Design, implementation and evaluation of transnational collaborative programmes in astronomy education and public outreach

Rodrigues Dos Santos Russ, P.M.

Author: Rodrigues dos Santos Russo, Pedro Miguel
Title: Design, implementation and evaluation of transnational collaborative programmes in astronomy education and public outreach
Issue Date: 2015-11-10

Design, Implementation and Evaluation of Transnational Collaborative Programmes in Astronomy Education and Public Outreach

Pedro Russo

Design, Implementation and Evaluation of Transnational Collaborative Programmes in Astronomy Education and Public Outreach

Cover image: *Universe Awarness Activity in Zielona Góra, Poland (21/9/2012) Credit: Mariusz Słonina/ UNAWE Poland/R. Monterde*

Design, Implementation and Evaluation of Transnational Collaborative Programmes in Astronomy Education and Public Outreach

Proefschrift

ter verkrijging van
de graad van Doctor aan de Universiteit Leiden,
op gezag van Rector Magnificus prof. mr. C.J.J.M. Stolker,
volgens besluit van het College voor Promoties
te verdedigen op dinsdag 10 november 2015
klokke 11.15 uur

door

Pedro Miguel Rodrigues dos Santos Russo

geboren te Figueira de Castelo Rodrigo, Portugal
in 1977

Promotiecommissie

Promotors:
Prof. dr. Jos van den Broek (Universiteit Leiden)
Prof. dr. George Miley (Universiteit Leiden)

Overige leden:
Prof. dr. Peter Barthel (Universiteit Groningen)
Prof. dr. Hidehiko Agata (National Astronomical Observatory of Japan)
Dr. Jarle Brinchmann (Universiteit Leiden)
Prof. dr. Huub Röttgering (Universiteit Leiden)

To my parents, brother, grandparents and Julia
for their unlimited support and continuous encouragement.

Design, Implementation and Evaluation of Transnational Collaborative Programmes in Astronomy Education and Public Outreach

Table of Contents

Introduction

This thesis presents a study of how science can most effectively be used to engage and educate the global public and specifically describes the role of astronomy in doing this.

Astronomy has a special place in the field of science education and public engagement with science. It has great appeal for large sections of the public for several reasons (National Research Council 2010). First, the sky and the stars are accessible to everyone. Secondly, astronomical images are spectacularly beautiful, as demonstrated most notably by the Hubble Space Telescope and the Very Large Telescope. Thirdly, astronomical and cosmological research deals with the origins and evolution of the Universe – a topic of broad philosophical interest. Fourthly, the idea of space travel exploits widespread excitement around exploration and adventure. Fifthly, the possibility of life in outer space is deeply embedded in social imagination (Graham, 2002). There are other aspects of astronomy that make it particularly suitable for large global initiatives in science engagement. During the last half century astronomy has become a “big science” with such expensive observational facilities that cross-national and even global collaborations are required to fund them. Astronomy brings together nations through international organisations and collaborations. Following the same trend, astronomy education and public outreach (EPO) is also a global endeavour, involving thousands of organisers and reaching millions of individuals.

Introduction

In this thesis, we shall use astronomy as a case study to consider the effect and impact of transnational collaborations with innovative approaches and centralised coordination in science education and public outreach. The thesis is based on eight years of designing, implementing and evaluating transnational collaborative programmes in astronomy education and public outreach, from the perspective of the practitioner. We shall also show that large global science EPO projects can result in sustainable outcomes that outlive the projects themselves and analyse the various aspects of global science communication project that are necessary for their success. The thesis will focus on two large projects in astronomy EPO, the International Year of Astronomy 2009 and an educational programme for young children, Universe Awareness. n this chapter, we shall set the scene by considering some relevant aspects of science communication and show how science communication has become an activity of two-way public engagement. We shall also discuss key aspects of the relationship between astronomy and society.

Science Communication and Public Engagement

"Science communication", "Public Engagement" and "Education and Public Outreach" are blanket terms covering communication aspects about scientific research to those members of the public who are neither professionals nor specialists in the relevant field. Public engagement with science is the topic that describes the myriad ways in which the scientific community can share its scientific enterprise and knowledge with the wider society in a more inclusive way. Lewenstein (2015) describes two main areas in public engagement under two main aspects: "engagement" as a learning activity and "engagement" as public participation in science. In Table 1 we present an overview of the main categories of public engagement initiatives. All have in common that scientists (in the case of astronomy, astronomy-related communities, such as educators and amateur astronomers) reach out to individuals and society-at-large to engage them with science. Engagement is, by definition, a two-way communication process, involving both listening and interacting, with the goal of generating mutual understanding. Public engagement has become an essential tool for building and strengthening public support for research, but has also instigated some criticism regarding the role of science in society.

Publication

This section is based on draft position paper by Bochove, C., Reid, G.,Russo, P. and Maes, K. (2015) *Science and society: why science both deserves and needs trust, and how universities and governments can build it*, LERU, in prep.

Table 1. Overview of the main categories of public engagement initiatives (based on Bell et al. 2009).

Category	**Characteristics**	**Examples of public engagement initiatives**
Developing interest in science	Experience excitement, interest, and motivation to learn about science.	• Exhibits • Media: TV news, generic newspapers/ magazines, etc.

Understanding some science	Understand concepts, explanations, arguments, models, and facts related to science. Manipulate, test, explore, predict, question, observe, and make sense of science.	• Public talks • Documentaries • Popular-science books and magazines • Workshops and hands-on exhibitions • Websites
Using scientific reasoning and reflecting on science	Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena.	• Dialogue initiatives, like Science Cafes
Participating in the science enterprise	Public participates in scientific activities and learning practices with others, using scientific language and tools Public identifies as someone who knows about, uses, and sometimes contributes to science.	• Citizen-science projects

In this thesis, we discuss different projects, issues of and best practices for public engagement with astronomy, which include all the categories presented in Table 1.

Evolving phases of science communication

Science communication can be considered to have undergone three main phases in its development: the "science literacy" phase (SL), the "public understanding of science" phase (PUS), and recently, the public engagement with science and technology phase (PE).

Scientific literacy (SL) assumes that the public should have a certain knowledge level of science (Miller, 1983). This approach tries to fill the "knowledge gap" between scientists and the public by communicating facts about science in a one-way direction. It has become known as the "deficit model" and is based on the assumption that a non-knowledgeable public cannot participate in science or scientific decisions. The public understanding of science (PUS) approach focuses on the primary concept that "*it's fine to disagree with science, but by being better informed, your choice is built on more secure foundations*" (Royal Society, 1985; Bowater & Yeoman, 2013). However, this phase still implies that all scientific knowledge lies with the scientific elite of professional scientists.

A recent phase of science communication that emerged during the past few decades involves a two-way "public engagement" with research. Practitioners of the PE approach regard PUS and SL science communication as too arrogant and elitist. The public engagement approach was boosted by a UK's House of Lords Science & Society 2000 report (House of Lords 2000). This report was prompted in the UK by two science-related controversies during the nineties, namely the Bovine spongiform encephalopathy (BSE – commonly known as mad cow disease) (Blue 2010), genetically modified (GM) food (Shaw 2002) and the controversial links between the immunization vaccine against measles, mumps, and rubella and autism (Clarke 2010). These controversies resulted in a public mistrust towards science and scientists, with large implications to the way science was communicated to society and the important aspects of science such as scientific uncertainty (Retzbach, Otto & Maier 2015).

Until the public engagement phase, the communication between researchers and society implied a "top-down" approach of one-way communication from the research community to the public. As a result of public awareness of the controversies mentioned above, the pressure increased for researchers to engage in dialogue activities with the public. It was realised that such dialogue is important for democratic participation in research (Irwin, 2006) and that it can lead to an increased trust and confidence in research (Haste et al. 2005).

Despite this new approach to science communication, Wildson, Wynne and Stilgoe (2005) argue that, while some aspects have improved, the new approach has not yet been proven sufficient and the dialogue has been seen as a way to control and manage public opinion. This has been the case of communication aspects of climate change issues (Hart & Nisbet 2011; Carvalho & Peterson 2012). Science communication needs to be prepared to engage with society in all aspects, and its uncertainties, of the scientific enterprise and not exclusively with scientific results or discoveries. As Miller (2001) expresses: "*it is important that citizens get used to scientists arguing out controversial facts, theories, and issues. More of what currently goes on backstage in the scientific community has to become more visible if people are going to get a clearer idea of the potential and limitations of the new wonders science is proclaiming*."

There are, however, new trends of public participation in scientific enterprise emerging in science communication, notably as citizen-science projects with crowd-sourced data collection and analysis, and as crowdfunding for science projects, as described in Chapter IV.2.

Despite the limitations, Public Engagment with Science (PES) brings a variety of benefits to science, research staff and students, as well as to the wider public: Public engagement activities inform the public about the ongoing research and provide a platform for researchers to discuss their research projects and plans with the wider public. To achieve these benefits, research communities need to design public engagement activities to be practical, innovative, educational, and research-based. All of these aspects feed each other with resources, ideas, and opportunities for research studies, and even support each other financially (NCCPE, 2012). In this thesis we analyse and discuss several case studies that have components of the three phases of science communication, but with a focus on public engagement with an active participation of the stakeholders.

Table 2. Phases and their characteristics associated with the development of science communication

Phase	**Characteristics**	**Criticism**	**Relevant literature**
Scientific Literacy (SL)	• Deficit of knowledge • Communication from scientists to public • One-way communication • Public is informed	• Public are simple receivers of knowledge without a say in the process. • Scientific knowledge lies with the scientific elite of professional scientists	Miller, 1983
Public Understanding of Science (PUS)	• Similar to scientific literacy • Focus on the understanding of the scientific enterprise, including the processes and uncertainties • Still one-way communication		Royal Society, 1985
Public Engagement with Science (PES)	• Dialogue between the public and the scientists. • Public engaged in scientific reasoning • Public reflects on science enterprise • Public engages in practical aspects of science • Ultimately public might identify themselves with the science enterprise	• PES has been seen as a way to control and manage public opinion	House of Lords, 2000 NCCPE, 2012

Practical science communication and public engagement

Public engagement with Science (PES) is a practical endeavour that takes many shapes and forms, ranging from large-scale education programmes to citizen-science projects and science festivals. All of these vehicles help researchers disseminate the benefits of their work to society while allowing them to keep abreast of public concerns and expectations. There are several reasons why PES has become a prime form of science communication. PES helps to maximize the flow of knowledge between research communities and society, giving research communities the potential to create impact through learning and innovation in the wider society (NCCPE, 2010). Strategic investment in public engagement helps to maximize this potential by focusing attention and support on the multiple, often informal, ways in which research enriches the lives of the wider public. PES contributes to both social inclusion and social responsibility and can lead to a range of positive outcomes. By embedding public engagement into their activities, researchers are better able to understand and respond to local, national, and global social issues (UUK, 2010 & Robinson et al. 2012).

PES can help to build trust and mutual understanding between research communities and the public. Trust is critical to healthy higher education and research systems, but it is difficult to establish trust unless there are opportunities for the public to engage with research. More than three-quarters of a random sample of the public were found to agree with the statement that, "*we ought to hear about potential new areas of science and technology before they happen, not afterwards.*" (Ipsos MORI, 2015) By facilitating such a desire, PES enables the understanding of research to grow at a time when deference to authority and professional expertise is decreasing.

The Internet has facilitated the development of science projects in which millions of people can collaborate towards a common research project. These so-called citizen-science projects enable the public to get involved in data collection, analysis, or reporting. The massive collaborations that can occur through citizen-science allow research at global spatial and temporal scales, leading to discovery that single scientists could never achieve on their own (SciStarter, 2015).

Science Communication and Academia

In recent years, science communication has become an established subject at universities in several countries, with an increasing number of bachelor and masters degree programmes[01] being offered. Science communication is embedded in different universities in different ways due to its inter- and multidisciplinary nature. This diversity is a "*sign of the subject's vitality, but it is also a condition of its vulnerability*" (Trench, 2008).

In parallel with its role in education, science communication is becoming an established research discipline, with research in both theoretical and applied topics. In-depth research in science communication is essential to provide the theoretical basis for the other core areas of public engagement activity described above. Results of research in the impact of public engagement initiatives are described in chapters IV.1 and IV.2 of this thesis.

Innovation in Science Communication

Until the last few years engaging the public in science has been traditional in its methods and not very creative. However, public engagement activities often generate unforeseen outcomes that can stimulate creativity and innovation. One of the most profound rewards of public engagement is its

[01] Chapters II.2, III.1, III.2, IV.1 and IV.2 of this thesis were developed as part of the projects of several master students in science communication and related fields.

unpredictability: new perspectives, challenging questions, and lateral insights can all help to sharpen thinking, release creativity, and unlock new collaborations and resources. In this thesis, we shall describe and analyse several new innovations in science communication, including the development of a new platform for peer-reviewed astronomy education activities and the astronomy educational resource Universe in a Box, as described in Chapter III.2.

Astronomy and Society

Publication

This section is based on Rosenberg, M., Russo, P., Bladon, G., & Christensen, L. L. (2013). *Astronomy in Everyday Life*, Communicating Astronomy with the Public Journal, 14.

With the increasing cost of curiosity-driven sciences such as astronomy and the diverse demands on national budgets, there is great pressure on scientists to justify the societal benefits of their research in an evidence-based approach. The difficulties in describing the importance of astronomy, and fundamental research in general, are summarised by Nobel Prize winner Ahmed Zewali: "*Preserving knowledge is easy. Transferring knowledge is also easy. But making new knowledge is neither easy nor profitable in the short term. Fundamental research proves profitable in the long run, and, as importantly, it is a force that enriches the culture of any society with reason and basic truth."*

More recently, C. Renée James (2012) outlines the recent technological advances that we owe to astronomy, such as global positioning systems (GPS), medical imaging, and wireless Internet. In defence of astronomy, Dave Finley (2013) states, "*In sum, astronomy has been a cornerstone of technological progress throughout history, has much to contribute in the future, and offers all humans a fundamental sense of our place in an unimaginably vast and exciting Universe*."

Thus, although "blue skies" research such as astronomy rarely contributes directly to tangible outcomes on a short timescale, the long-term societal benefit has been demonstrated. Although difficult to quantify economically, there are a large number of examples that show how astronomy has contributed to technology development and society by constantly pushing for instruments, processes, and software that are beyond our current capabilities. The pursuit of this research requires cutting-edge technology and methods that can, on a longer timescale and through their broader application, make a substantial difference to peoples lives. The fruits of scientific and technological development in astronomy include applications such as personal computers, communication satellites, mobile phones, GPS, solar panels, and magnetic resonance imaging (MRI) scanners (National Research Council 1991).

Carl Sagan described astronomy's simplest and most inspirational contribution to society in his book The Pale Blue Dot (Sagan & Druyan 2011): "*It has been said that astronomy is a humbling and character-building experience. There is perhaps no better demonstration of the folly of human conceits than this distant image of our tiny world. To me, it underscores our responsibility to deal more kindly with one another, and to preserve and cherish the pale blue dot, the only home we've ever known.*"

Although public support for investment in astronomy and space exploration over the last thirty years has been strong (ESA 1998; NSB, 2002; Mori, 2004; Eurobarometer, 2005; Safwat et al., 2006; Entradas 2011), doubts have also been expressed about the wisdom and effectiveness of such expenditure when measured against the large number of problems facing society (Ottavianelli, 2002; Mori, 2004, Safwat et al., 2006; Jones, 2007). The Nobel Prize winner in Literature José Saramago (1998) expresses his scepticism in his acceptance Nobel acceptance speech "*This same schizophrenic humanity that has the capacity to send instruments to a planet to study the composition of its rocks can with indifference note the deaths of millions of people from starvation. To go to Mars seems more easy than going to the neighbour.*"

Astronomy encompasses a broad range of disciplines including biology, geology, chemistry, physics, engineering, philosophy and history. Astronomy and its related fields are at the forefront of science and technology, answering fundamental questions and driving innovation. These considerations prompted the International Astronomical Union's strategic plan "Astronomy for Development 2010–2020" (Miley, 2009). This has three main areas of focus: technology and skills; science and research; and culture and society.

Astronomy education and public outreach provides an important link between the scientific astronomical community and society, giving visibility to scientific success stories and supporting both formal and informal science education. While the principal task of an astronomer is to further our knowledge about the Universe, disseminating this new information to a wider audience beyond the scientific community is becoming increasingly important.

This Thesis

In this thesis, we explore the features, characteristics, constraints, and challenges in designing, implementing, and evaluating transnational collaborative programmes in science education and public outreach. Our astronomy case studies will illustrate several innovations and the importance of centralised coordination in ensuring that large global science EPO projects result in sustainable outcomes. Table 3 gives an overview of the issues and innovations we shall address.

In Part II, we shall study in detail the design, implementation and evaluation of two large astronomy EPO initiatives, the International Year of Astronomy 2009 (Chapter II.1) and the educational Universe Awareness programme (Chapter II.2). The International Year of Astronomy 2009 (IYA2009) was a platform for sharing the latest discoveries in astronomy with society and for emphasizing the essential role of astronomy in science education. We treat IYA2009 as an example of a successful massive science communication project and draw lessons relevant to the design and implementation of future large global science communication projects.

