Institution: *Nottingham Trent University*

Unit of Assessment: C25 Education

Title of case study: (3) *Innovations in Science, Technology, Engineering and Maths (STEM) Education – the potential of visual, kinaesthetic and empathetic learning for children and the wider community*

1. Summary of the impact The impact of this work lies in its increased engagement with, and attainment in, science and technology of pupils of varied ages and social background. It uses a broad portfolio of innovative approaches, (from novel labs to science-art theatre collaborations and community-based archaeo-astronomy projects); using visual, kinaesthetic and empathetic learning models to promote STEM learning alongside cultural enrichment and improved literacy. The work has led to changes in teacher training practice, aspects of which have been embedded locally and internationally. Its interdisciplinary nature offers new models in education for sustainable development.

2. Underpinning research

NTU has a long history of research innovation in teaching science, including with disadvantaged groups e.g. Jones' national work on adaptions allowing disabled pupils to carry out practical science (C Hopkins & A V Jones,1998), *Able scientist or technologist, disabled person*.)

Since 2005, cross-disciplinary relationships produced innovations including Science and Art projects, achieving critical acclaim. The HEFCE £4.85 million funded *Centre for Effective Learning in Science*[CELS], and the *Dragon Breath Theatre Company* (both at NTU), developed two theatre productions as innovative STEM outreach vehicles. Led by Rumney and Scriven (Ref1&2), this research examined the impact theatre can have on scientific understanding, through its power to engage all the senses and learning styles as well as the 'intellect'. *ICARUS* explored the ethics of stem cells for GCSE students. *COSMOS*, explored astronomy for four to six year olds with parallel research on how literacy attainment can be improved through visual and kinaesthetic learning styles. *COSMOS* attracted £53K of funding and *ICARUS* £30K(from Arts Council England) with £16K of additional funding from non-NTU sources.

Understanding superconductivity is challenging at university level – even more for schools. Ireson's work (Ref3) on the 'minds-on' approach to learning and teaching science, took up this challenge as part of the EU FP7 *MOSEM Project*, (Minds On Superconductivity, Electricity and Magnetism) involving 11 Countries, (NTU share £28K). Further work was sponsored by NTU's *Student Projects for Undergraduate Researchers* (SPUR) scheme. Ireson's work produced two superconductivity kits and associated activities for use in schools and universities across Europe.

Many people perceive astronomy as complex, night-only, activity needing expensive equipment. Brown (Ref4), has shown that basic astronomy, and archaeo-astronomy, can be carried out in the local countryside, at all times of day, with minimal equipment. Brown developed activities in partnership with local schools, teachers, communities and the Peak District National Park, with funding from Science & Technology Facilities Council and Institute of Physics (£16.4K). These include: exploring global citizenship through astronomy; how aspects of our history and beliefs have been shaped through astronomy and encapsulated in ancient monuments; and light pollution education. Associated public engagement activities reached a non-traditional astronomy audience leading to the installation of permanent 'sky interpretation panels' at sites in the Peak District, national Dark Sky status at one site and involvement in the BBC's Stargazing Live. These models and parallel teacher training activities, have transferred to Portugal with funding from the EU Comenius/Gruntvig programme(No.PT-2012-086-001).

Further educational impact derives from work in statistical education for schools in collaboration with the *Royal Statistical Society's Centre for Statistical Education(RSSCSE)* (NTU based 2001 to 2009). Crowley (Ref5) worked on packages for teaching statistics, and developed web resources used in the international projects ExperimentsAtSchool and CensusAtSchool run by the centre.

Research by Moss (Ref6) focused on innovation in STEM outreach including the internationally disseminated Kit-in-a-Kase model and associated teacher CPD activities. Over 11,500 pupils benefited from this approach in UK. The Regional Development Agency funded six bespoke kits for Nottingham Science City (£93K). The *Centre for Effective Learning in Science*(CELS) through Moss, actively participated in three European FP7 *Science in Society* projects: Wonders; Two Ways and PLACES(€32K), researching new models of science communication, informal education and public engagement.

