Institution: Liverpool John Moores University (LJMU)		
Unit of Assessment: UOA9		
Title of case study: A Universe for All: The National Schools' Observatory		
Period when the underpinning research was undertaken: 2014-2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Professor Nate Bastian	Professor of Astrophysics	01/11/2012 to date
Dr Chris Copperwheat	Liverpool Telescope Astronomer in Charge	17/09/2012 to date
Dr Stacey Habergham-Mawson	NSO Project Manager	21/01/2010 to date
Professor Philip James	Professor of Extragalactic Astrophysics	01/01/1994 to date
Professor Andrew Newsam	NSO Director	01/08/1998 to date
Professor Iain Steele	Professor of Astronomical Technology	01/03/1996 to date
Period when the claimed impact occurred: 2013-2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

The National Schools' Observatory (NSO) is a web-based resource run by LJMU that gives UK and Irish schools, and independent learners internationally, free access to their own observations from the world's largest fully-robotic telescope – the Liverpool Telescope. Giving its participants unique and privileged access not only to the instrument itself, but also to the astronomical research carried out by the telescope, the NSO is a powerful blend of cutting-edge research, professional instrumentation and education that inspires, motivates and supports the learning of pupils and their teachers. Driven by the need to close the growing STEM skills gap, the NSO is using astronomy to cut across age groups, gender and social demographics and inspire school students to consider STEM careers by giving them access to scientific research and instrumentation, and supporting their teachers.

Since 2014 the NSO has reached more than 3,000 registered UK and Irish teachers and their classes, with over 100,000 sets of observations requested by schools. Independent evaluation shows that the impact on both teachers and pupils is considerable and is described by teachers as "transformational" and "hugely inspirational". By providing research-driven materials across a number of STEM subjects, including advising on the redesign of the GCSE Astronomy syllabus, the NSO is inspiring a generation of school students. As one pupil put it: "…the NSO was like an open door. It didn't hold us back, made us feel like we were smart enough."

2. Underpinning research

The sky varies with time, and investigation of that variation leads to further understanding of the physical processes that take place in stars and other astronomical objects. Some of the variations are fast and take place in hours to seconds or less, indicating that the objects are small. Yet their effects can be seen across space, indicating that the energy involved is large, and therefore that the physics is extreme. This motivated need for a time-domain branch of astrophysics has led to the development of robotic telescopes with a rapid response capability, with the Liverpool Telescope (LT) as a leading example. The early stages of the LT and its design can be traced back to the mid 1990s, when the scientific drivers behind and requirements of robotic telescopes were first clearly set out. From these initial seeds a detailed design was developed, including important advances in the scheduling systems and algorithms that are the key to the ongoing scientific power of robotic telescopes - see, for example, [Ref1] (Copperwheat: LT Astronomer in Charge, Steele: LT Director, Newsam: NSO Director).

From the very start of the design process, it was realised that robotic telescopes facilitated new ways of remotely operating observatories, and opened them up to new communities, such as schools, whose pupils and teachers could not travel to distant mountains. Thus a strong driver for the LT project was to use the facility as an educational tool (at primary and secondary levels) by providing dedicated time and support in the form of the NSO. The result is a telescope and scheduling system that not only produces high-quality science data for a variety of science programmes but seamlessly supports non-professional use [Ref1, 7].

At its simplest level, the NSO uses the LT as an educational “toy”, with which even the youngest students can take their own images of planets, nebulae and galaxies and process them. The LT acts as a mind-expanding motivational facility for such students, thrilled by their participation in astronomy with a large, professional telescope in an exotic location. At the next level, the NSO provides the raw material for exercises such as measuring the height of lunar mountains through the trigonometry of shadows. At the most advanced level the NSO provides opportunity for students to participate in cutting-edge research, making observations and analysing data that contribute to a research frontier, in areas as diverse as exoplanets [Ref2] and stellar evolution in clusters of stars [Ref3]. The educational use of the telescope has grown, not just alongside the science programmes, but directly influenced by (and influencing) them.