Universe Awareness (UNAWE) is a global science education programme that uses the beauty and grandeur of the Universe to encourage young children, particularly those from underprivileged backgrounds, to have an interest in science and technology, and to foster their sense of global citizenship. We shall discuss several innovations in science education developed during the course of implementing this programme, such as Space Scoop – an astronomy service news for children – and duo internships – teacher training provided jointly by an astronomy student and a student teacher.

In Part III, we shall investigate the design and implementation of two additional innovations in astronomy educational resources International Astronomical Union's astroEDU (Chapter III.1) and UNAWE's Universe in a Box (Chapter III.2). Hundreds of thousands of astronomy education resources exist, but their discoverability and quality is highly variable. As a web platform for astronomy education activities, astroEDU tackles this issue. Using the familiar peer-review workflow of scientific publications, astroEDU is improving standards of quality, visibility, and accessibility. astroEDU targets activity guides, tutorials, and other educational activities prepared by teachers, educators, and other education specialists. The innovative aspect of astroEDU is that each of the astroEDU educational activities is peer-reviewed double-blindly by an educator and an astronomer to ensure a high standard in terms of scientific content and educational value. Physical educational resources, then, provide a useful supplement for educators to demonstrate abstract or complex concepts. There has been considerable research on the benefits of resources based on inquiry-based learning for scientific and technical subjects.

UNAWE's Universe in a Box is an astronomy kit developed to explain difficult and abstract astronomical concepts to young children by providing practical activities, as well as the materials and models required to do them. The innovative approach to a collaborative development across the UNAWE network has made Universe in a Box the first international astronomy education resource produced as well as used globally. We investigate the advantages and disadvantages of different models for the production and distribution of global science education kits. We also present and discuss the preliminary social and educational impact and potential of such an educational kit.

In Part IV, we study the impact of astronomy EPO initiatives on astronomical research and provide evidence that appropriate public engagement initiatives can lead to long-term public support for scientific research. However there is not yet a complete understanding of the impact of public engagement initiatives within the context of long-term science policy. We show that public engagement initiatives like IYA2009 or large grassroots movements led by citizen scientists and space *aficionados* can have profound long-term effects on research funding and research productivity. To demonstrate this, we explore changes of research capacity in developing countries (Chapter IV.1) and the role and relevance of public grassroots movements in the policy of space astronomy initiatives, such NASA/ESA's Hubble and James Webb (Chapter IV.2). We present recent cases that illustrate policy decisions involving broader interest groups and consider new avenues of public engagement, including crowdfunding and crowdsourcing.

Table 3. Issues and innovations addressed in this thesis.

Chapter	**Issues investigated**	**Innovations described**	**Contributions of the author**
II.1. The International Year of Astronomy as a Massive Science Communication Project	The need for centralised coordination to enable the participation of large numbers of geographically dispersed people in astronomy EPO initiatives.	Exploitation of non-professional astronomers for public engagement initiatives.	Coordination and implementation of IYA2009 globally, including the planning, execution, and evaluation of the global IYA2009 activities, projects, and events.
II.2. Universe Awareness as a Transnational, Collaborative Programme in Education	Design, implementation, and assessment of a large transnational collaborative programmes in astronomy education	Innovations in science education: Space Scoop (astronomy news service for children) and duo internships "Duo" teacher training provided jointly by astronomy and teaching students.	Coordination, design, implementation, and assessment of Universe Awareness.
III.1. Peer-review Platform for Astronomy Educational Activities	The implementation of a peer-review process to improve the educational and scientific quality of educational activities.	Each astroEDU educational activity is peer-reviewed double-blindly by an educator and an astronomer to ensure a high standard of scientific content and educational value.	Development, concept and the editorial processes of IAU astroEDU.
III.2. Design, Development, and Impact of Physical Resources for Science Education	Design and development of a global physical educational resource.	Collaborative development across the UNAWE network has made Universe in a Box the first international astronomy education resource produced and used globally.	Identification of the need for such global resources and supervision of the development, distribution, and assessment of Universe Awareness.

IV.1. A Survey of Astronomical Research: A Baseline For Astronomical Development	The impact of astronomy EPO initiatives in the development of astronomy as a research field in developing countries.	This is the most complete study of the evolution of astronomy research publications in the developing world.	Research co-design and analysis.
IV. 2. The Influence of Social Movements on Space Astronomy Policy	Public engagement initiatives as catalyser for long-term public support for science.	For the first time, we investigate the role of social/ grassroots movements in astronomy policy.	Research co-design and analysis.

References

Aitken, R. G. (1933) The Use of Astronomy, Astronomical Society of the Pacific, Leaflet 59, December 1933, 33–36

Blue, G. (2010). Food, publics, science. *Public Understanding of Science*,*19*(2), 147-154.

Bowater, L., and K. Yeoman. 2013. *Science Communication. A Practical Guide for Scientists*. Chichester: Wiley-Blackwell.

Carvalho, A., & Peterson, T. R. (Eds.). (2012). *Climate change politics: Communication and public engagement*. Cambria Press.

Clarke, C. E. (2010). A case of conflicting norms? Mobilizing and accountability information in newspaper coverage of the autism-vaccine controversy. *Public Understanding of Science*.

Entradas, M.C.d.F.; (2011) *Who's for the planets? An analysis of the „public for space exploration" and views of practitioners of science communication on „their publics" and public communication in the UK*. Doctoral thesis, UCL (University College London).

ESA (1998). Space exploration and ESA awareness in the European general public
ESA Science.

Eurobarometer (2005). Special Eurobarometer 224: Europeans, Science and Technology. Brussels European Commission

Graham, E. L. (2002). *Representations of the post/human: Monsters, aliens, and others in popular culture*. Rutgers University Press.

Hart, P. S., & Nisbet, E. C. (2011). Boomerang effects in science communication: How motivated reasoning and identity cues amplify opinion polarization about climate mitigation policies. *Communication Research*

Haste et al., 2005, Connecting Science: *What We Know and What We Don't Know About Science and Society*. The British Science Association.

House of Lords (2000). *House of Lords - Science and Technology - Third Report*. Retrieved 14 April 2015, from http://www.publications.parliament.uk/pa/ld199900/ldselect/ldsctech/38/3801.htm

Ipsos MORI, 2015, Public Attitudes to Science 2014 . Retrieved 14 April 2015, from: https://www.ipsos-mori.com/researchpublications/researcharchive/3357/Public-Attitudes-to-Science-2014.aspx

Irwin, A. (2006*), The politics of talk: coming to terms with the "new" scientific governance*. Social Studies of Science, 36

Jones, H., et al. (2007). A pilot survey of attitides to space sciences and exploration
among British school children. *Space Policy*, 23(1), 20-23.

LERU (2015). *How Research Can Inform Policy*. Retrieved 14 April 2015, from http://www.leru.org/files/publications/HowResearch09_DEFINITIEF.pdf

Lewenstein, B. (2015). *Informal Science - A resource and online community for informal learning projects, research, and evaluation*. Retrieved 14 April 2015, from http://informalscience.org/research/wiki/Public-Engagement

Miller, S. (2001). Public understanding of science at the crossroads. *Public understanding of science*, *10*(1), 115-120.

Miley, G. et al. (2012). *Astronomy for Development, Building from the IYA2009: Strategic Plan 2010–2020 with 2012 update on implementation*. Retrieved from http://iau.org/static/education/strategicplan_2010-2020.pdf, International Astronomical Union

Mori (2004). Public Perceptions of the Space Industry. London: Mori.

National Research Council (1991), Working Papers: Astronomy and Astrophysics Panel Reports, (Washington, DC: The National Academies Press)

National Research Council (2010,) New Worlds, New Horizons in Astronomy and Astro- physics (Washington, DC, The National Academies Press)

NCCPE- National Co-ordinating Centre for Public Engagement, (2010), *How public engagement helps to maximise the flow of knowledge and learning between HEIs and society*

NCCPE National Co-ordinating Centre for Public Engagement, (2012), *The Engaged University: A manifesto for public engagement.*

National Science Board (NSB), (2002), Science and Engineering Indicators 2002. Arlington VA: National Science Foundation 2002.

Ottavianelli, G., and Good, M. (2002). Space education: a step forward. Space Policy, 18(2), 117-127.

Retzbach, J., Otto, L., & Maier, M. (2015). Measuring the perceived uncertainty of scientific evidence and its relationship to engagement with science. *Public Understanding of Science*

Robinson, F., Zass-Ogilvie, I. Hudson, R., (2012), How can universities support disadvantaged communities?, JRF, 23.

Royal Society, 1985, The Public Understanding of Science

Sagan, C., & Druyan, A. (2011). Pale blue dot: A vision of the human future in space. Ballantine books.

Saramago, J., 1998, Banquet Speech". *Nobelprize.org.* Nobel Media AB 2014, Retrieved from http://www.nobelprize.org/nobel_prizes/literature/laureates/1998/saramago-speech_en.html

Shaw, A. (2002). "It just goes against the grain." Public understandings of genetically modified (GM) food in the UK. *Public Understanding of Science*,*11*(3), 273-291.

SciStarter, (2015). SciStarter. Available at: http://scistarter.com/page/Citizen%20Science.html

Safwat, B., Stilgoe J., and Gillinson, S. (2006). Open Space: A Citizen's Jury on Space Exploration. London: DEMOS.

Trench, B. (2008). Vital and vulnerable: science communication as a university subject*. Communicating science in social contexts*. Springer Netherlands, 2008. 119-135.

Wilsdon, J., Wynne, B., & Stilgoe, J. (2005). The public value of science. *London: Demos*.

UUK, (2010), *Universities: Engaging with Local Communities*

II

Innovation in Global Science Education and Public Outreach Programmes

II.1

The International Year of Astronomy 2009 as a Massive Science Communication Project

The International Year of Astronomy 2009 (IYA2009) was the largest ever science communication project, with more than 815 million people participating from 148 countries. IYA2009 was declared by the United Nations General Assembly and officially ratified by UNESCO, the International Astronomical Union and the International Council of Science. Here we describe and analyse IYA2009 as an example of a successful massive science communication project (MSCP) and draw lessons that are relevant to the design and implementation of future large global science communication projects. We provide an account of IYA2009 from its inception to its legacy; discuss the goals, objectives, results and impact of the project; and compare them to those of other UN-endorsed scientific years. The importance of coordination in ensuring the success of an MSCP is emphasised. We also consider the influence that the legacy of IYA2009 has had on astronomy education and public outreach globally. The project has demonstrated that there are diverse ways to engage the public using astronomy. A unique aspect of IYA2009, which proved vital in ensuring its large reach, was the exploitation of non-professional astronomers for various levels of engagement. A limitation of the project was the absence of the key component of long-term evaluation. We describe and discuss lessons learned from IYA2009 that are relevant to future global MSCPs. These lessons are particularly relevant for the organisation of the International Year of Light and Light-based Technologies in 2015 and other upcoming science-related International Years or International Years of Science (IYSs).

Publication

This chapter is based on Russo, P., Christensen, L.L., Cesarsky, C., 2015, Science Communication (in press).

1. Introduction

Astronomy is one of the oldest fundamental sciences, and it continues to have a profound impact on human culture (Rosenberg, Russo, Bladon, & Christensen, 2014). As a research field, it has witnessed several major scientific breakthroughs in the last century that can be used to interest and intrigue non-professional astronomers (Hughes, 2007). One hundred years ago, we were ignorant of the nature of the Milky Way; but today, we understand that many billions of galaxies make up our Universe and that it originated approximately 13.8 billion years ago (Ade et al., 2013). One hundred years ago, we did not know whether our solar system was unique, but in the last two decades, astronomical facilities have detected almost 2000 planets revolving around other stars in the Milky Way (Schneider, Dedieu, Sidaner, Savalle, & Zolotukhin, 2011), and we are exploring the possibility that life originated beyond our solar system. One hundred years ago, we studied the sky using only optical telescopes and photographic plates; today we use the complete electromagnetic spectrum, from radio waves to gamma rays, to observe the Universe from Earth and from space. Such advances in astronomy have changed the perception of our place in the cosmos, and stimulated the interest of the public in science (Christensen & Russo, 2007). The media attention given to astronomical topics in most developed countries evinces this interest (Bauer, 2013; Sjøberg & Schreiner, 2010; Zuluaga, 2014).

The International Astronomical Union (IAU) organised the International Year of Astronomy 2009 (IYA2009) to exploit this widespread interest in astronomy among a large section of the public (Russo & Christensen, 2010) and to provide the first contact with inspirational science for others (Hesser et al., 2010). In this chapter, we discuss IYA2009 in detail as an example of an innovative global science communication project. Besides describing the goals and objectives, we also discuss the results and impact of the project and, where possible, compare the organisation of IYA2009 with those of other UN-endorsed scientific years. We will then generalise the experience with IYA2009 to apply it in the design and implementation of future large science communication projects.

1.1. International Years of Science as global massive science communication projects

IYA2009 is an example of a massive science communication project (MSCP). Similar to a massive open online course (MOOC), an MSCP is designed for the participation of large numbers of geographically dispersed people. The most prominent examples of global MSCPs are the International Years of Science (IYSs). IYA2009 built upon previous IYSs and included several additional innovative aspects. We shall here consider the history and elements of previous IYSs.

The IYSs have a long and varied history (see Table 2), from the first International Polar Year in 1882/1883 (Baker, 1982) to its modern versions such as the International Heliophysical Year in 2007/2008 (Thompson, Gopalswamy, Davila, & Haubold, 2009). These previous projects provided the necessary framework for holding IYA2009 (Russo, Cesarsky, & Christensen, 2009). Every project begins with a concept and the justification for it. The concept should capture people's imaginations, be relevant to society, and ideally have the potential to continue beyond the year in question. It is also necessary to build a case that will persuade policymakers of the value of having a year dedicated to a specific theme. For an official international year, recommendation from a UN specialized agency is necessary before seeking the final official step of a UN proclamation (see Table 3). For science-related years, the relevant UN agency is the United Nations Educational, Scientific and Cultural Organisation (UNESCO). To achieve global reach, the IYS organisation needs to work with a large network or networks that ideally already exist and can serve as the foundation upon which to build. There must be ideas for national and world-wide activities, as well as the funds to implement these. Finally, enthusiasm, engagement and excitement from all involved stakeholders are necessary.

Although a number of IYSs have been held in the past, little has been done towards the evaluation or assessment of these events. This makes it difficult to compare IYA2009 with other similar projects and demonstrates the need to create a baseline to which the impact of future International Years or other MSCPs can be compared. The participation of large numbers of geographically dispersed people in a diverse number of projects makes the evaluation of such projects a difficult task. Other constraints that impede proper assessment are the lack of clear objectives, no common language for the projects, the absence of an evaluation framework, and the dearth of evaluation professionals. A part of this chapter presents the first attempt to define and perform a quantitative and, to a certain extent, qualitative analysis of an MSCP. In the Evaluation section, we discuss the participation numbers of IYA2009, the levels of engagement of these participants in IYA2009-related activities and their relevance to the evaluation of other IYSs.

Table 1. Science-related International Years

Year(s)	**International Observance**	**Scope**	**Reference**	**Number of Countries and International Organisations involved**
1882/1883	International Polar Year	Research-oriented	Baker, F. W. G. (1982). The first international polar year, 1882–83. Polar Record, 21(132), 275–285.	Not available

1932/1933	International Polar Year	Research-oriented	Fleming, J. A. (1933). Progress report on the International Polar Year of 1932–33. Eos, Transactions American Geophysical Union, 14(1), 146–154.	Not available
1957/1958	International Geophysical Year	Research-oriented	Odishaw, H. (1959). International Geophysical Year. Science, 129, 14.	Not available
1961	International Health and Medical Research Year	Research-oriented	World Health Organisation. (1959). International health and medical research year.	24 nations
1992	International Space Year	Public- and research-oriented	'Mission to Planet Earth'. United Nations Chronicle, 29 (4), 49.	29 national space agencies and 10 international organisations
2005	World Year of Physics	Public- and research-oriented	Stone, C. (2004). The World Year of Physics in 2005. The Physics Teacher, 42(1), 18–23.	Not available
2007–2008–(2009)	International Polar Year	Public- and research-oriented	Committee on the Legacies and Lessons of International Polar Year 2007-2008, 2012, Lessons and Legacies of the International Polar Year 2007-2008	60 nations
2007-2009	International Year of Planet Earth	Public- and research-oriented	Woodfork & de Muller, 2010, International Year of Planet Earth – Final Report	79 nations and 25 international organisations
2009	International Year of Astronomy	Public-oriented	Russo & Christensen, 2010, International Year of Astronomy – Final Report	148 nations and 73 international organisations

2010	International Year of Biodiversity	Public-oriented	Johns, D. (2010). The international year of biodiversity-from talk to action. Conservation Biology, 24(1), 338.	87 nations and 1 international organisation
2011	International Year of Chemistry	Public-oriented	Zolotov, Y. A. (2010). International year of chemistry. Journal of Analytical Chemistry, 65(8), 769–769.	Not available
2013	International Year of Crystallography	Public- and research-oriented	Desiraju, G. R. (2014). Celebrating the International Year of Crystallography 2014. Crystal Growth & Design, 14(1), 1–1.	52 nations
2015	International Year of Light and Light-based Technologies	Public-oriented	McKenna, J. (2014). A look ahead to the 2015 International Year of Light and Light-based Technologies. Journal of Optics, 16(12), 120201.	80 nations (as of March 2015)

2. IYA2009 – Case Study of an International Year of Science

In this section, we will discuss the various elements and procedures of IYA2009 to use it as a case study for designing and implementing an International Year of Science

2.1. Vision and goals

IYA2009 was a global project initiated by the IAU and UNESCO. The mission of IYA2009 was to '*help the citizens of the world rediscover their place in the Universe through the day- and night-time sky, and thereby engage a personal sense of wonder and discovery*' (Russo & Christensen, 2010). As later defined in the book *Learning Science in Informal Environments* (Bell, Lewenstein, Shouse, & Feder, 2009), IYA2009 used a framework of interrelated aspects of astronomy education and public outreach of astronomy to fulfil this mission. IAU and UNESCO defined the goals of IYA2009 (Russo & Christensen, 2010) taking in account the different levels of people's engagement with astronomy: developing interest in astronomy, understanding astronomy knowledge, engaging in scientific reasoning, reflecting on astronomy, engaging in practical aspects of astronomy, and identifying themselves with the astronomy enterprise (Table

2). IYA2009 was the first science-related international outreach project with such a defined public engagement framework.