3. References to the research (indicative maximum of six references)

1. Kuska I., Scriven N. and Rumney P., (2011) *The Cosmos Project: a journey to the stars*, Youth Theatre Journal, **25** pp. 87-100, DOI: 10.1080/08929092.2011.569307
2. Rumney P. and Scriven N .(2008) *ICARUS – the ethics of stem cell technologies for GCSE students*, IX-World Congress on Bioethics, Croatia, August 2008. Reported in *Bioethical Inquiry* (2011) 8:71–85 DOI 10.1007/s11673-010-9279-6 available at http://bioethics-international.org/docs/papers/MacnFerranJBI_ArtBioethics_2011.pdf (pp 74)
3. Ireson, G., (2006), *Measuring the transition temperature of a superconductor in a pre-university laboratory*', Physics Education, 41(6), November, pp556-559. doi:10.1088/0031-9120/41/6/012
4. Brown D., (2011), *Archaeo-astronomy in Society: Supporting Citizenship in Schools across Europe*, International Journal of Science in Society **2** pp. 153-164. Available at http://danielbrown.pbworks.com/w/file/fetch/45761811/Y10_28618_Archaeo-AstronomyinSociety_final.pdf
5. Crowley, M., Richards K., and Davies N., (2010) , *On and off-line dynamic data interrogation*, 8th International Conference on Teaching Statistics ICOTS-8 , Conference Proceedings ISBN: 978-90-77713-54-9I, Ljubljana, July 2012, available at http://icots.net/8/cd/pdfs/invited/ICOTS8_9F3_CROWLEY.pdf
6. Moss K., and Crowley M., (2011), *Using Personal Response Systems for Effective Learning*, Computers In Education, **56,** pp36-43, http://dx.doi.org/10.1016/j.compedu.2010.03.021

Indicators of Quality

- Each of the above references were published in international journals and/or presented at international conferences and all were subject to rigorous peer review processes.
- *The Icarus Project was short listed for the Times Higher Education / Arts Council England Award for Excellence and Innovation 2007, and the Brian Way Award for Young People's Playwriting 2008.*
- *Cosmos was shortlisted for the Brian Way Award for Young People's Playwriting 2010*
- Brown's work on global citizenship attracted media attention e.g. BBC, CBBC (2009) *We met the world's top astronomers!* http://news.bbc.co.uk/cbbcnews/hi/newsid_8010000/newsid_8014100/8014158.stm
- Ref6 has been cited 26 times including in EU Joint Research Council report "The Use of ICT for the Assessment of Key Competences" ftp://ftp.jrc.es/pub/EURdoc/JRC76971.pdf

4. Details of the impact

The research has impacted upon:

1. *Creativity, Culture and Society:* theatre productions and astronomy activities which enhance understanding, inform values, and engage communities with their local landscape and cultural heritage;
2. *Developing Practitioners & their Practice:* changing teacher training practice and increasing pupil attainment in conceptual understanding and literacy;
3. *Developing new models for Public Engagement:* leading to increased engagement with effective STEM education by young people and their teachers, regionally, nationally and internationally

COSMOS(2008-2009) allowed 500 children (aged 4-6 years) to grasp complex concepts about space and planets, through its multi-sensory and multi-textual form(Source1). Feedback from teachers and children(Source8) showed theatre encouraging children's curiosity in the world around them and engaging them in greater scientific understanding. Children achieved 'secure' or 'partial' understanding of all scientific concepts in *COSMOS* compared to pre-performance evaluations. Post-performance evaluation showed for those schools where scientific follow-up took place, children remembered planets and had a sense that stars, suns and moons were 'beyond the clouds', i.e. in space. A School reported the parallel literacy work 'had a huge impact on the writing attainment of children'. Children said the strategies helped them feel more positive about their writing. *COSMOS* demonstrated novelty in the levels of curiosity and understanding that could be sustained by *very young children* through the multi-sensory experiences they enjoyed; offering a new vehicle for cross-curricula learning.

MOSEM(2007-2010), funded by the EU's Leonardo da Vinci programme, built on its predecessor's results (SUPERCOMET and SUPERCOMET2 projects). MOSEM involves 30 partners in 11 countries, involving 9 universities, 2 foundations and an educational company Simplicatus AS. Testing and dissemination was carried out with 13 upper-secondary schools and 8 valorisation partners,(Sources2&4). In the UK alone, over 400 pupils/students have been reached through over 20 presentations, at NTU and in school outreach activities. The project's *Maglev Train*, (designed by Ireson NTU), was taken to a new level. Evaluation by both students and teachers showed that both groups are equally positive about the learning materials and the success of the 'Minds-on' presentation for teaching superconductivity. The positive response was independent of student gender or teacher background. *"It is interesting and at the same time challenging"(*Norwegian student).

The RSCCSE's *ExperimentsAtSchool & CensusAtSchool* projects collect and provide data from/to school pupils on four continents. Originally data was manually extracted and processed by pupils. Research into developing an active learning interface created the *Statistics Data Analysis Tool.* Pupils can now rapidly process, and visualise graphically, extensive data sets, allowing them to format, rapidly test their own hypothesis make.(Source5) This internationally disseminated research was adopted and used by over 30,000 UK pupils.

