earth.