Table 2. Overview of the IYA2009 public engagement framework

Goals	**Objectives**
1. Increase scientific awareness among the general public through the communication of scientific results in astronomy and related fields as well as the process of research and critical thinking that leads to these results.	Make astronomical breakthroughs more visible in the daily lives of billions of people through all available means of communication (e.g., TV/radio documentaries, newspapers, web pages, exhibitions, stamps, blogs, web portals, advertising campaigns, etc.). Facilitate opportunities for individual astronomical observations.
2. Promote widespread access to the universal knowledge of fundamental science by popularising astronomy and sky-observing experiences.	Enable as many laypeople as possible, especially children, to look at the sky through a telescope and gain a basic understanding of the Universe.
3. Empower astronomical communities in developing countries through the initiation and stimulation of international collaborations.	Involve astronomical communities of developing nations in the Year, thus providing examples of how outreach and education are carried out in different parts of the world.
4. Support and improve formal and informal science education in schools as well as in science centres, planetariums and museums.	Develop formal and informal educational material and distribute all over the world. Conduct focused training of event leaders and presenters.
5. Provide a modern image of science and scientists to reinforce the links between science education and science careers and stimulate a long-term increase in student enrolment in the fields of science and technology and an appreciation for lifelong learning.	Organise popular talks by scientists for people of every gender, age and ethnic background. Share profiles – on TV, in blogs, in biographies – of scientists who break the traditional ‘lab coat’ stereotype, by showing the excitement of scientific discovery, the international aspect of scientific collaborations and the social sides of scientists.

6. Facilitate new and strengthen existing networks by connecting amateur astronomers, educators, scientists and communication professionals through local, regional, national and international activities.	Connect as many individuals (named 'IYA ambassadors') as well as organisations (amateur and professional) in networks as possible, by creating, for instance, new internal and external electronic communication infrastructures. These networks will become part of the heritage of IYA2009.
7. Ensure gender-balanced representation of scientists at all levels and promote greater involvement of underrepresented minorities in scientific and engineering careers.	Provide access to excellent role models and mentors, formally and informally, and publicize them. Provide information about the female 'dual-career' problem and offer possible solutions.
8. Facilitate the preservation and protection of the world's cultural and natural heritage of dark skies in places such as urban oases, national parks and astronomical sites by spreading awareness about their importance in the natural environment.	Involve the dark-sky community in IYA2009. Collaborate for the implementation of the UNESCO and IAU 'Astronomical and World Heritage' initiative. Lobby with organisations and institutions as well as local, regional and national governments for the approval of preservation laws for dark skies and historical astronomical sites. Bring the issues of natural environment and energy preservation to the agendas of decision makers.

2.2. Setting up the project

Table 3. Key milestones leading up to the UN declaration of the IYA2009 resolution in December 2007

Year	**Milestones**
2002	The IAU presented the concept Italian astronomer and the then IAU president Franco Pacini (1939–2012) reasoned that as 2005 was set to be the World Year of Physics, there was potential for astronomy to achieve the same status in 2009, the year that marked 400 years of Galileo's achievements (Isidro, 2012).

2003	IAU General Assembly, Sydney IAU members voted unanimously in favour of Resolution IAU GA 2003 B3 (International Astronomical Union, 2003), which recommended that 2009, the 400th anniversary of Galileo's accomplishments and the birth of modern telescopic astronomy, be declared the Year of Astronomy.
2005	UNESCO endorsement The Italian Ambassador to UNESCO submitted a request to UNESCO. August 2005: UNESCO decided to endorse 2009 as the International Year of Astronomy (UNESCO, 2005).
2006	IAU General Assembly, Prague, Czech Republic A special session helped reinforce plans for IYA2009 that would be implemented in the event of a positive decision by the UN.
2007	To convince the UN that a particular topic deserves the International Year status, support from many countries is necessary. Lobbying took centre stage, with an IAU delegation (including the IAU president) presenting the project at the UN Headquarters in New York in mid-2007. December 2007: UN Proclamation On 17 December 2007, the UN accepted the recommendation, and 2009 was officially declared the International Year of Astronomy (United Nations, 2007).

The IYA2009 network and the importance of amateur astronomers. Once the UN proclamation was confirmed, the implementation was under way. For IYA2009, the IAU, in close collaboration with UNESCO, played the role of the central coordination body. However, the IAU had only 64 national members as against the 192 sovereign states recognized by the UN at the time. To involve as many countries as possible, the organisers first identified countries that counted professional astronomers. The organisers asked countries active in astronomy to support neighbouring nations that lacked experts and also sought support in identifying scientific communities from UNESCO delegations. Over time, the organisers amassed a long list of astronomy experts or high-level amateurs from nations around the globe. A unique aspect of astronomy as a tool for science communication is the presence of a large community of amateur astronomers, whose size exceeds that of the professional astronomical community by at least an order of magnitude (DeVoss, 1998). From the outset, the organisers of IYA2009 were keen to involve large numbers of these amateur astronomers. This decision ensured that the project would widen its global reach substantially. On the other hand the involvement of amateur astronomers posed the risk of undermining the scientific knowledge of some of those involved in the implementation of IYA2009. The organisers asked the local astronomy communities to designate a single point of contact (SPoC), whose responsibility was to establish and lead an IYA2009 National Node. The membership of these National Nodes was very heterogeneous, with a typical composition consisting of senior professional astronomers (mainly IAU members), senior science communicators (science museum and planetarium directors, university press officers) and presidents of amateur astronomy societies. This distribution provided the National Nodes with the necessary astronomy background, scientific knowledge and access to networks and knowledge of public engagement projects to implement IYA2009 at national and local levels. The IYA2009 organisers established 148 National Nodes. During this phase of assessment and definition of the agents of IYA2009, several successful transnational science communication and education institutions joined IYA2009, and were designated as 'Organisational Nodes'. These institutions had the potential to lend their valuable expertise to the project by supporting and implementing activities in their communities and networks around the globe.

Designing IYA2009 as a global project. In 2003, the IAU established a Special Working Group (IAU IYA2009 WG 2007), which defined and oversaw the global implementation of IYA2009. The initial task of the IAU IYA2009 WG was to establish a rationale, a vision, goals and objectives. In 2006, the IAU IYA2009 WG also started planning some initial IYA2009 global projects, such as the Portal to the Universe (concept presented for the first time in the IAU GA in Prague) and the Cosmic Diary (initially presented in 2006 as The Universal Times). Further, the goals of the working group led to the establishment of specific cornerstone projects, including 'Dark Skies Awareness' and '100 Hours of Astronomy' (including 'Around the World in 80 Telescopes'). Drawing on different concepts and studies, the IAU IYA2009 WG also defined the final logo and slogan (The Universe, Yours to Discover) of the project in 2007. The organisers engaged the relevant astronomy communities through key meetings, such as the SPoCs' meeting in Germany in March 2007 (IYA2009 Meeting at ESO, 2007) and the Communicating Astronomy with the Public conference in October 2007 in Athens, Greece (Christensen, Zoulias, & Robson, 2007).

Setting up the global coordination. By July 2007, the IYA2009 Secretariat was established at the European Southern Observatory's Headquarters in Garching, near Munich in Germany. The secretariat was the central hub of IYA2009, coordinating activities during the planning, execution and evaluation phases. An important aspect of the secretariat's coordination function was that it aimed to support, not control. The secretariat acted as a catalyst and facilitator, providing a strong framework, strong standards and strong sets of procedures. It became evident that a central coordination office was an essential component for the organisation of science communication projects involving the participation of large numbers of geographically dispersed people, such as IYSs.

Fundraising. To raise funds, the organisers contacted organisations, institutions and agencies related to astronomy, space science and the natural sciences. They offered private companies the opportunity to become Global Official Partners or Global Sponsors. The strategy was to send a direct mail initially and to then follow it up with personal calls to specific contacts and fundraisers (Russo & Christensen, 2008). As a result, 33 'Organisational Associates' agreed to provide financial backing, in addition to three Global Sponsors. Unfortunately, the organisers found no Global Official Partners, but they did raise a total of €650 000 for the implementation of the project through the IYA2009 Secretariat. The other IYA2009 stakeholder budgets, for the National Nodes, Organisational Nodes and global funding, amounted to at least €18 million – and this financial investment was complemented by large in-kind contributions from amateur and professional astronomers, educators and organisers who helped to run the events. By the end of 2007 and beginning of 2008, a significant amount of groundwork had been completed, and a clear vision of the Year was emerging.

2.3. Implementation

The IYA2009 was implemented at several levels: global, national, regional and local. Most of the events were organised locally and relied on local amateur and professional astronomers. However, an international network of interconnecting organising bodies ensured that the best ideas and practices were shared. In this section we present several examples of the implementation of different public engagement initiatives during IYA2009 at global and national levels. These initiatives were selected on the basis of their reach, relevance and originality (Table 4). A complete overview of the IYA2009 initiatives, including detailed information on individual projects and countries, can be found in Russo & Christensen (2010).

Table 4. Selected IYA2009 projects

IYA2009 Project	Scope	Reach	Highlights	Main IYA2009 Goals Attained (See Table 2)	References
Worldwide Star Parties	Global	At least three million people	100 Hours of Astronomy (April 2009) Galilean Nights (October 2009) Event at the US White House (October 2009) Many members of the public seeing celestial objects through a telescope for the first time. Around the World in 80 Telescopes, a live 24-hour webcast, which gave members of the public a snapshot of a day in the life of astronomical research observatories around the world.	1, 2, 3, 5,8	Pompea & Norman, 2009 Pierce-Price et al., 2009
From Earth to the Universe	Global	1000 locations in 70 countries and 10 million people viewed the exhibits, which were translated into 40 languages	Photographic exhibition, staged in unexpected and easily accessible locations, such as parks, metro stations, shopping malls, hospitals, libraries, and even prisons. The exhibition is held at venues around the world to this day.	1,3,5,6	Arcand & Watzke, 2010 Arcard & Watzke, 2011

Galileoscope	Global	110 000 of these educational telescope tools were distributed in 96 countries	A low-cost telescope educational kit that was specifically designed for IYA2009.	1,2,3, 4,6	Fienberg & Pompea, 2007 Bohannon, 2010
Transnational Educational Projects	Global	At least 3000 educators involved in these projects	Universe Awareness programme: targeting preschool and primary education. Galileo Teacher Training Programme: targeting secondary education	1,2,3,4 ,5,6,7	Ödman, 2007 Doran, 2010
Planetarium Shows	Global	85000 people	Three planetarium shows had a global impact: Two Small Pieces of Glass attracted 500 000 visitors; ALMA: The Search for our Cosmic Origins had over 250 000 viewers; and the ESA production Touching the Edge of the Universe had an audience of 100 000.	1,5,6	Russo & Christensen, 2010 Boffin, Acker, & de Langue Française, 2008 Habison, 2013
Large-Scale Models of the Solar System	National (Sweden and Finland)	Sweden and Finland with around 1000 000 people reached in both countries	The large, spherical Ericsson Globe Arena in central Stockholm represented the Sun and the planets were distributed through the country. The Sun was marked by a giant sticker in the busy Helsinki Central Railway Station and the planets were distributed across the rail line	1	Russo & Christensen, 2010

World's longest canvas with astro-nomical motifs	Nati-onal (Por-tugal)	300 000 people	4.8 kilometre long canvas with astrono-mical motifs Guinness World Record	1	Frade, Doran, & Fern-andes, 2011
Sky observa-tions	Nati-onal (Ca-nada and Japan)	2 000 000 in Canada 7 000 000 in Japan	Two million people registered on the Canadian IYA2009 website to say they had experienced a 'Galileo moment' (observing through a telescope) In Japan, seven milli-on people observed the night sky through a telescope during IYA2009	1,2,5	Percy, 2009 Seki-guchi, 2010
Parade	Nati-onal (India)	700 milli-on people	Indian astronomers showcased their work at the Republic Day parade in Delhi. With 30 000 people watching in person and an estimated 700 million watching on television	1,2,5	Russo & Chris-tensen, 2010
Solar eclipse	Nati-onal (South Korea)	400 000 people	A partial solar eclipse on 22 July was the highlight of the year, with viewing events held in 45 locations across the nation, attracting over 400 000 people, from kin-dergarten children to the president of the Republic of Korea	1,2,5	Seo-Gu, 2010

Astro-nomical Exhibiti-on	Nati-onal (USA)	100 plane-tariums, museums, nature cent-res and schools across the US	The Great Observato-ries Image Unveiling, NASA sent images to 100 planetariums, museums, nature centres and schools across the US to mark Galileo's birth-day on 15 February	1,2,4,5	Sum-mers, Smith, Stoke, Eisenha-mer, & Team, G. O. I. U., 2008

The IYA2009 global projects received significant coverage in the 'new media': there were many reports on IYA2009 on the Web, including blog stories and social media mentions (Russo & Christensen, 2010). The Portal to the Universe website was the first one-stop shop for astronomy news and has had 800 000 visitors since its launch in April 2009. Cosmic Diary was a blog in which 60 professional astronomers from around the world wrote more than 2100 posts on their work, family life, friends and hobbies, attracting 250 000 visitors. The bloggers also produced feature articles about their areas of astronomy expertise, explaining complex ideas in easy-to-understand language. These features formed the basis of a published book, *Postcards from the Edge of the Universe* (Pullen, Barrosa, & Christensen, 2010), which served as a record of the project.

2.4. Impact

IYA2009 had 216 main stakeholders – 148 countries, 40 international organisations and 28 global projects. Only half of the stakeholder organisations (108) noted the number of people reached by their events and the budgets they had available to implement their activities. Funds equivalent to at least €18 million were devoted to IYA2009 activities – and large in-kind contributions from amateur and professional astronomers, educators and organisers, who helped to run the events, complemented this investment.

Table 4. Levels of engagement of non-scientists with astronomy during IYA2009

Levels of Engagement	**Examples of Activities**	**Aspect of Astronomy Learning in Informal Environments**
Informal Contact	Exhibits in non-traditional places and walk-ins News: TV news, generic newspapers/magazines, etc.	Developing interest in astronomy
Passive Participation	Expert talks Astronomy documentaries Specific exhibitions	Understanding some astronomical knowledge

Active Participation	Popular science books Workshops and hands-on exhibition Sky observation nights	Using scientific reasoning and reflecting on astronomy
Participation as data collectors and analysts: Citizen Science	Monitoring/ data collection by amateur astronomers Data analysis, e.g., Galaxy Zoo	Practicing astronomy
Amateur Researcher	Defining scientific questions Participation in the whole scientific process	Identifying with the astronomy enterprise

Different types of IYA2009 activities led to different levels of engagement of non-scientists with astronomy. These levels of engagement were linked closely with the aspects of learning science in informal environments, discussed by Bell et al. (2009). To develop a simplified definition of the level of engagement of non-scientists with astronomy, we can consider the degree of participation in IYA2009 activities by non-scientists, and a common metric of engagement is the quantifiable volume of activity (Zhang, Jiang, & Carroll, 2011). Table 4 below summarizes the levels of engagement of non-scientists with astronomy during IYA2009, and Figure 1 gives an overview of the distribution of projects sorted by level of engagement during IYA2009. We retrieved the activities from individual reports provided by the IYA2009 organisers (Russo & Christensen, 2010).

The reports provided show that IYA2009 activities reached at least 815 million people worldwide. Assuming that the reporting by stakeholders is truthful, the numbers reported make IYA2009 the world's largest science communication project (Russo & Christensen, 2010). In terms of global reach for a science outreach project, the impact of IYA2009 in engaging the public was larger than any event since the Apollo Moon programme 40 years before.
At its peak in 1969, Neil Armstrong and Buzz Aldrin's first steps on the Moon

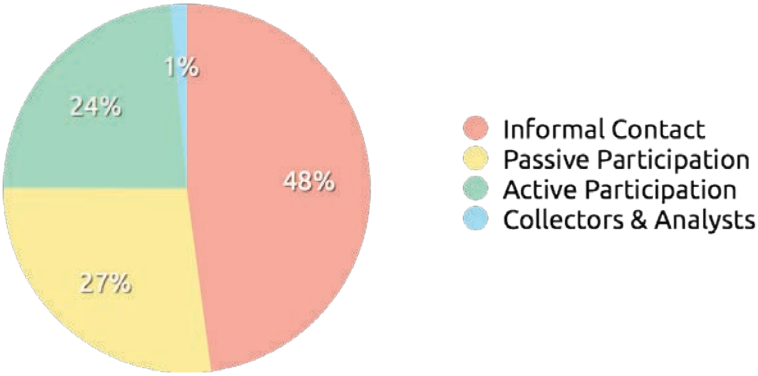

Fig 1 Percentage of people engaged in different levels with IYA2009 activities. The raw data can be found at www.goo.gl/gAAQIf.

reached an audience of more than a billion ('Apollo 11 Turns Out as Biggest Show on Earth,' 1969). Forty years later, IYA2009 reached a mass audience of at least 800 million people.