Centre of Effective Learning in Science' research into public engagement resources (including Kit-in-a-Kase, delivered to over 11,500 local pupils) was disseminated through regional, national and international conferences(Source6). We organised three National Outreach Conferences for HE (supported by AimHigher, STEMNET, HEA) to share outreach best practice (150 people attended). Staff and students from Liverpool adopted examples. Outcomes led to partnerships with South Korea, producing new teacher training schemes in creative science teaching, two sponsored summer science camps in Korea (2008 & 2009, with LG Corporation sponsoring in 2009) and *Gyeonggi Institute of Science Education* Science Camp at NTU for 30 Korean pupils aged 13-15(2011). Research into use of *Personal Response Systems* with local children, was disseminated at an international conference and invited workshops (Swedish teachers and Norwegian Research Council) in 2009. The CELS website disseminated outputs internationally (Google Analytics showed 45,000 visits from 73 countries to CELS Outreach resources, (Table 1, 2009-10) and over 19,000 users of the Molecular Geometry learning resource from Europe the Americas, Oceania and Asia,(Source7). A Scottish HE adopted our 'Mole Calculator' for their students.

*Astronomy Global Citizenship r*esearch is delivered annually to ~350 school pupils and community groups members. Now embedded within NTU teacher training (~120 trainee teachers annually) it impacts on pupil learning in schools across the UK). Co-presentation of findings with local pupils at national and international meetings attracted local and national media attention. Dissemination at national and international conferences led to collaboration with Portugal and Germany. Outputs were incorporated into Portugal's GALILEO/Commenius funded teacher training

program,(2012)(Source10). This innovative non-traditional use of ancient monuments' produced masterclasses for 60 student, CPD activites for 30 teachers annually and innovative work-placements which were 'Highly Commended' (2012 National *Green Gown Award for Social Responsibility)*. Three accessible sites with public-interpretation panels to explore skyscape and landscape were installed; one site achieved *'Dark-Sky Discovery Site'* status, leading to invited participation in *BBC Stargazing Live,* (~2,500 local people attended). In 2011, 85% of 400 local attendees at two local Peak District events rated highly(4.64/5), the amount learned about the impact of light pollution; 87% wanted to find out more about ancient history and 93% wanted to find out more about astronomy. This collaborative approach has successfully engaged local communities with both science and culture in a meaningful context,(Sources3&9).

5. Sources to corroborate the impact (indicative maximum of 10 references)**.**

People who can be contacted re Impact of the research

1. **For ICARUS and COSMOS and PLACES** Director of Programmes, Ignite, www.ignitefutures.org.uk. (Statement about the impact on COSMOS on children's learning)
2. **For MOSEM partner from** University of Paris Sud, France (Testimonial evidencing how Ireson's research added to project outcomes and practice in schools)
3. **For Archeo-astronomy Projects in Derbyshire**, Rights of Way Officer, Peak District National Park Authority. (Letter about impact on local community and evidence regarding Peak Park installations)

Web sites & Reports

4. MOSEM superconductivity kits & teacher guides: http://mosem.eu/category/products/ with maglev train developments and project news
5. For Statistics resources used internationally, see the site http://www.censusatschool.org.uk/resources/science. ExperimentsAtSchool site was developed whilst RSSCSE was at NTU, with research and development of interactive FLASH ®resources by Crowley(2005-2011). For example:-Colour maker experiment and the random data generator on the site, there is evidence of thousands of users.
6. CELS worked with over 36,000 people with 11,500 undertaking Kit-in-a-Kase activities, for pupil and teacher feedback http://www.ntu.ac.uk/cels/outreach/Kits/Feedback/53642gp.html
7. Overview of CELS outputs with quotes from teachers & partners can be found in *What is Effective Learning in Science?* http://www.heacademy.ac.uk/assets/ps/documents/new_directions/new_directions/issue5/moss.pdf
8. Dragon Breath Theatre Company http://www.dragonbreaththeatre.com links to about ICARUS & COSMOS videos showing interviews with pupils and teachers.
9. Astronomy –outreach work, in The Physics Teacher (2013) Volume 51, 160 **The Orion Constellation as an Installation: An Innovative Three-Dimensional Teaching and Learning Environment** used by other international outreach groups to deliver an event, impacting on other outreach teams and the children worked with in America/Canada (Site at http://yorkuniverse.com/2013/06/york-universe-attends-whats-up-in-space states "*We chose Orion because it is very well known, and very easy to see both in the country and in the city. Lucky for the team, this is a demonstration that has been done before. It is common for astronomers to want to explain the 3D nature of constellations, so we were able to borrow from the work of others. More specifically, in our research we found a paper entitled 'The Orion Constellation as an Installation' by Dr. Daniel Brown of Nottingham Trent University. In the paper, Dr. Brown lays out the different 3-dimensional locations of each of the 7 major stars in the Orion constellation. The model stretched 10 meters by 2 meters on the floor, and 2 meters vertical. The fun part was presenting. Ryan was able to introduce the idea that stars are different sizes and at different distances in the Universe"*
10. NUCLIO & GTTP Comenius and Gruntvig training course *"BRIDGES – Bridging the skies, the earth and the human beings. From ancient landscape exploration to digital era on science education"* http://ec.europa.eu/education/trainingdatabase/index.cfm?fuseaction=DisplayCoursePrint&cid=31097