An exemplar will show the direct connection between research and education: several LJMU researchers are involved in a variety research projects to identify and study supernovae (the cataclysmic explosions of a massive star) including [Ref4] and [Ref5] and supported by [Ref6] (Habergham is also the NSO Project Manager). This expertise has been brought together with the resources of the NSO to develop a combined research/education project that enables students explore observational data of supernovae and feedback their discoveries to the researchers.

3. References to the research

All papers were subject to rigorous peer review before publication.

Citation numbers correct as 7/12/2020. LJMU researchers in bold.

[Ref 1] “Liverpool telescope 2: a new robotic facility for rapid transient follow-up”, **Copperwheat, C; Steele, I; Barnsley, R; Bates, S; Bersier, D; Bode, M; Carter, D; Clay, N; Collins, C; Darnley, M; Davis, C;** Gutierrez, C; **Harman, D; James, P**; Knapen, J; **Kobayashi, S**; **Marchant, J; Mazzali, P; Mottram, C; Mundell, C; Newsam, A**; Oscoz, A; Palle, E; **Piascik, A**; Rebolo, R; **Smith, R**; 2015, Experimental Astronomy, **36**, 119, 10.1007/s10686-015-9447-0, 10 Citations

[Ref 2] “Seven temperate terrestrial planets around the nearby ultracool dwarf star TRAPPIST-1”, Gillon, M; Triaud, A; Demory, B; Jehin, E; Agol, E; Deck, K.; Lederer, S.; de Wit, J; Burdanov, A; Ingalls, J; Bolmont, E; Leconte, J; Raymond, S; Selsis, F; Turbet, M; Barkaoui, K; Burgasser, A; Burleigh, M; Carey, S; Chaushev, A; **Copperwheat, C**; Delrez, L; Fernandes, C; Holdsworth, D; Kotze, E; Van Grootel, V; Almleaky, Y; Benkhaldoun, Z; Magain, P; Queloz, D; 2017, Nature, **542**, 456, 10.1038/nature21360, 647 citations.

[Ref 3] “A general abundance problem for all self-enrichment scenarios for the origin of multiple populations in globular clusters”, **Bastian, N; Cabrera-Ziri, I; Salaris, M**; 2015, Monthly Notices of the Royal Astronomical Society, **449**, 3333, 10.1093/mnras/stv543, 102 citations.

[Ref 4] “Bolometric light curves and explosion parameters of 38 stripped-envelope core-collapse supernovae”, **Lyman, J; Bersier, D; James, P; Mazzali, P**; Eldridge, J; Fraser, M; Pian, E; 2016, Monthly Notices of the Royal Astronomical Society, **457**, 328, 10.1093/mnras/stv2983, 167 citations.

[Ref 5] “On the environments of Type Ia supernovae within host galaxies”, Anderson, J; **James, P**; Förster, F; González-Gaitán, S; **Habergham, S**; Hamuy, M; Lyman, J; 2015, Monthly Notices of the Royal Astronomical Society, **448**, 732, 10.1093/mnras/stu2712, 28 citations.

[Ref 6] Science and Technology Facilities Council (STFC) Grant ST/R000484/1, “Astrophysics Research at LJMU: Consolidated Grant Renewal”. Includes funding for **Newsam** and **Habergham** to enhance impact of research activity through the NSO.

[Ref 7] STFC/National Astronomical Research Institute of Thailand Newton Fund Grant ST/P005616/1, “Long-term capacity building in STEM using astronomy with younger school pupils”. PI **Newsam**.

4. Details of the impact

The NSO is a web-based resource set up by LJMU to exploit the educational and engagement potential of the Liverpool Telescope (LT) [Source 1]. The target audiences are pupils in UK and Irish schools of ages 8 to 18 and their teachers, and independent learners internationally, using involvement in astronomical research as a way to increase engagement with and enthusiasm for STEM subjects.