3. Discussion

Although many features of IYA2009 are special, the following aspects of the International Year of Astronomy are relevant to setting up general global MSCPs and IYSs.

3.1. The need for a global relevant case

Astronomy as a science is especially suited to science communication. This is due to the fact that the sky is visible and accessible to everybody, whether they live in a developed or developing country. Astronomy touches on the largest philosophical questions facing humanity (Christensen & Russo, 2007), which brings astronomy closer to other cultural aspects of society. IYA2009 used these aspects to engage the public with the Universe. Although not all sciences appeal to the public to the degree of astronomy, in planning a MSCP, it is important to feature aspects of the project that are suited to engaging with and inspiring a large public. It is important to consider the activities that can best serve this purpose and showcase these in the project.

3.2. The need for advance planning

Planning MSCPs requires a considerable amount of time. Developing the case, framework and engaging the different stakeholders is a lengthy process and should start as early as possible. The planning for IYA2009 started in 2005, almost 5 years in advance (Table 3). This advance planning allowed the project to develop a solid framework (Table 2) and to engage diverse stakeholders (policymakers, research astronomers, amateur astronomers and science communicators). Evaluation usually does not start until the PE project is already underway. This might result in time, budget or data constraints for the evaluation process, which will affect the reliability and validity of the evaluation process. Project planning and evaluation planning should start at the same time.

3.3. The need for global coordination

MSCPs are mainly implemented by large numbers of unpaid volunteers. Hence, they often run into problems associated with low-performance of activity organisers. This problem is known as the reliability problem (Pearce, 1993) in volunteer organisations. The reliability problem is not easily solved, but a responsive coordination office supports the engagement of volunteers. Moreover, publishing regular reports and updates on the activities also induces a sense of ownership, pride, importance and respect from the global organisers. Avoiding the reliability problem is a crucial aspect in organising an MSCP (Boezeman & Ellemers, 2007). The establishment of the secretariat in mid-2007 as a small streamlined office to ensure global coordination played a vital role in addressing these issues during the implementation of IYA2009. Further, coordination was done via support and facilitation, not control. The secretariat acted as a catalyst and facilitator, providing a clear project framework (Table 2), standards, sets of procedures and information on the results. A global coordination office is an important component for the organisation of science communication initiatives involving the participation of large numbers of geographically dispersed people, such as IYSs. We recommend that future MCSPs establish a coordination office in as early as the planning phase to ensure successful implementation.

3.4. The need for assessment and evaluation

Although conducting a professional evaluation of an MSCP is a difficult task, it is an important aspect of such a massive project and is needed to justify the expenditure to fund givers. Insufficient attention was paid to evaluation while planning and implementing IYA2009, and difficulties in evaluation were encountered. These difficulties were mainly due to late planning, budget limitations, lack of data, language differences and a lack of evaluation training provided to the individuals implementing the public engagement initiatives. These had negative implications for the validity, reliability and transferability of the IYA2009 evaluation. Below we discuss some recommendations for other MSCPs, such as the IYSs.

Insufficient budget. Allocating sufficient budget for evaluation was an issue with IYA2009 and is a general limitation. Frequently, public engagement projects face budget constraints, primarily because most projects do not include an evaluation budget. The budget limitations make it difficult to develop and apply the most appropriate evaluation instruments effectively. Project organisers may address budget constraints by simplifying the evaluation design; revising the sample size; exploring other data collection methods (such as using volunteers to collect data, shortening surveys, or using focus groups) or looking for reliable secondary data (Bamberger, 2004).

Other limitations. If evaluation is initiated too late into the program, insufficient baseline data poses a problem. Another possible problem that may compromise evaluation data, and must be tackled, is systematic reporting biases or poor record-keeping standards. This is a major issue for MSCPs. Data constraints may also result from difficulty in reaching and collecting data from a specific target group; for example, it is difficult to record the number of 'walk-ins' in an open-air exhibit. Evaluators can address data constraints by, for example, reconstructing baseline data from secondary data (Bamberger, 2004).

Language and culture. Cultural aspects, such as language, influence many facets of the evaluation process, including data collection, implementation of the evaluation program and the analysis and interpretation of the evaluation results. Language can be a major barrier to communicating concepts that the evaluator is trying to access, and translation is often required (Ebbutt, 1998). Thus, evaluators need to take this into account when planning the evaluation process (Bulmer & Warwick, 1993).

Need for training. It is important to provide basic training in the basic principles of impact evaluation design for national organising committees. The training materials and resources should include information about the following evaluation principles: comparable pre-test/post-test design; focus groups; instrument development and testing; random sample selection, etc.

Several authors (e.g., Bamberger, 2004) have offered new suggestions for addressing these impediments to MSCPs: plan the evaluation strategy from the design phase; explore options for dealing with constraints related to costs, time and data; identify the strengths and weaknesses (threats to validity and adequacy) of the evaluation design; and take measures to address the threats and strengthen the evaluation design and conclusions from the design phase of the project. A central coordination office can act as the lead for the development of an evaluation strategy from the design phase.

4. IYA2009 Legacy

From its inception, IYA2009 was envisaged as more than just a series of activities occurring over twelve months; it was seen as a springboard for the popularisation of astronomy with a much longer timeframe in mind. While planning a global MSCP, the long-term sustainability and effect of the project and its legacy should be considered and taken into account from the beginning.

Several global astronomy projects have continued beyond 2009. For example, the designation of astronomical sites by the UNESCO World Heritage program has made significant progress since 2009 (Ruggles & Cotte, 2011). More work remains to be done in the coming years, but protecting and preserving our astronomical cultural heritage for future generations to appreciate must remain a priority.

IYA2009 also provided a less-stereotyped image of scientists and astronomers, through both the Cosmic Diary blog, in which working astronomers posted entries about their work, and the ‘She is an Astronomer’ project, which promoted gender equality. The stereotype of astronomers as oddball figures with long beards in towering observatories is not only inaccurate, but also damaging to the field (Buldu, 2006). Helping to reshape preconceptions and expectations is notoriously difficult, and the extent to which IYA2009 has had a positive impact in this area will be monitored over time (Frade et al., 2011). Discussions must continue to address the gender-balance issue in astronomy, as highlighted in the ‘She is an Astronomer’ project. The project has revived the debate on gender issues in astronomy, and several projects have started at institutional level.

Several filmmakers have produced movies that serve as excellent examples of the tangible, lasting legacy of IYA2009. The film 400 Years of the Telescope (Oman & Koenig, 2008) gave rise to a widely distributed planetarium show that will continue to fascinate and educate the public for many years to come. Robert Pansard-Besson produced the film Tours du monde, tours du ciel for IYA2009, and it was aired on the French-German channel Arte in November 2009, and continues to appear regularly on this and other TV channels around the world. Additionally, Eyes on the Skies, an IAU-produced educational movie that celebrates the 400th anniversary of the telescope, is expected to be frequently screened in classrooms, astronomy clubs and homes around the world, as it has been subtitled in many languages (Schilling & Christensen, 2011).

Combining increased opportunities for developing nations with improved education, the Universe Awareness project (UNAWE) openly tackled some challenging issues during IYA2009. Its aim of creating an international awareness of our place in the Universe and on Earth, targeted at children in underprivileged environments, has inspired many. The program has received considerable support beyond IYA2009 (Ödman-Govender & Kelleghan, 2011; Schrier, Nijman, & Russo, 2013).

Over 2009, and ever since, developing nations have enjoyed increased access to astronomy groups and organisations at home and abroad. New openings and opportunities at both the professional and amateur levels initiated during IYA2009 are set to increase, making the best use of the expertise within these countries and helping global astronomical research and science communication. The IAU remains at the forefront of these efforts, and the IAU Strategic Plan for Astronomy Development identifies the consolidation of links between the IAU and developing nations as a priority. From the IYA2009 networks, we know that efficient global coordination is the foundation of success. The IAU Offices of Astronomy for Development and for Astronomy Outreach (based in Tokyo, Japan) will continue the work started during IYA2009.

5. Conclusions

IYA2009 has received considerable positive feedback. While the impact of IYA2009 on the scientific literacy of the general public will take time assess, there is little doubt that the communication of astronomical research throughout 2009 has contributed to an increase in the public understanding and appreciation of science. IYA2009 facilitated an increased awareness that we are living in an extraordinary era of discoveries about the Universe; introduced a less stereotypical image of astronomers to the public; demonstrated that a career in astronomy is also for women and minorities; created international networks of scientists, communicators, teachers and amateurs that remain in existence far beyond 2009; produced a wealth of educational material on astronomy in the form of books, films, movies, planetarium shows, and astronomy-related theatre and music productions; and inspired a new generation of amateur and professional astronomers.

On the basis of our experience with implementing and evaluating IYA2009, we here present several recommendations that should be taken into account while designing future MSCPs: MSCPs should be based on strong and relevant science cases. They should engage with a large number of stakeholders not only in science, academia and governance but also in less traditional communities, like artistic communities. The organisers implementing the projects at local level should feel a sense ownership, pride and importance towards the implementation of MSCPs. The global coordination body should ensure that this is the case. Planning (including evaluation) should start as soon as the concept is developed. Experts in the evaluation of science communication programmes should be included in the global coordination team from the start and provide input to the MSCPs.

IYA2009 was the first event that brought a large network – consisting of 148 nations – together on a single science communication venture. This brief account should provide a head start and support to other organisers of MSCPs. It is also expected that the new International Years or other MSCPs will use some of the approaches, strategies and recommendations devised by the International Year of Astronomy 2009.

References

Ade, P. A. R. et al. (2013). Planck 2013 results. XVI. Cosmological parameters [*arXiv* preprint]. arXiv:1303.5076 [astro-ph.CO]

Apollo 11 turns out as biggest show on Earth. (1969). *Broadcasting*, *50.*

Arcand, K. K., & Watzke, M. (2010). Bringing the universe to the street. A preliminary look at informal learning implications for a large-scale non-traditional science outreach project. *JCOM, 9*(2).

Arcand, K. K., & Watzke, M. (2011). Creating public science with the From Earth to the Universe Project. *Science Communication*, *33*(3), 398–407.

Baker, F. W. G. (1982). The first international polar year, 1882–83. *Polar Record*, *21*(132), 275–285.

Bamberger, M. (2004). Shoestring evaluation: Designing impact evaluations under budget, time and data constraints. *American Journal of Evaluation, 25*, 1–5. doi:10.1177/109821400402500102

Bauer, M. (2013). *EPO in a multinational context*. Retrieved April 2014 from http://www.eso.org/public/archives/static/events/special-evt/astronet2013/presentations/1-3-Bauer.pdf

Bell, P., Lewenstein, B., Shouse, A. W., & Feder, M. A. (Eds.). (2009). *Learning science in informal environments: People, places, and pursuits*. Chicago: National Academies Press.

Boezeman, E. J., & Ellemers, N. (2007). Volunteering for charity: Pride, respect, and the commitment of volunteers. *Journal of Applied Psychology*, 92, 771–785.

Boffin, H., Acker, A., & de Langue Française, A. P. L. F. (2008). Exploring the Cold Universe–A Planetarium Show for the IYA 2009. In L. L. Christensen, M. Zoulias & I. Robson (Eds.) *Communicating astronomy with the public 2007.* Paper presented at the IAU/National Observatory of Athens/ESA/ESO Conference, Athens, 8–11 October (p. 74). Eugenides Publishing.

Bohannon, J. (2010). Galileo in Senegal. *Science*, *328* (5976), 296.

Buldu, M. (2006). Young children's perceptions of scientists: A preliminary study. *Educational Research*, *48*(1), 121–132.

Bulmer, M., &Warwick, D. (1993). *Social research in developing countries: Surveys and censuses in the third world*. London: Routledge.

Christensen, L.L. & Russo, P. (2007). Communicating astronomy with the public. In A. Heck (Ed.). *Proceedings from Future Professional Communication in Astronomy*. Paper presented at Future Professional Communication in Astronomy, Brussels, 10-13 June (p. 199). Belgian Royal Academy of Sciences, Letters and Fine Arts.

Christensen, L.L., Zoulias, M., & Robson, I. (2007). *Proceedings from communicating astronomy with the public*. XXXX: Eugenides Publishing.

Damimeli, A. (2010). *IYA2009 in Brazil - past and future* [PowerPoint presentation]. Retrieved from http://www.communicatingastronomy.org/cap2010/presentations/damineli_100315.ppt

DeVoss, D. (1998). In Arizona, it's an all-night party for the stars. *Smithsonian Magazine, 29* (9).

Doran, R. (2010). The Galileo Teacher Training Programme. In *38th COSPAR Scientific Assembly* (Vol. 38), p. 3892.

Ebbutt, D. (1998). Evaluation of projects in the developing world: Some cultural and methodological issues. *International Journal of Educational Development, 18* (5), 415–424.

Fienberg, R. T., & Pompea, S. M. (2007). Progress toward a low-cost "Galileoscope" for the IYA2009. *CAP2007 Conference Proceedings*, 32.

Frade, A., Doran, R., & Fernandes, J. (2011). Evaluating the impact of the International Year of Astronomy 2009 in Portugal. *Communicating Astronomy with the Public Journal*, *11*, 35.

Habison, P. (2013). Astronomy and space in curricula—Towards a continental education. In *European identity through space* (Vol. 9). (pp. 186–199). XXXX: Springer.

Hesser, J. et al. (2010). *International Year of Astronomy 2009 in Canada final report*. Retrieved from http://www.astronomy2009.org/static/reports/Canada/finalreporte.pdf

Hughes, D. W., & de Grijs, R. (2007). The top ten astronomical breakthroughs of the 20th century. *Communicating Astronomy with the Public Journal*, *1*, 11–17.

Isidro, M. (2012). Franco Pacini, 1939–2012. Retrieved from http://www.eso.org/public/announcements/ann12009/

International Astronomical Union. (2003). *IAU XXVth General Assembly Resolu-*

tions. Retrieved from http://www.iau.org/static/resolutions/IAU2003_French.pdf

IYA2009 Meeting at ESO. (2007). Retrieved from http://www.communicatingastronomy.org/iya_eso/index.html

Kleijn, G. V., Barthel, P., & Baan, M. (2007). The International Year of Astronomy 2009 in the Netherlands. *CAP2007 Conference Proceedings*, p. 148.

Kinney, A., Khachadourian, D. Millar, P. & Hartman, C. (2009). Women in Astronomy and Space Science: Meeting the Challenges of an Increasingly Diverse Workforce, NASA

Mignone, C., Russo, P., & Christensen, L. L. (2010). Beyond 2009: ESO at the closing ceremony of the International Year of Astronomy. *The Messenger*, *139*, 62–64.

Miley, G. et al. (2012). *Astronomy for Development, Building from the IYA2009: Strategic Plan 2010–2020 with 2012 update on implementation*. Retrieved from http://iau.org/static/education/strategicplan_2010-2020.pdf, International Astronomical Union

Miley, G., Carignan, C., & Govender, K. (2010). Building on IYA2009: IAU strategic plan "Astronomy for the Developing World". *Proceedings of the International Astronomical Union*, *6*(S277), 203–210.

Naicker, L., & Govender, K. (2009). Towards a global baseline for astronomy development. *Communicating Astronomy with the Public Journal*, *7*(14), 1.

Ödman, C. (2007). Making young children aware of the universe. *Astronomy & Geophysics*, *48*(4), 4–20.

Ödman-Govender, C. J., & Kelleghan, D. (2011). Astronomical perspectives for young children. *Science*, *333*(6046), 1106–1107.

Oman, J., & Koenig, K. (2008). 400 Years of the Telescope. In *Preparing for the 2009 International Year of Astronomy: A Hands-On Symposium* (Vol. 400, p. 548).

Owens, S. & Robson, I. (2010). Report of the Activities of the International Year of Astronomy 2009 in the United Kingdom.

Pearce, J. L. (1993). *Volunteers: The organizational behavior of unpaid workers*. Routledge.

Percy, J. R. (2009). Tafelmusik's The Galileo Project: An out-of-this-world IYA2009 arts experience. *Astronomy with the Public Journal*, *7*, 24.

Pierce-Price, D., Russo, P., & Christensen, L.L. (2008). ESO and the International Year of Astronomy 2009. *The Messenger*, *134*, 66–67.

Pierce-Price, D., Lowery, S., Emundts, M., Wojtaschek, A., Simmons, M., Christensen, L. L., & Russo, P. (2009). Around the World in 80 Telescopes. *Communicating Astronomy with the Public Journal*, *6*, 18.

Pompea, S. & Norman, D. (2009). The White House Star Party; Reports from the South Lawn. *Astronomical Society of the Pacific, 35*, 1–6.

Pullen, L., Barrosa, M & Christensen, L. L. (Eds.). (2010). *Postcards from the edge of the Universe: An anthology of frontline astronomy from around the world*. Munich: ESO.

Rosenberg, M., Russo, P., Bladon, G., & Christensen, L. L. (2014). Astronomy in everyday life. *Communicating Astronomy with the Public Journal*, *14*, 30.

Rowe, G., & Frewer, L. (2000). Public participation methods: A framework for evaluation. *Science, Technology & Human Values*, 25(1), 3–29.

Ruggles, C. L., & Cotte, M. (2011). *Heritage sites of astronomy and archaeoastronomy in the context of the UNESCO World Heritage Convention: A thematic study*. Paris: International Council of Monuments and Sites.

Russo, P., & Christensen, L.L. (2008). *IYA2009 partnership opportunities*. Retrieved from
http://www.astronomy2009.org/static//archives/documents/pdf/iya2009_partnership_opportunities.pdf

Russo, P., Cesarsky, C., & Christensen, L. L. (2009). SpS2-The International Year of Astronomy 2009. *Proceedings of the International Astronomical Union*, *5*, 559–609. doi:10.1017/S1743921310010744.

Russo, P., & Christensen, L.L. (Eds.) (2010). *International Year of Astronomy 2009 — Final Report*. Retrieved from http://www.astronomy2009.org/resources/documents/detail/iya2009_final_report/

Russo, P., Christensen, L.L. (2015). *International Year of Astronomy 2009 Press and Blog Coverage*. Retrieved from http://astronomy2009.org/news/presscoverage/index.html

Schilling, G., & Christensen, L. L. (2011). *Eyes on the skies: 400 years of telescopic discovery*. Berlin: John Wiley & Sons.

Schneider, J., Dedieu, C., Sidaner, P. L., Savalle, R., & Zolotukhin, I. (2011). Defining and cataloging exoplanets: The exoplanet.eu database [*arXiv* preprint]. arXiv:1106.0586.

Schrier, W., Nijman, I., & Russo, P. (2013). Universe Awareness: inspiring every child with our wonderful cosmos. *Communicating Science: A National Conference on Science Education and Public Outreach*, *473*, 141.

Sekiguchi, K. (2010). Evaluations and future plans of IYA2009 activities in Japan [PowerPoint presentation]. Retrieved from http://www.communicatingastronomy.org/cap2010/presentations/sekiguchi_100315.ppt

Seo-Gu. (2010). IYA2009 activities and survey results of public opinion for the astronomy. In case of Republic of Korea. Retrieved from http://www.communicatingastronomy.org/cap2010/presentations/seogulee_100316.ppt

Sjøberg, S., & Schreiner, C. (2010). *The ROSE project. An overview and key findings*. Retrieved from http://roseproject.no/network/countries/norway/eng/nor-Sjoberg-Schreiner-overview-2010.pdf

Summers, F., Smith, D., Stoke, J., Eisenhamer, B., & Team, G. O. I. U. (2008). Image unveilings and traveling exhibits: IYA programs to reach audiences old and new. *Bulletin of the American Astronomical Society*, *40*, 261.

Thompson, B. J., Gopalswamy, N., Davila, J. M., & Haubold, H. J. (2009). *Putting the" I" in IHY: The United Nations Report for the International Heliophysical Year 2007* (Vol. 3). Vienna: Springer.

UNESCO. (2005). *Proclamation of 2009 as the United Nations International Year of Astronomy*. Retrieved from http://unesdoc.unesco.org/images/0014/001413/141314e.pdf

United Nations. (2007). Resolution adopted by the General Assembly on 19 December 2007. Retrieved from http://www.un.org/en/ga/search/view_doc.asp?symbol=A/RES/62/200&Lang=E

United Nations. (2013). Globalization and interdependence: Science and technology for development. Retrieved from http://www.un.org/en/ga/search/view_doc.asp?symbol=A/68/440/Add.2

Zhang, S., Jiang, H., & Carroll, J. M. (2011). *Integrating online and offline community through Facebook*. Paper presented at the 2011 International Conference on Collaboration Technologies and Systems (CTS), 569–578. doi: 10.1109/CTS.2011.5928738

Zuluaga, J. [zuluagajorge]. (2014, Apr 13). Evolution of "scientific trending topics" in the covers of Scientific American (via @SciAm) - Great Infographics! http://t.co/kOhq6rUJch [Tweet]. Retrieved from https://twitter.com/zuluagajorge/status/455376928623845376/photo/1

II.2

Universe Awareness as a Transnational Collaborative Programme in Astronomy Education

Universe Awareness (UNAWE) is a pioneer global science education programme that uses the beauty and grandeur of the Universe to encourage young children, particularly those from an underprivileged background, to have an interest in science and technology and foster their sense of global citizenship. A description is given of the EU Universe Awareness project that was implemented in 6 countries between 2011 and 2013. After showing that targeting young children is highly cost effective we discuss in detail the design and implementation of the project. A framework for evaluating the project was developed and applied, which shows that the project was highly successful in achieving its goals. The implementation of innovations in science education like Space Scoop – astronomy service news for children – and duo internships – teacher training provided by astronomy and teaching students – are also discussed in this chapter. The global network of 61 countries involved with Universe Awareness makes it a truly transnational collaborative programme in science education.

Publication

This chapter is based on Russo et al 2015, Journal of Science Education and Technology (in prep).

1. Introduction

1.1 Background

Universe Awareness (UNAWE) is a unique international programme to use space science and astronomy to inspire very young children, aged 4 to 10 years; it embodies a unique combination of scientific and cultural aspects: our awe-inspiring Universe captures children's imagination, making it a great stepping-stone to introduce youngsters to science and technology. Indeed, many scientists can trace their interest in science to single moments they experienced as young children when they were first introduced to the wonders of the cosmos. Considering the vastness and beauty of the Universe and our place within it provides a special perspective that can help broaden the mind and at the same time stimulate a sense of global citizenship.

UNAWE has been endorsed by the International Astronomical Union (IAU) and is an integral part of the IAU Strategic Plan 2010–2020 Astronomy for the Developing World, a blueprint that aims to use astronomy to foster education and provide skills in science and technology throughout the world, particularly in developing countries (Miley, 2009). In this chapter, we will present and discuss the design, implementation, and evaluation of UNAWE as a transnational collaborative programme in Astronomy Education.

Effectiveness of educating young children. Most pre-university astronomy education programmes focus on secondary school children with the direct goal of stimulating them to choose careers in science and technology. UNAWE uses inspirational aspects of astronomy and space sciences to inspire younger children, because a child's early years have been demonstrated to be highly important for their long-term development.

UNICEF's "Programming Experiences in Early Child Development 2006" report states that educating disadvantaged children in their earliest years offers the best opportunity to give them an equal start in life. *"[This is] when children's brains are developing most rapidly, and the basis for their cognitive, social and emotional development is being formed*," the report states.

The High/Scope Perry Preschool Study (HSPP) is an example of what investing in the education of young disadvantaged children can achieve in the long-term. Beginning in the 1960's, HSPP randomly divided 123 disadvantaged African-American children aged between 3 to 4 years into a group that received a pre-school programme and a control group that received no intervention. HSPP maintained contact with the study's participants every year until the age of 11, and then conducted follow-up interviews at ages 14, 15, 19, 27 and 40. In 2005, a study of 97% of participants (then aged 40) revealed that those who had taken part in the pre-school programme achieved greater success in life than the control group such as experiencing higher graduation rates, better paid jobs, and – most importantly – fewer criminal records (Schweinhart, 2005).

However, despite the greater successes in the children's later life in the HSPP pre-school group, these children did not achieve higher IQ scores than the

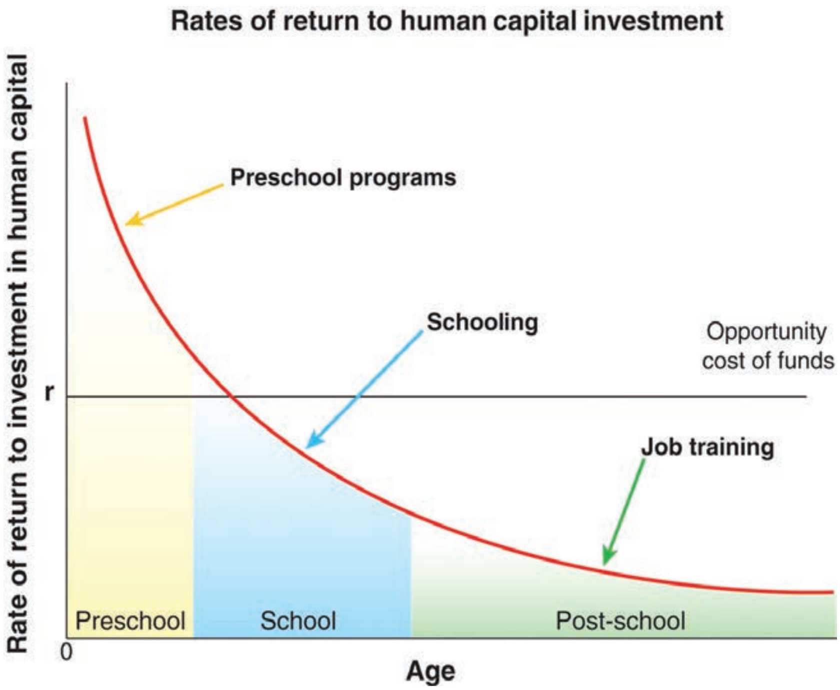

Figure 1. Rates of return to human capital investment in disadvantaged children. Credit: Science Magazine / Heckman.

control group when they were tested at the age of 10. They did, however, achieve greater success in life because they had improved non-cognitive abilities such as motivation and perseverance (Heckman, 2008).

A further conclusion of the study was that the programme had also been an economic investment for society (Schweinhart, 2005). Overall, $15 166[01] was spent on the pre-school programme, but the economic return to the general public was calculated to be an astounding $195 621– a $12.90return per Euro invested, mostly due to decreased crime-related costs[02].

According to Heckman (2006), who has reviewed a large body of economics and developmental psychology research, the rate of return would have been lower if the investment in education was instead made when the disadvantaged children were older. Figure 1 displays Heckman's depiction of the relationship between age of intervention and the benefit-to-cost ratio of an educational programme. Heckman's work shows that based on the HSPP follow-up, investing in education during a child's earliest years is not only worthwhile, but also represents the most appropriate time to intervene.

1.2 Astronomy & Young Children

From the age of 4, children can readily appreciate and enjoy the beauty of astronomical objects and can learn to develop a "feeling" for the vastness of the Universe. On the one hand, the Universe is an excellent and exciting vehicle for introducing the scientific method and the concept that nature can

[01] United States Dollars

[02] Education savings, taxes on earnings and welfare savings represent $24 149.

be interrogated by rational means (Baram-Tsabari & Yarden, 2009). On the other hand, exposure to inspirational astronomical observations and space data can broaden a child's perspective and mind while stimulating a global perspective.

Some developmental psychologists have hypothesised that young children form naïve theories about the Earth based on what they witness (e.g., the world around them appears flat, and objects need a surface to stand on; therefore, they believe Earth is flat and supported by another object). Proponents of this hypothesis (Vosniadou, 1994 a, b), say that counter-intuitive scientific theories are difficult for young children to accept and that scientific explanations about how the Universe works can only be introduced at later stages of a child's education (around 10 years old), once they become aware that their naïve theories are wrong. However, there is a growing body of research that disputes this "naïve theories" hypothesis, claiming that children are "theory neutral." In these studies, developmental psychologists argue that children build up a picture of the Earth in a fragmented fashion, and there are no strong intuitions and misconceptions to overcome (Nobes, 2003; Siegal, 2011; Panagiotaki, 2008). Therefore, children can gradually learn and accept scientific explanations of the world around them from a young age.

Panagiotaki (2008) states that children as young as four years old are able to understand basic scientific ideas. "*Even though children are often not able to explain their ideas in great detail, scientific information and facts can be present from early on. [...] Children benefit enormously for appropriate instruction and educational activities aimed at teaching them basic facts.*" Liberman (2012) shows that learning about distant objects promotes more abstract thought. When visualizing proximal objects, individuals tend to use concrete and detailed images while picturing distant objects, such as those often dealt with in astronomy, in a more abstract and decontextualized way. Liberman found that after spatial distance priming, children are more creative in both fluency and originality. Moreover, Sjøberg and Schreiner (2010) have shown that Space and Life in Outer Space are the most interesting topics for pupils, both boys and girls, across several countries.

Introducing young children to astronomy is challenging, especially in a multi-national project that must consider many different local cultures. However, much of the current literature regarding children's cognitive development indicates that a project, such as EU-UNAWE, is of great benefit to the youngsters that it reaches. Time and time again, a child's early years are shown to be the most crucial in determining their future prospects.

Underprivileged Communities. Astronomy is an important tool for motivating young children in underprivileged communities, thereby helping to alleviate social problems and build the knowledge and innovation economy. Early educational interventions during the young formative years are crucial in stimulating child development (OECD, 2006, Worth & Grollman, 2003, Rocard 2007). Furthermore there is an enormous untapped potential and talent in underprivileged communities. Such communities are frequently alienated from society at large and this alienation begins at childhood. According to a UNICEF report (DATE), "*The opportunity to help disadvantaged children have* *a more equal start in schooling is in the earliest years when the basis for their cognitive, social and emotional development is being formed*". Educating very young children from underprivileged communities is highly cost effective (Schweinhart et al 2005), but needs a special approach. The Early Years Learning Framework for Australia (2009) states, "*When early childhood educators respect the diversity of family and communities…they are able to foster children's motivation to learn*" and further "*Poor math trajectories in low-socioeconomic status children begin early…. Studies suggest that early interest can be influenced*" (Arnold and Doctoroff 2003). However, it is clear that further such studies are needed in a range of diverse environments and cultural settings.

1.3 Components of Universe Awareness

Universe Awareness' goal is to inspire young children and encourage them to develop an interest in science and technology. The programme also aims to introduce children to the idea of global citizenship at a crucial stage of their development – to show them that they are part of an international community. Universe Awareness exploits several tools and activities to achieve the top-level goals of the programme taking account of the theoretical framework presented above. These include:

Teacher training. A particularly important UNAWE ingredient is to provide training activities for teachers and other educators of young children. UNAWE aims to give teachers the confidence necessary to introduce astronomy and other science topics in the classroom and create innovative methods for engaging young children in astronomy. To achieve this goal, UNAWE organises teacher training workshops. In section Teacher Training, we will discuss teacher training activity implementation in detail.

Development of localised educational resources. Learning should be creative, exciting, and interesting (Abadzi et al., 2014). UNAWE develops resources using the pedagogical method of inquiry-based learning (Bell et al., 2010). In section Educational Resources, we will discuss educational resources development of in detail.

An international network. The international network provides a platform for sharing ideas, best practices, and resources between educators from around the world and guarantees understanding of cultural differences when developing resources. UNAWE is a multi-national programme, so it is also important to note the impact that local cultures play in educating young children. In a background paper for the UNESCO "Education For All Global Monitoring Report 2007," Arnold et al. claim that education programmes that are not responsive to local cultures will suffer from lower enrolment and retention levels (Arnold, 2006). The researchers argue that education programmes, which are at odds with local cultures, can be viewed by parents as having a damaging effect on their children's welfare. UNAWE recognises the importance of considering local cultures and uses local experts who understand the local cultural needs and histories to effectively implement its activities in each partner country (Samarapungavan, 1998).

Evaluation and impact assessment. Evaluation is the analysis of on-going or completed activities and an effective way of learning how to better perform tasks and apply ideas (Russo & Barrosa, 2008). It is a way of collecting information that helps all those who manage projects to understand and justify the results and impacts as well as build best practices. For UNAWE, evaluation is a source of learning. Through evaluation, UNAWE does the following:

- Determines if the programme objectives were reached
- Obtains information on the programme outcomes along with suggestions for improvement
- Identifies the changes resulting from programme implementation
- Identifies ways in which the programme could have been more effective and efficient
- Identifies unexpected results
- Develops ideas about the programme and what it intends to achieve
- Provides encouragement by demonstrating that one's efforts have been worthwhile
- Guarantees intercultural attitudes.

In section 4, we will discuss the evaluation framework of UNAWE and the programme's impact assessment in detail.

1.4 Genesis of EU-UNAWE

EU Universe Awareness (EU-UNAWE) was initiated in 2011 when the European Union awarded a 7th Framework Programme (FP7) grant of 1.9 million Euros to fund a 3-year project to build on the existing UNAWE programme's work (CORDIS, 2015). The FP7 grant supported the development and implementation of UNAWE programmes in six countries: Germany, Italy, The Netherlands, the United Kingdom, South Africa, and Spain. South Africa's inclusion in the EU-UNAWE evidences the close collaboration in the fields of science and technology that the country has developed with the European Union.

2. Design of the EU-UNAWE Programme

2.1 Objectives

The EU-UNAWE proposal contained several specific objectives as part of the EU-UNAWE implementation of Universe Awareness. The objectives were categorized by operation in conjunction with the programme's managerial processes (Table 1), and cognitive objectives regarding the skillsets, abilities, and processes related to knowledge (Table 2). The cognitive objectives and skills were further developed into an evaluation framework (discussed in detail in the discussion sections)

Table 1. Overview of EU-UNAWE Operational objectives and respective evaluation estimators.