The NSO has three overlapping components: a system to allow pupils and teachers to make their own observations alongside researchers on the LT (10% of the time of the LT is allocated to the NSO); a range of projects that they can take part in, many of which have a strong research element; and a wide selection of support materials for those teaching astronomy or wanting to use astronomy and space science to support the teaching of other subjects, especially STEM. In addition, the Astrophysics Research Institute (ARI) offers face-to-face support, work-placements and a wide range of talks, workshops and other events (e.g. in the 2017/18 academic year, NSO staff delivered over 500 hours of school activities and teacher CPD to a total of 4,000 pupils and teachers). This combination gives the maximum scope not just to motivate teachers and improve curriculum teaching, but to inspire pupils of all abilities, who can work inside or outside the curriculum at their own pace and in areas that particularly attract and interest them. All NSO activities are developed and evaluated using a bespoke Evaluation Framework based on a set of Generic Learning Outcomes (GLOs) that emphasise attitudes to STEM and careers, as well as knowledge.

Oversight of the NSO is provided by the NSO Board, whose broad range of educational, astronomical, commercial and management experience from external organisations is supported by the ARI.

The NSO has developed against a background of international concern over a growing STEM skills shortage (e.g. the UK Government White Paper *Industrial Strategy: building a Britain fit for the future*). We therefore focus on using astronomy as a motivator for engagement with a variety of STEM subjects through both skills development and inspiration. This has allowed us to deliver significant research-driven impact in 5 key ways.

Impact 1 — Supporting teachers to deliver world-class STEM education to a generation of children: Since 2014 the NSO has supported more than 3,000 registered UK and Irish teachers, reaching around 20% of all UK secondary schools and 6% of primary schools, with a further 2,000 registered independent learners. In the same period over 100,000 sets of observations have been requested (averaging over 1,400 per month since 2014). Together with use by non-registered schools and the public, this leads to about 3,000,000 webpages served each year (many from the UK, but with growing usage internationally) [Source 2]. As a free resource, we can ensure that registered schools cover a very broad demographic and age-range, with a significant uptake by schools from lower socio-economic areas [Source 3].

Impact 2 — Inspiring a generation of children to study STEM subjects: To achieve a positive impact on aspirations of pupils, their confidence must be boosted (through learning and skills development) and they need to be inspired. We therefore commissioned an independent evaluation of the NSO carried out between 2019 and 2020 by Hope-Stone Research [Source 4]. This used a blend of targeted questionnaires and in-depth case studies to examine the effect of the NSO on both learning and attitudes to STEM education and careers, as well as to identify the strengths and weaknesses of the NSO (to inform future developments). The online questionnaire was completed by over 50 schools (including 160 individual students) and a further 140 independent users (including international schools). The case studies involved lesson observations, focus group discussions and in-depth interviews in 12 schools, most with repeat visits to assess progress and development. The schools were targeted to cover the broad geographic, demographic and age coverage of the NSO.

The evaluation demonstrated significant learning and emotional impacts of the NSO on school students and teachers. For example, it concluded that the NSO had a strong positive impact on attitudes to STEM with 61% of students reporting that they “feel more interested in STEM” (0% were less interested). This impact continued outside school with 83% of secondary students using the NSO website outside lessons, and 75% sharing what they did with friends and/or family (“Really nice, me and my Dad, bonding time because I don’t see him that much.” – secondary student). Use of the NSO also increases student confidence with, for example, 71% saying they felt “more able to share skills and knowledge with others” with one secondary student saying “I now feel more equipped for more complicated topics” and another “The NSO was like an open door. It didn’t hold us back, made us feel like we were smart enough”. A number of students made it clear that using the NSO had made them rethink their potential career (e.g. “I am thinking in future I could be part of the science industry, even though science I didn't really like. But now I do because astronomy interests me”). This combination of inspiration and confidence boost across a range of ages is a testament to the important, ongoing impact of the NSO.

Impact 3 — Shaping science education at a national level: As part of a national overhaul of all GCSE teaching and assessment, NSO Director Newsam was asked to advise on the practical work for the GCSE in Astronomy (2015-present, approximately 1,700 students per year). As a result, this was redesigned to encourage students to use robotic telescopes [Sources 5, 6]. This has opened up the GCSE to schools in deprived areas who cannot afford telescopes, and urban schools where it was previously impossible due to both light pollution (“The students I work with are SEN [Special Educational Needs] from an inner city, most of the time the only object they can see is the moon.” – teacher) and the significant challenges of safely gathering students for night work (“The fact that they can go online and do observations makes it possible in a school like this to run GCSE Astronomy” – teacher).