EU-UNAWE Operational Objectives	Evaluation estimators
Train and empower primary school teachers in 6 countries to include astronomy and space topics in the classroom	Number of teachers trained.
Develop and translate hands-on material where appropriate, emphasising the EU and SA science and technology	Number of resources produced and distributed.

Provide a network for exchange of expertise and material between educators - Lay the groundwork for programme expansion throughout the European Union and Associated Countries	Number of educators engaged. Number of Universe Awareness National Nodes.
Act as a showcase for the EU and SA astronomy/space and related technologies by disseminating the products among very young children, their teachers, and families.	Number of exchange activities between the EU and South Africa.
Use astronomy/space products to stimulate awareness and strengthen public support for the EU and SA space science research and technology.	Number of activities engaging general public.
Stimulate the next generation of EU and SA engineers and scientists, particularly girls.	Number of activities targeting girls.
Contribute to the integration of disadvantaged communities in participating countries.	Number of activities engaging disadvantaged communities.
Strengthen collaboration between the EU and SA over mutually-beneficial scientific, technological, educational, and social topics.	Number of exchange activities between the EU and South Africa.
Provide significant added value for Europe's expenditure on astronomy and space sciences for a modest incremental cost.	Number of educators and children reached by astronomy and space sciences activities.
Pooling complementary expertise and partner resources makes for a project whose whole is greater than the sum of its parts.	Number of resources produced for the EU-UNAWE consortium.

Table 2. EU-UNAWE Cognitive Skills and Objectives

EU-UNAWE Cognitive Skills	**Cognitive Objectives**
Motivation	Enjoyment Inspiration Curiosity Tenacity

Scientific Skills	Develop Scientific Thinking and Problem Solving Techniques: • Planning and Conducting Investigations • Discussing and Questioning • Planning • Observing • Interpreting • Ideas and Evidence • Recording • Evaluation
Knowledge	Knowledge and understanding of astronomy and space–related concepts
Intercultural Attitudes	Valuing different cultural perspectives Recognising different physical perspectives of the Earth Positive attitude towards astronomy Working individually and in teams

2.2 Teacher Training

The effectiveness of reaching children is increased significantly through the multiplicative effect of targeting their teachers. Except for professional science educators, teachers are often afraid of science, engineering, and mathematics (Peacock, 1991; Beilock et al., 2009). This is a particularly acute problem for many primary school teachers who have a substantial influence on young children's initial school years. Exposure to astronomy-oriented topics can build confidence in teachers and sow the seeds of a science-oriented future career choice. Furthermore, teacher training is a crucial instrument for encouraging science, technology, engineering and mathematics (STEM) literacy and interest in astronomy among the general public.

EU-UNAWE training courses (also known as CPD – Continuous Professional Development) are embedded in a conceptual framework that demonstrates how to integrate astronomy and space-related activities successfully into the classroom in both formal and informal settings. The framework is based on the pedagogical approach of Inquiry Based Science Education (Rocard et al., 2007) with an inquiry cycle that specifically targets space-related activity implementation in different settings and grade levels. The sets of activities will demonstrate the connection between natural phenomena, and the concepts behind them and will show the progression from small to large scientific ideas. During the training sessions, teachers gain subject knowledge for teaching their pupils in the domains previously explained. In addition, there is potential for the programme impact to significantly increase through teachers disseminating knowledge to pupils, critically appraising resources and activities in order to make recommendations for future projects, and embedding astronomy activities into curriculum.

2.3 Educational resources

Inquiry-based learning techniques were taken into consideration in EU-UNAWE educational resources design. All necessary background information and a clear step-by-step "walkthrough" were included so that educators can implement the activities regardless of their scientific background. In addition, all subject matter can be linked to the curriculum to help teachers incorporate the activities in their lesson plans. EU-UNAWE resources are open source and produced using a Creative Commons License (Attribution-Non-Commercial-Share Alike 4.0 Unported). This closely follows the recommendations from the European Commission on Open Education and Open Access. Moreover, this approach allows the global UNAWE network to localise the educational resources. The crowd-sourced efforts and online educational resources therein increase the impact of astronomy outreach and education (Ödman-Govender & Kelleghan, 2011). The EU-UNAWE resources have been designed to be low-cost and are available for free under the Creative Commons License in a range of formats for ease of use, adaptation, and translation.

2.4 Web Communication

The EU-UNAWE website was launched in June 2011 and is the central hub for all of the programme's news, activities, and educational resources. Since its launch, the website has seen an increase in visitors each month (Figure 2). In addition to hosting all of the EU-UNAWE educational materials (currently 70 items), there has also been a stream of regular news updates. This flow of information engages educators and shows that EU-UNAWE is an active project while also inspiring them with ideas for new educational activities. The EU-UNAWE national websites have been developed using the same technology and visual identity as the international EU-UNAWE sites. The national EU-UNAWE websites complement the international website by providing information about events and resources that are country-specific and written in the country's national languages. The EU-UNAWE websites were developed with a coherent web infrastructure for each partner. The websites use Djangoplicity, an astronomical digital asset management system based on the Django Web Framework, which is also used for websites such as The International Year of Astronomy 2009 (Russo et al. 2008).

2.5 Evaluation Framework

Based on the EU-UNAWE programme's background information and the educators' input, initial concepts were produced to develop a coherent evaluation framework across the EU-UNAWE programme. These were discussed by the EU-UNAWE team and the following list of actions and concepts to be introduced was agreed upon, in preparation for the final Evaluation Framework:

1. Stimulate via images, playful activities, experiments, and models children´s awareness of the sun, the moon, the Earth as a planet and their related phenomena (day and night, tides, eclipses, and seasons), other planets, the stars in our galaxy, other galaxies, and their clusters and be-

yond. In doing so, try to use household materials in the activities, experiments, and models so that children can reproduce them at home.
2. Stimulate children giving them time and the occasion to formulate their own questions and to broaden their view of the “world” while delivering the program.
3. Create occasions for direct observations of the sun, moon, stars, and planets, taking into account school breaks, timelines, excursions, and project days.
4. Motivate children to appreciate other cultures (via stories and Skype conversations with children living in other countries), making them aware of the place in which other children live, their common cultural features, and differences.

These initial concepts suggested a framework is appropriate for EU-UNAWE evaluation that covers a range of learning domains linked to cognitive objectives, which are respectively as follows:

1. Astronomy awareness (knowledge)
2. Curiosity
3. Observation skills
4. Motivation and engagement
5. Global cultural respect

The final EU-UNAWE framework (Kimble et al., 2013) was based on the US Informal Science Education framework (National Science Foundation, 2008), Earthsmarts’ Conceptual framework (Nichols, 2012), and Generic Learning Outcomes (Museums, Libraries and Archives, 2008).

Using these models as a basis, the domains of learning were defined. Corresponding evidence was identified before methodologies and draft materials were produced for comment. These included pre- and post-visit activities appropriate for different age groups using a drawing methodology derived from Personal Meaning Mapping (Falk and Dierking, 2000). For younger children, a behaviour observation template was outlined using methodology derived from Barriault and Pearson’s work on behaviour analysis (2010). Moreover, EU-UNAWE produced surveys for children and teachers as well as a data collection process outline and template letters for teachers and parents. Ethical conduct codes were followed in the consent letter production for participation and visual evidence, such as photos or videos.

The EU-UNAWE framework encompasses both formative and summative evaluation. Summative evaluation is characterised as assessment of learning while formative evaluation is assessment for learning. Each national EU-UNAWE team undertook formative evaluation appropriate to their capacity and resources, in order to develop the optimum programme for their country. The national programmes used teacher questionnaires as a methodology to collect data. Data shows evidence of the summative programme impact, and therefore, these areas will be highlighted in this chapter, which focuses on summative evaluation.

Table 3. EU-UNAWE Evaluation Framework

EU-UNAWE Cognitive Objectives		**Evidence**
Motivation	Enjoyment Inspiration Curiosity Tenacity	Children are performing the tasks with pleasure Children seem enchanted Children react with diligence towards the proposed activities Children demonstrate attention Children apply perseverance/tenacity Children manifest inquisitiveness Children introduce some complex questions

Scientific Skills	Develop scientific skills, for example: • Develop Scientific Thinking and Problem Solving Techniques; Planning and Conducting Investigations • Observation, Identification, Classification, Making interconnections, Changing Perspective and Communication • Discussing and Questioning • Ask questions that can be answered through an investigation • Use scientific language regularly in discussions • Planning • Plan and carry out tests to collect evidence • Select information from a range of resources • Observing • Decide what observations must be made • Select appropriate equipment for observation or measuring results • Interpreting • Draw conclusions linked to scientific knowledge and understanding • Recognise patterns and trends based on the observation or investigation • Ideas and Evidence • Recognise that scientific ideas are based on evidence which can be verified by observations • Use the imagination together with scientific knowledge to understand and think about why something happens • Recording • Decide on an appropriate recording method • Present results using tables, graphs, and pictures • Evaluation • Review the work and reflect on the results	• Correct use of vocabulary or gestures to name objects and phenomena observed in the sky • Grouping objects/phenomena to indicate developing understanding of astronomy concepts • Making conjectures available to be contrasted • Developing some experiences related to the hypothesis • Linking new information with existing conceptions of the same or different areas • Removing previous points of view according to new inputs • Sharing with others their new knowledge

Universe Knowledge	Knowledge & Understanding Observing, exploring and discovering: • The Sun, its relative position, sunlight (shadows), day/night cycle, time zones, the seasons, the Moon, the Earth as a planet, awareness of how water, the Earth's atmosphere and sunlight are needed for the development of life on Earth, solar and lunar eclipses, etc. • The Solar system: planet characteristics and movements, dwarf planets, asteroids, comets, etc. • Stars in the night sky, constellations, orientation, life-cycle of stars, formation of stars and planets, etc. • Our place in the Milky Way, family of galaxies, etc. • Current developments in astronomy • Magnetic fields (compass, northern lights, etc.)	Direct observation and/or recording of naming, first explanations, discussing, drawing, construction, creative responses, movements, and dances, etc. to demonstrate knowledge of one of the features listed in the left column.
Intercultural Attitudes	• Valuing different cultural perspectives • Recognising different physical perspectives • Positive attitude towards astronomy • Valuing inclusive education • Working individually and in teams	• Demonstrating awareness of different cultures • Ability to observe and explain differences in phenomena in different countries • Statements of future activity with regards to astronomy • Acting appropriately in a frame of diversity

The EU-UNAWE evaluation framework was developed to meet the needs of a 3-year programme. A longitudinal evaluation would be needed in order to assess the long-term impact for pupils who have participated in UNAWE activities. Methodology and capacity to carry out such in-depth future research would be beneficial to the astronomy education field.

3. Implementation of the EU-UNAWE Programme

3.1 Teacher & Pupil Engagement

EU Universe Awareness is, first and foremost, an educational programme for children and educators aimed at inspiring young children from every corner of the world to take an interest in science and technology and develop a sense of global citizenship. Throughout the project's duration (2011-2013), several-thousands of children and educators were engaged in EU-UNAWE related activities, from teacher training to direct activities with children. Table 4 provides an overview of the numbers reached by the project in the 6 participating countries as well as the list of the organisations and personnel involved.

Table 4. EU-UNAWE project overview and impact numbers.

	Italy	**Germany**	**The Nether-lands**	**United King-dom**	**Spain**	**South Africa**	**Total**
Institu-tion	INAF - Arcetri Astrophysi-cal Obser-vatory	Haus der astrono-mie / Uni-versity of Heidel-berg	Leiden University	Ar-magh Obser-vatory and Plane-tarium	Universitat Politecnica de Catalu-nya	National Rese-arch Foun-dation – South African Astro-nomical Obser-vatory	
Coordi-nator	Franco Pacini and Filippo Mannucci	Andreas Quirren-bach	George Miley	Mark E. Bailey	Rosa Ros and Jaime Fabregat	Sivuyile Manxoyi	
National Project mana-gers	Alessandra Zanazzi and Lara Albanese	Natalie Fi-scher and Cecilia Scorza	Wouter Schrier and Erik Arends	Libby McKe-arney	Eloi Arisa and Ale-xandra Stavinschi	Troshini Naidoo	
Num-ber of teachers trained	393	348	487	328	286	531	2372
Num-ber of children reached	11 217	11 253	15 652	26 872	10 950	5 984	81 892

3.2 Communication

The EU-UNAWE websites comprised the programme's main communication tool. Each national project had national websites consisting of both national organisation websites and national resources websites. The websites contained information about the programme with news and educational resources in the national language.

Table 5. EU-UNAWE communication tools overview, including social media, as of 31 December 2013.

Communication tool	Impact Numbers
Facebook	1 960 followers
Twitter UNAWE	4 155 followers
Twitter UNAWE_NL	103 followers
Google +	150 followers
Flickr	1 700 pictures published
SlideShare	128 presentations (UNAWE account was one of the top 2% most-viewed SlideShare accounts in 2013)
ISSU	108 documents
International mailing list	1 609 subscribers

Table 6. Statistics for EU-UNAWE websites from 1 January 2011 to 31 December 2013

Website	Website	Number of Visitors	Unique Visitors	Page views	Pages/ Visit	% new visits (%)
International	www.eu-unawe.org	179 915	121 271	500 289	2.78	67.40
Germany	http://de.eu-unawe.org	2 805	1 576	9 070	3.23	55.61
Spain	http://ed.eu-unawe.org	18 643	14 400	52 767	2.83	77.12
Italy	http://it.eu-unawe.org	4 499	3 260	15 116	3.36	72.10
The Netherlands	http://nl.eu-unawe.org	13 763	9 780	31 475	2.29	70.78
The UK	http://uk.eu-unawe.org	3 189	2 407	7 399	2.32	75.07
South Africa	http://za.eu-unawe.org	1 237	705	3 660	2.96	56.75
Total		224 051	152 799	616 482		

3.3 Educational Resources

Educational resources developed in the context of the UNAWE project were collected and published on the project websites. Many UNAWE network members contributed translations, which were also made available on the sites.

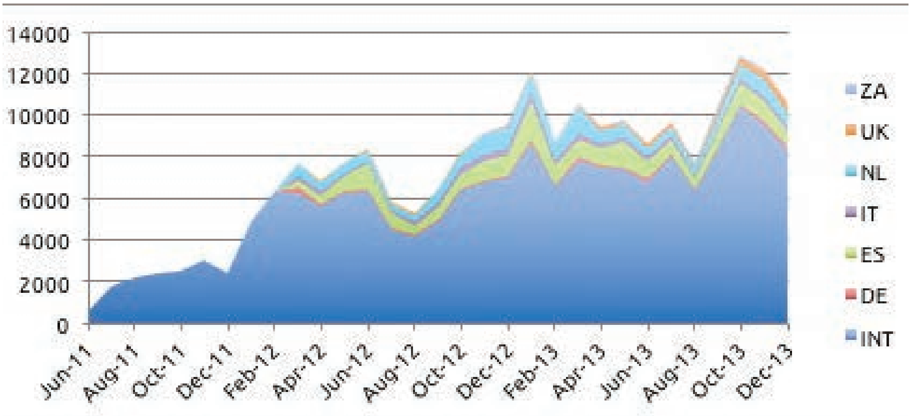

Figure 2. EU-NAWE Websites Statistics Overview: Cumulative number of visitors of different EU-UNAWE websites from January 2011 to December 2013.

The resources were checked for scientific accuracy by qualified astronomers and for pedagogical quality by experienced educators. Four of the educational activities were peer-reviewed through the IAU astroEDU platform (Chapter III.1). Table 7 presents an overview of the different resources pro
duced during the EU-UNAWE programme as well as additional information about the impact and distribution.

Table 7. Overview of the different resources produced during the EU-UNAWE programme.

Resource	**Type**	**Target**	**Domain of Learning**	**Impact**	**Additional Information**
Earth Ball and handbook	Physical Resource (Handbook also available in PDF)	Children and Educators	Motivation, Scientific Skills, Knowledge, and Intercultural awareness	7 000 distributed	
Universe in a Box	Physical Educational Kit(Handbook also available in PDF)	Educators	Motivation, Scientific Skills, Knowledge, and Intercultural awareness	750 distributed	Discussed in Chapter III.2
Space Scoop	Astronomy news articles (digital)	Children	Scientific Skills and Knowledge	255 Space Scoops in 28 languages	www.unawe.org/kids/

Levitating Astronaut	Digital Peer-reviewed resource	Educators	Scientific Skills and Knowledge	Available in English	Roberts, S., 2014, *Levitating Astronaut*, astroEDU, 1407, doi:10.14586/astroedu.1407
Model of a Black Hole	Digital Peer-reviewed resource	Educators	Scientific Skills and Knowledge	Available in English	Turner, M., 2013, *Model of a Black Hole*, astroEDU, 1304, doi:10.14586/astroedu.1304
Lunar Landscape	Digital Peer-reviewed resource	Educators	Scientific Skills and Knowledge	Available in English	Ramchandani, J., 2013, *Lunar Landscape*, astroEDU, 1311, doi:10.14586/astroedu.1311
Deadly Moons	Digital Peer-reviewed resource	Educators	Scientific Skills and Knowledge	Available in English	Kelleghan, D., 2014, *Deadly Moons*, astroEDU, 1404, doi:10.14586/astroedu.1404
Kamishibai – Stella & Giotto	Physical educational kit (also available digitally in PDF and iBook)	Children	Motivation, Scientific Skills, Knowledge and Intercultural awareness	Available in Italian, English and Dutch	https://itunes.apple.com/nz/book/stella-giotto-
Cosmos in Your Pocket	Activity book (also available in PDF)	Children	Motivation, Scientific Skills, and Knowledge	20 000 distributed in 17 languages	www.unawe.org/updates/unawe-update-1367/
UNAWE Booklet Collection	7 Activity and Storytelling books (also available in PDF)	Children and Educators	Motivation, Scientific Skills, Knowledge, and Intercultural awareness	Available in 5 languages	http://es.unawe.org/resources/books/

The Invisible Universe	Activity book about radioastro-nomy	Children	Motivation, Scienti-fic Skills, Knowledge, and Intercul-tural	Availa-ble in English and Dutch	www.unawe.org/resources/education/Radioastro-nomy_activi-ty_booklet/
Into a Black Hole	Digital educatio-nal book (iBook)	Children	Motivation, Scientific Skills, and Knowledge	Availa-ble in English	https://itunes.apple.com/us/book/into-
Astrono-mers vs. Kids	Set of educational videos with Nobel Prize Winner Bri-an Schmidt	Children	Motivation, Scientific Skills, and Knowledge	Availa-ble in English with Dutch sub-titles. More than 1500 plays	www.unawe.org/updates/unawe-up-date-1322/
The Dre-amgazer	Educational Video pro-duced by children	Children	Motivation, Scientific Skills, and Knowledge	Availa-ble in Dutch with English subtit-les.	www.unawe.org/updates/unawe-up-date-1362/

EU-UNAWE Human Orrery	Physical educational installation	Children	Motivation, Scientific Skills, and Knowledge	Implemented in King's School in Peterborough (UK), Christ the Redeemer Primary School (UK) in Belfast, and Eureka High School, Kathmandu (Nepal)	http://www.unawe.org/static/archives/presentations/pdf/2012workshop_baileyi_human_orrery.pdf

3.4 Case Study: Space Scoop

An innovative resource developed in the course of the project was "Space Scoop", a news service for older children. The idea behind Space Scoop is to change the way science is often perceived by children as an out-dated and dull subject (Allodi, 2002). By sharing exciting new astronomical discoveries with them, we can inspire children to develop an interest in science and technology. Space Scoops are short news articles about astronomical discoveries written in a child-friendly language and accompanied by a stunning astronomical image. Space Scoop is a wonderful tool that can be used in many different settings to teach, share, and discuss the latest astronomy news.

The main educational goals of Space Scoop are as follows:

- Share the excitement of new discoveries with children.
- Show that there is still potential for contributions in the area.
- Enhance understanding of the world and encourage critical thinking.
- Broaden children's minds and cultivate world citizens.

Each Space Scoop begins with a new discovery or observation in the field of astronomy and space science. Partner organisations (e.g., ESO[03], NAOJ[04], ESA[05], NASA[06]) then prepare a press release which undergoes a critical science check before being sent to us where the release is translated into a

[03] ESO – European Southern Observatory

[04] NAOJ – National Astronomical Observatory of Japan

[05] ESA- European Space Agency

[06] NASA – National Aeronautics and Space Administration

child-friendly language. Similarly, Space Scoop undergoes an internal educational review to assure the highest quality. The final texts are then sent to our group of volunteer translators from all over the globe, where they are translated into 33 different languages. Finally, the Space Scoops are released to the public at the same time as the original press release to ensure that kids, much like adults, can keep up-to-date with the latest discoveries.

Space Scoop is a versatile resource which can be adapted to many different formats and digested by many audiences, including various age groups, the visually-impaired, illiterate, those without internet access, etc. Space Scoop is already being used by children, teachers, astronomers, museums, and more (see table 8). Some examples include *Anorak*[07], a children's magazine, and *Timbuktu*[08], an interactive digital magazine for children, American Association for the Advancement of Science, "Eurekalert!", a global news service featuring each Space Scoop in their "News Reporting for Kids" section[09], Goa's *Nahvind Times*[10], Dutch science magazine, *Universum*, *Wired.com,* the popular Indonesian website, "Langitselatan," *National Geographic Indonesia*, and the Slovenian magazine and website, *Portal v Vesolje*. Additionally, the Space Scoop article, "The Universe is Big, Beautiful...and Mostly Invisible," has been featured in an official South African textbook (Spring 2013) which is used in primary schools all over the country, reflecting the quality of Space Scoop in terms of both scientific and educational content. Space Scoop content is also used in the Cambridge University Press English Language Book, *IGCSE English as a Second Language*[11].

Today, for most parts of the world, digital media is exceedingly accessible, able to reach a mainstream audience of the tech-savvy young generation (Rosen 2010), and if presented correctly, this format can attract even more readers. In response to this demand, a Space Scoop app[12] has been created for Android mobile devices. Space Scoop can also be used as the basis for educational activities. Space Scoop Storytelling uses the articles as the basis for a creative cross-curricula activity that touches on astronomy, literature, presentation skills, and more.

Table 8. Space Scoop Impact Numbers from March 2011 to November 2013.

Number of Space Scoops published	196
Languages in which Space Scoops are available	22
Number of Space Scoops translated	2108
Number of Space Scoop Partners	10

[07] www.anorakmagazine.com
[08] www.timbuktu.me
[09] www.eurekalert.org/kidsnews/
[10] www.navhindtimes.in
[11] http://www.amazon.com/Cambridge-IGCSE-English-Second-Language/dp/1444191624
[12] The app can be downloaded here: https://play.google.com/store/apps/details?id=com.gdogaru.spacescoop

Page views on UNAWE website	100,000 (80% unique page views)

3.5 Case Study: Innovation in Teacher Training: *Universe in the Classroom*

During the school year of 2009-2010, Universal Awareness (UNAWE) organized and coordinated a pilot project in teacher training called duo internships. During these internships, aspiring primary-school teachers and astronomy university students were coupled to develop astronomy lessons and to implement those lessons at primary schools. Throughout this pilot, 16 duos participated in activities at primary schools in Groningen, Arnhem, Den Haag and Utrecht (the Netherlands). The combination of an astronomy student and an aspiring teacher guarantees quality both ways, astronomy lessons were both scientifically correct and pedagogically sound. Interns learned from each other: Astronomy students learned how to explain science with more comprehensive words, while aspiring teachers experienced young children's fascination with science in addition to learning how to make science accessible via approachable, hands-on exercises. As a follow-up to this pilot activity, in 2014 astronomy students from Leiden University paired up with trainee teachers from the teacher training school *Hogeschool Inholland* (Rotterdam) in a project designed to introduce the Universe to children in three primary schools in the second-to-largest city in the Netherlands, Rotterdam. Each student pair developed educational astronomy materials and gave their own classes. Similar to previous results, this scheme allowed children to learn about astronomy, as well as both students within a pair to learn from each other. The trainee teachers learned about astronomy and science in general, and the astronomy students gained experience in how to communicate science to young children and explain difficult concepts in simple terms.

3.6 International Workshops

EU Universe Awareness International Workshops have provided educators, teachers, astronomers and members of the UNAWE network with an opportunity to come together and share ideas, techniques, and resources developed by the programme. The first EU-UNAWE International Workshop was held at Leiden University, the Netherlands, in March 2012, drawing participants from 28 countries. In October 2013, the second EU-UNAWE International Workshop took place at the *Haus der Astronomie* in Heidelberg, Germany, and the number of participating countries rose to 40 with a total of 60 participants.

One goal of the workshops was to consolidate existing EU-UNAWE astronomy education and communication resources for very young children. Participants also discussed, in depth, the role of astronomy and space science in early childhood development, curricula development, culture in astronomy education, global capacity building and evaluating the long-term effectiveness of exposing very young children to inspirational and motivational astronomy activities. During the discussions, a number of action points arose which the EU-UNAWE international network then endeavoured to implement. On the topic of curricula for different ages, it was found that teachers need guidelines for suitable topics to introduce into their classroom, but these should take into consideration the different ages that children start school around the world. Furthermore, children in remote villages do not have the same resources at home to follow-up with classroom topics as children in cities. It was proposed that guidelines for suitable topics should be provided in stages or levels, rather than associated to a specific age group, with recommendations for what stages should be used that are based on, for example, the school's location.

Workshop members recognised the need for an online platform to act as a central hub for the many educational materials that are available around the world, which EU-UNAWE began to implement through the repository on its website, and developed further with IAU astroEDU. Another important topic for the international UANWE network is culture in astronomy education and the need to collect high quality materials about the connection between culture and astronomy as it is currently difficult to find such resources. During the workshops, it was noted that the programme must work to fill available material gaps as many stories about astronomy in indigenous cultures have not yet been recorded in a written format. The international workshops are an essential platform to build the UNAWE community, and the current plan is to organise a workshop every two or three years.

3.7 Exchange Programmes Case Studies

Exchange Activities within EU-UNAWE. An important benefit of the Universe Awareness network is the ability of educators in different countries to exchange experiences and learn from each other. This was stimulated in the EU-UNAWE project through several physical international exchanges of team members. EU-UNAWE Italy participated in two exchange activities with other partners. In January 2012, they were invited to Northern Ireland to take part in the BBC's annual Stargazing LIVE event. EU-UNAWE Italy performed their shadow theatre show, "Galileo Galilei: a sky full of discoveries" and other science activities for about 150 children from four different schools (http://uk.unawe.org/updates/UKEvents/).

From July 30 to August 7, 2012, the Italian team joined EU-UNAWE South Africa during the country's National Science Week. Together they visited five schools located in disadvantaged areas of Cape Town and two schools in Sutherland. At a planetarium, children enjoyed hands-on workshops. The events also offered teacher-training sessions, which included a Skype connection with Italian teachers, allowing participants to exchange experiences and ideas. (http://www.unawe.org/updates/unawe-update-1260/).

The South African Skype programme's success prompted EU-UNAWE Italy to arrange similar events for schoolchildren. During the Skype calls that followed, students not only exchanged results from their scientific investigations and lessons, but songs and stories about the night sky as well.

Skype Exchange Programmes. In the summer of 2013, the EU-UNAWE programmes of South Africa and the Netherlands joined together to organise a collective project with primary school students in Buffalo City (South Africa) and Leiden (the Netherlands). The project challenged students to observe the Moon for a full month, from 21 May till 21 June, to learn about the seasons and the lunar phases. By comparing their observations, the children discovered some important differences between the Northern and Southern Hemispheres. For example, they noticed that the Moon appears "upside down" to the other half of the world and that the seasons appeared at different times in different countries.

3.8 Outreach to Policy-makers

Lobbying within the EU Parliament is an additional but important activity that has been employed to increase the impact of EU-UNAWE on policymakers. Not only do such activities contribute to the visibility of EU-UNAWE, but they are also important for demonstrating the social and political relevance of the European astronomy programme and the long-term sustainability of pan-European astronomy education programmes. Throughout the EU-UNAWE programme several activities at the European Parliament were implemented alongside added support from additional Members of the European Parliament.

Table 9. EU-UNAWE impact with parliamentarians

Event/Activity	Date	Parliamentarians Engaged	EU-UNAWE Participation
Science and Technology Options Assessment Workshop: *Importance of astronomy* (EU Parliament)	24 May 2011	T. Riera Madurell, MEP S. Tatarella, MEP	Invited Talk G. K. Miley Invited Organisation G. K. Miley, P. Russo
EU Universe Awareness Workshop (Leiden University)	26 March 2012	G. Mitchell, MEP T Riera, Madurell MEP, E. Ngcobo MP, Chair, South African Parl. Comm. on Science and Technology B.J. van Bochove, Chair, Netherlands Parl. Comm. for Education, Culture and Science	Organisation G. K. Miley, P. Russo Talk G. K. Miley
Science For Global Development: Astronomy– A Case Study	6 March 2012	W. Newton Dunn, MEP	Invited Convenor and talk G.K. Miley Report in Plenary Session in presence of Irish Taoiseach G. K. Miley

Parliamentary questions to Commission urging EU-UNAWE continuation	15 May 2013	A. Smyth MEP EN E-002852/2013 EN E-002853/2013 Available on European Parliament website: http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+W-	Lobbying
Additional pledges of support	March 2013	L. Aylward MEP T. Berman MEP J. Evans MEP M. Harbour MEP F. Kaczmarek MEP V. Prodi MEP	Lobbying

A conclusion that we draw from EU-UNAWE lobbying activities is that programmes, such as EU-UNAWE, which provide a bridge between scientific research, society, and education, are attractive to policymakers. They are therefore a cost-effective way of demonstrating the social relevance of astronomy and space sciences

4. Evaluation

In order to investigate impact, different methodologies based on quantitative and qualitative methods have been used. Teacher surveys have been used to gather evidence about the impact of teacher workshops. These have used both closed questions (i.e. quantitative data) and open-ended responses (qualitative data, which has been coded). In-depth qualitative methods have been used in case studies to gather video evidence of teachers and pupils. Case studies will be presented and sorted by the EU-UNAWE evaluation framework's cognitive skills.

4.1 Motivation

The domain of motivation refers to the following objectives: enjoyment, inspiration, curiosity and tenacity. The type of evidence that would be acceptable for this domain comes from teachers who experienced a positive association with Astronomy workshops and children behaviour:

- Children are completing the tasks with pleasure
- Children are engaged in the activity
- Children react with diligence towards the proposed activities
- Children demonstrate attention
- Children apply perseverance/tenacity
- Children manifest inquisitiveness
- Children introduce some complex questions

Motivation Case Study: Evaluation with children at Circolo didattico di Zafferana school in Etnea, Italy. Children were asked to write essays after taking part in UNAWE activities for 2 weeks. The EU UNAWE Italy National project managers had ensured that content was linked to a topic the children were already studying in class; thus, the Year 2 children received constellation stories linked to American Indians. The Year 3 children had narratives tying in with Ulysses. Planning to respect the existing curriculum units makes it more likely that activities will be used again. Following the activities, children were asked to write freely about the night sky and its mythologies and phenomena. Using an observation paradigm, recorded children's responses to a variety of activities include the following:

• Children are performing the tasks with pleasure, writing spontaneity texts and drawing.

• Children react with diligence towards the proposed activities, and they write texts longer than requested or write more essays than expected.

• Children introduce some complex questions. Many of the texts relate to lives of stars and the existence of extra-terrestrial life.

Motivation: Evaluation of teachers training workshop at House of Astronomy, Heidelberg, 2012. The teacher survey, carried out after a teacher training session with 78 teachers presents evidence that teachers had positive associations with parts of the course. The workshop facilitators, (EU-UNAWE Germany

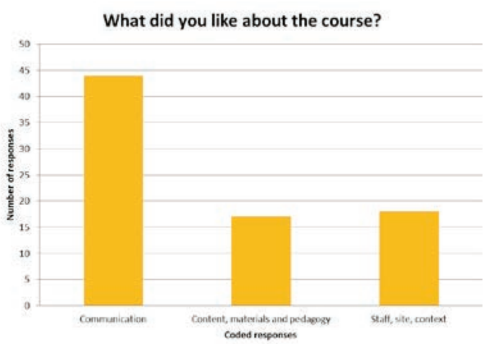

Figure 3. Overall results of teachers training workshop at House of Astronomy, Heidelberg, 2012

National Project Managers), were particularly highly regarded due to their enthusiastic presentation skills.

4.2 Scientific Skills

The Scientific Skills domain refers to developing scientific thinking and problem solving techniques such as observation, identification, classification, making interconnections, changing perspective, and communication. Evidence for this domain has been gathered from teachers in the form of self-report in questionnaires, teacher training workshop observations using video, and teacher interviews. Evidence has been gathered from children in the form of discussion and group tasks and class observation following teachers attending training workshops.

The types of evidence that would demonstrate scientific skill development are as follows:

- Correct use of vocabulary or gestures to name objects and phenomena observed in the sky
- Grouping objects/phenomena to indicate developing understanding of astronomy concepts
- Making conjectures available to be contrasted
- Developing some experiences related to the hypothesis
- Linking new information with existing concepts of the same or different areas
- Removing previous points of view according to new inputs
- Sharing with others their new knowledge

Scientific Skills: Evaluation of children at Brownhall Primary School in Dumfries, Scotland, 2013

Teachers who attended the teacher-training workshop in Dumfries were contacted and asked permission to visit their classroom and observe a session related to the workshop content. One teacher was selected for a visit two weeks after the teacher-training workshop. Parental consent forms were distributed and collected for permission. The session was recorded, and children were interviewed using a semi-structured interview technique which covered the EU-UNAWE domain framework: motivation, skills, knowledge, intercultural awareness, and legacy. A class from Brownhall Primary School in Dumfries was observed taking part in an activity inspired by the workshop (Figure 4).