Impact 4 — Giving a generation of children first-hand experience of cutting-edge scientific research from the comfort of their own schools and homes: As is clearly highlighted by the evaluation and feedback, the links with research are invaluable for achieving the impact (“They are learning how data is collected in a real scientific community” - primary teacher. “This is about doing what astronomers do and I think that’s absolutely brilliant” - secondary teacher). We have, therefore, an ongoing programme of developing research-led projects that are open to anyone and pupil-focussed (using an Inquiry-Based Education approach), but which derive from and support LJMU research. Examples of recently developed projects include research into the Colour-Magnitude Diagrams of stellar clusters [Ref3], a statistical exploration of exoplanet discoveries [Ref2], and light-curves of supernovae [Ref4].

This direct participation in research activity (doing, not just passively learning about) is key to increasing a sense of agency, belonging and inclusion with STEM. This was shown by the ASPIRES project to be a significant part of improving the “Science Capital” of students – a way of understanding why some children pursue science, while others do not (e.g. *ASPIRES 2: Archer, Moote, MacLeod, Francis & DeWitt, 2020*).

Importantly, as well as involving pupils in research, these projects provide a stimulating context for skills development in data analysis including handling multiple data sources, plotting, and error analysis – all important, transferrable skills in any STEM field. As these skills are developed, students also gain confidence in their abilities, further enhancing their Science Capital.

Impact 5 — Widening the reach of STEM education: If the STEM skills shortage is to be solved, the skewed demographic of students studying STEM subject must be addressed (e.g. in 2019 only 23% of A-level physics entries were female with imbalances also seen across socio-economic and ethnic groups). The impact of the NSO, however, is seen across demographics, with teachers commenting in particular on “the NSOs value in helping students who learn in different ways who might otherwise disengage from STEM”. This was seen in both lessons and extra-curricular activities with a particularly beneficial impact on otherwise disinterested pupils (“I really found that this helped re-engage disengaged pupils who were having a lot of problems in school. … It was transformational for some." - teacher) and those underrepresented in STEM careers ("A normally quiet and subdued girl has been hugely inspired by the NSO... The NSO has been a big part of building her confidence. Now there is 50/50 female/male split in the enrichment club which is great." – teacher).

It is also crucial that this reach is across age groups as well as demographics. Attitudes and even prejudices to STEM subjects are known to crystalize at a young age, so the participation of primary schools is important. Targeted development of resources aimed at younger age groups has led to registrations by primary school teachers increasing six-fold since 2017 [Source 3].

The NSO is also supporting international educational and economic development. A pilot project working with Thailand in 2017/18 (funded by the Newton Fund) allowed the NSO and LT to deliver educational support for a Thai version of the NSO project [Source 7, Ref 7], already reaching approximately 1,000 Thai teachers. This pilot is now being extended in Thailand and to other ODA Recipient countries, including Kenya and Indonesia

In summary, the NSO is large-scale, world-leading, research-led project that, to quote a teacher from North Wales "…gives teachers a powerful platform from which to proceed with inspiring students in science through astronomy".

5. Sources to corroborate the impact

[Source 1] NSO Website www.schoolsobservatory.org

[Source 2] NSO Website usage statistics www.schoolsobservatory.org/about/statistics

[Source 3] NSO 2020 User survey www.schoolsobservatory.org/about/user-survey

[Source 4] Independent evaluation www.schoolsobservatory.org/about/evaluation

[Source 5] Exam Board (Pearson) Observational Astronomy Skills Guide for GCSE Astronomy: qualifications.pearson.com/content/dam/pdf/GCSE/Astronomy/2017/Teaching-and-learning-materials/Observational_Skills_Guide.pdf

[Source 6] Department for Education Astronomy GCSE Subject Content 2015: assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/510690/Astronomy-GCSE-subject-content.pdf

[Source 7] Thai NSO: nso.narit.or.th