4.3 Astronomy Knowledge

EU-UNAWE programmes aimed to develop teacher and pupil knowledge about astronomy through observing, exploring, and discovering:

- The Sun, its relative position, sunlight (shadows), day/night cycle, time zones, the seasons, the Moon, the Earth as a planet, aware-

Figure 4. The Nine-year-old student at Brownhall Primary School demonstrating communication skills through explaining why people in different countries are awake at different times. He turns the earth in the correct direction, holding out his left hand to represent the sun shining on different countries at different times. He identified where Dumfries is located and referred to the Pole star, which is fixed to the classroom wall. This interview provides evidence for cognitive skills, including knowledge and intercultural awareness, although scientific communication skills comprise the main focus.

ness of water, the Earth's atmosphere, and sunlight's roles in the development of life on Earth, solar and lunar eclipses, etc.
- The Solar System: planet characteristics and movements, dwarf planets, asteroids, comets, etc.
- The Stars in the night sky, the constellations, orientation, the life-cycle of stars, the formation of stars and planets, etc.
- Our place in the Milky Way, family of galaxies, etc.
- Current developments in astronomy
- Magnetic fields (compass, northern lights, etc.)

Knowledge: EU-UNAWE Teacher Training Workshop in Barcelona, Spain. The evaluation (Figure 5) of the EU-UNAWE teacher training workshop was used to demonstrate improvement; clearly the effectiveness of workshops improved in response to teacher comment (N=33) , and 88% of teachers consider that they learnt new content.

4.4 Intercultural Awareness

The domain of intercultural awareness was defined by development in being able to value different cultural perspectives, recognising different physical perspectives, and valuing inclusive education. Children must be able to work individually and in teams. Teacher self-report and workshop observation have

Figure 4. Results of the content evaluation of the workshop.

allowed data collection for this aspect. For children, evidence can be seen in the form of:

- Demonstrating awareness of different cultures
- Ability to observe and explain differences in phenomena in different countries
- Statements of future activity with regards to astronomy
- Act in an appropriate way in a frame of diversity

Intercultural Awareness: Evidence of children's participation. A number of links have been and continue to be facilitated through Skype and connections made possible by the EU-UNAWE programme. The video available at http://vimeo.com/52849722 shows children from Nompumelolo Primary in East London, South Africa, interacting with children from Morskring Primary in Leiden, The Netherlands. The project was conducted for one month, focusing on moon phases and seasons. Learners observed the different moon phases from the 21st of May to the 21st of June. During this month, the learners watched the night skies and recorded their observations on a moon calendar. This information was reinforced through various activities about the moon in

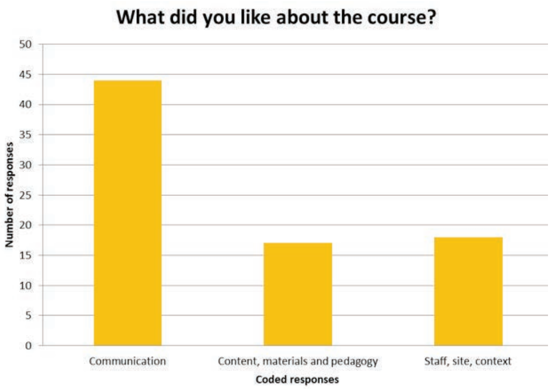

Figure 6. Intercultural awareness results from activity between EU-UNAWE Italy and South Africa.

the classroom. The learners made moon phase flipbooks illustrating moon craters and their weight on the moon.

Intercultural Awareness: Activity between EU-UNAWE Italy and South Africa. Italian EU-UNAWE National Project Managers travelled to South Africa during Science Week 2012 (July- August). They organised activities at 5 schools, seeing approx. 600 pupils and 20 educators. South African astronomer, Shazrene Mohamed, offered a discussion session with pupils to initiate interest in the topic. Pupils then saw a planetarium show (the first time they had seen this). Italian teachers used puppets to enhance student understanding of the constellations Orion, Crux, and Scorpio. A live link took place between South African teachers and Zafferana Etnea school in Sicily, Italy. Teachers were surveyed regarding children's ability following the exchange, and the teacher reports evidence that learners developed cultural awareness (figure 6).

The direct exchange projects are in addition to teaching which explicitly shares different cultural approaches to, for example, explaining the seasons. The project resources, which encourage appreciation of narrative in early astronomy experience, have been produced and translated, such as the Earth Ball and activity book.

4.5 Legacy
Legacy refers to the continued programme impact beyond its completion in December 2013. For teachers, this includes embedding astronomy learning from UNAWE into the curriculum and continuing to teach using resources from EU-UNAWE. They may share their knowledge with other teachers in school-based continuing professional development courses and change long-term planning. For children, this includes their aspirations for studying astronomy and assimilation of learning as outlined in the domains listed above. In addition to the legacy in terms of teacher and pupil learning, what are the long-term benefits of this programme? This was assessed through asking teachers and pupils about their long-term intentions regarding astronomy and what they had learnt through participating in EU UNAWE programmes.

Legacy: Evaluation of United Kingdom teacher training in November 2011. In a survey of 48 teachers, teachers were asked to state what they would do following the teacher-training workshop. The results were generally positive, e.g. the following examples:

Initial Action Plan – As a result of this training I will: "*Endeavour to deliver the programme to my own P6 class within our World Around Us planning/teaching. Disseminate today's programme to my other 3-year group colleagues in P6 and possibly to the P7 year group. Explore resources indicated to us today and try to secure funding for those requiring purchases.*"

Follow up: Have you ever had a chance to talk to your colleagues about EU-UNAWE to disseminate what you have learned? "*I disseminated some of the materials at a staff meeting. I have also incorporated the materials into a* *unit called Razzle Dazzle – all based on light, planets, constellations etc. and have shared it with two colleagues from other schools who have also used it.*"

Another teacher in Scotland at the senior management level stated the intention to build the materials into existing astronomy curriculum areas. She said, "We are aiming to develop experiences and outcomes (Scottish curriculum Es and Os) which will take learning from the primary curriculum into the secondary curriculum in biology, chemistry, and physics."

It is therefore recommended that teachers attend the workshop in pairs if possible, with one teacher a junior, enthusiastic member of staff, and the other being a more advanced member of staff from the same institution. In this way, the desire to take on ideas will be facilitated by the ability to overcome bureaucratic barriers which may arise. In addition, it would be helpful to ask teachers to bring copies of the short, medium, and long-term planning so that they can share and pinpoint exactly where the opportunities for modification of existing plans are. This will also help highlight any paucity in potential for change, which needs to be addressed institutionally.

4.6 Discussion

The EU-UNAWE project was assessed using the evaluation framework, according to 5 domains, as described above. However, this framework was devised during the project lifetime, and it would be beneficial to move on from this programme by using the existing framework as a starting point for future projects. Its goals are clear, and the literature supports the fact that it is an ambitious task to bring together different learning approaches and philosophies under one common framework. In reality, local adaptation has been the solution to allow assimilation of evidence coherently, despite different philosophies.

This section will return to the original operational objectives and show where existing activities and resources meet the initial objectives of EU-UNAWE. Examples are drawn from both national programmes and the wider international network, which has expanded throughout the programme timescale.

Table 10. Overview of evaluation numbers for the operational objectives.

Operational Objectives	**Evaluation Numbers & Additional Information**
Train and empower primary school teachers in 6 countries to include astronomy and space topics in the classroom	Number of teacher trained: 2 373
Develop and translate hands-on material, where appropriate, emphasising EU and SA science and technology	Number of Resources produced and distributed: > 11 000 (see table 7)

Provide a network for exchange of expertise and material between educators - Lay the groundwork for expansion of the programme throughout the EU, Associated Countries and ICP Countries.	Number of Universe Awareness National Nodes: 61 National Programmes, mainly from EU, Associated and ICP countries. Complete list available here: http://www.unawe.org/network/national/
Act as a showcase for EU and SA astronomy/space and related technologies, by disseminating the products among very young children, their teachers, and families.	Number of exchange activities between EU and South Africa: 2 Space Scoop news service is unique in providing information about innovations in astronomy and space, which are suitable for children aged 8 and above, their teachers, and families both in Europe and South Africa.
Use astronomy/space products to stimulate awareness and strengthen public support for EU and SA space science research and technology.	Number of activities engaging general public: 15 Whilst the focus of this evaluation has been on teachers and children, members of the public have also seen UNAWE resources at some festivals attended by the EU-UNAWE during the project lifetime. For example: • EU Festival of Europe, Brussels, Belgium http://www.festivaldeuropa.eu/en • "The Dreamgazer" children's astronomy story film premiered at a Leiden Film Festival, The Netherlands http://www.nachtvankunstenkennis.nl/ • Festival Nauke, Belgrade http://www.festivalnauke.org/ • SciFest, South Africa http://www.scifest.org.za/ • BBC Stargazing live http://www.bbc.co.uk/programmes/b019h4g8

Stimulate the next generation of EU and SA engineers and scientists, particularly girls.	Number of activities targeted to girls: 10 EU-UNAWE activities have contributed to some specific initiatives to inspire girls to study science and engineering at advanced levels, such as Green Light for Girls http://greenlightforgirls.org/. EU-UNAWE took part in an event in Brussels, Belgium in October 2012, where 300 girls participated in interactive workshops and the UNAWE activity: designing an alien life form.
Contribute to the integration of disadvantaged communities in participating countries.	Number of activities engaging disadvantaged communities: 33 It is clear that there is an aspiration to work with disadvantaged communities, both within the partner countries and internationally. International outreach has focused on disadvantaged communities. For example: • Timor-Leste; see project report: http://www.unawe.org/static/archives/reports/pdf/TL_VT2012_project_EN.pdf • Spain (Universitat Politècnica de Catalunya - UPC) offered teacher training programmes and summer schools, which included specific training for pupils with special need • Northern Ireland initial project team meeting (2004) highlights the issues facing disadvantaged communities in their context.
Strengthen collaboration between EU and SA over mutually beneficial scientific, technological, educational, and social topics.	Number of exchange activities between EU and South Africa: 2 Additional links between schools in Leiden, The Netherlands, and East London, South Africa as described. South African pupils visited the House of Astronomy, Heidelberg, Germany

Provide significant added value for Europe's expenditure on astronomy and space sciences for a modest incremental cost.	Number of resources produced for all the EU-UNAWE consortium: 11 000 (mainly Earth balls and Universe in a Box kit)
Pooling complementary expertise and partner resources creates a project whose whole is greater than the sum of its parts.	Number of resources produced for all the EU-UNAWE consortium: 11 000 (mainly Earth balls and Universe in a Box kit)

As demonstrated above, the main goals of the EU-UNAWE project were accomplished. With support of the funding from the European Union more than 10 0000 of new inquiry-based learning educational resources and training of more than 2,300 teachers, reaching over 81 000 pupils through direct and indirect activities. Besides the accomplishments of the EU-UNAWE in training teachers and developing general educational resources, highlights of the projects were as follows:

- The development and distribution of 10,000 EU-UNAWE Earth balls
- The development and distribution of 1,000 Universe in a Box astronomy kits for primary school teachers
- The creation of Space Scoop: astronomy and space news for children
- UNAWE awarded the prestigious 2011 *Science Magazine* Science Prize for Online Resources in Education (Ödman-Govender & Kelleghan 2011).

The European Union's External Review Report states: *"The project has achieved all its objectives in an excellent way. In addition, there is a large number of spinoff activities initiated by the consortium that, although not mentioned in the Description of Work, are extremely relevant to the project. The teacher training part of the EUNAWE exceeded its quantitative goals by a wide margin. The project has resulted in a vast amount of educational resources on the web, organised in an excellent manner. Most of the educational output resources have been evaluated and tested in practice for suitability for the target groups (young children and their teachers). They can lay the foundation for deeper understanding of astronomy (and hence science in general), both through creating factual knowledge and the building of a conceptual framework. [...]The project has fully achieved its objectives and technical goals for the period or has even exceeded expectations.*"

4.7 Recommendations

Based on the experience of implementing and evaluating the EU-UNAWE project, we here present several recommendations that should be taken into account in designing future UNAWE activities as well as other similar science education activities for young students. It is recommended that:

- Teachers should be invited to teacher training workshops in pairs, ideally with one senior and one junior member of staff, in order to maximise the ability of each school to embed new materials at strategic and operational levels.

• Teachers should be asked to bring copies of their short, medium, and long-term planning to ensure that part of the day involves sharing with other schools where they can fit the new information into timetables. The purposes of this are twofold; the first is for the institution to realistically plan. The second is for comparison with other organisations to bring a flexible approach to considering other ways of organising the curriculum.

• Existing educational resources should be peer reviewed using IAU astroEDU (or similar) in order to assess and improve quality.

• The infrastructure, which has facilitated resource dissemination and translation, should continue.

• Science and Education Festivals are excellent formats for engendering public support.

• The development of a template for longitudinal evaluation is needed in order to assess the long-term impact of UNAWE. This is particularly important for evaluating the success in accomplishing the non-cognitive UNAWE goals, such as sustaining motivation, encouraging tolerance and respect and stimulating a sense of world citizenship.

• The preparation of a set of guidelines and instructions for setting up and testing Skype international video exchanges would be useful for interested schools.

• Produce resources for young children in their native languages.

• Experts in the professional evaluation of science education programmes should be included in the team from the start and provide input to the design of the project.

5. Legacy, Future, and Sustainability of Universe Awareness

After the EU-UNAWE project formally concluded in December 2013, several follow-up activities were carried out In the first half of 2014, a successful crowdfunding campaign was initiated to distribute the UNAWE Universe in a Box educational resource to educators throughout the world. In September 2014, a Creative Industries Grant from the Netherlands research funding agency, NWO, was acquired to develop video instruction lessons for some of the Universe in a Box activities and by January 2015 Space Scoop had published more than 555 news stories for children.

Furthermore in November 2014, the European Union awarded 2 million Euros in support of a follow-up project, EU Space Awareness (EUSPACE-AWE). This project that will use the excitement of space to attract young people to science and technology and stimulate European and global citizenship. EU-

SPACE-AWE will build on EU-Universe Awareness. The project will show children and teenagers the opportunities offered by space science and engineering and inspire primary-school children when their curiosity is high and their value systems are being formed. EUSPACE-AWE, a 3-year project, will start in March 2015 with 10 partner organisations and 15 network nodes in 17 European countries and global dissemination by the IAU Office of Astronomy for Development in South Africa. Activities will include teacher training, the development and distribution of educational resources, and a high-impact event for teachers and policymakers at the European Parliament. EUSPACE-AWE will exploit extensive European school networks and science museums to reach teachers, schools, and the general public and will work closely with the European Space Agency. Particular attention will be paid to stimulating interest amongst girls and ethnic minorities, reaching children in underprivileged communities where most talent is wasted. A special EUSPACE-AWE toolkit showcasing the history and accomplishments of Islamic science and technology will target children from the Turkish and North African migrant communities. In this chapter we have attempted to demonstrate the large potential societal benefits that can be provided by an educational programmes such as UNAWE, that exploit cutting edge research and researchers to inspire young children. The EUSPACE-AWE project will facilitate limited continuation of UNAWE activities for an additional three years. We suggest that the experience of EU-UNAWE shows that the provision of long-term structural funding for UNAWE and its infrastructure would be highly cost effective and of considerable benefit to society.

6. References

Abadzi, H., Martelli, M., Primativo, P. (2014). Explorations of Creativity: A review for educators and policy making, WISE Matters.

Allodi, M. W. (2002). *Children's experiences of school: narratives of Swedish children with and without learning difficulties*. Scandinavian Journal of Educational Research, 46(2), 181-205.

Arnold, C., Bartlett, K., Gowani, S., & Merali, R. (2007). *Is Everybody Ready? Readiness, Transition and Continuity: Reflections and Moving Forward*. Working Papers in Early Childhood Development, Number 41. Bernard van Leer Foundation. PO Box 82334, 2508 EH, The Hague, The Netherlands.

Arnold, D.H., Doctoroff, G.L., (2003), *The Early Education of Socioeconomically Disadvantaged Children,* Ann Rev. Psych. Vol. 54: 517-545

Bell, T., Urhahne, D., Schanze, S., and Ploetzner, R. (2010). *Collaborative inquiry learning: Models, tools, and challenges*. International Journal of Science Education. 3(1), 349-377.

Beilock, S.L., Gunderson, E.A., Ramirez G. and Levine, S.C. (2009). *Female teachers' math anxiety affects girls' math achievement*, Proc. US Academy of Sciences, 107, 1860 – 1863

Commonwealth of Australia,2009, *Belonging, Being and Becoming: the Early*

Years Learning Framework for Australia, ISBN 9780642778185

CORDIS (2015). *European Commission : CORDIS : Projects and Results : Periodic Report Summary 2 - EU-UNAWE (Building on the international year of astronomy: Making young children aware of the Universe)*. Retrieved 15 January 2015, from http://cordis.europa.eu/result/rcn/5368

Gopnik, A. (2012). *Scientific thinking in young children: Theoretical advances, empirical research, and policy implications*. Science, 337(6102), 1623-1627.

Heckman, J. J., Moon, S. H., Pinto, R., Savelyev, P. A., & Yavitz, A. (2010). *The rate of return to the HighScope Perry Preschool Program*. Journal of Public Economics, 94(1), 114-128. Chicago

Heckman, J.J. (2006). *Skill Formation and the Economics of Investing in Disadvantaged Children*. Science, Vol. 312.

Farah (2012). *Books Trim the Brain*. Retrieved 18 January 2015, from http://news.sciencemag.org/2012/10/books-trim-brain

Friedman, A. (Ed.). (2008). *Framework for Evaluating Impacts of Informal Science Education Projects* http://insci.org/resources/Eval_Framework.pdf

Falk, J. & Dierking, L. (2000). *Visitor Experiences and the Making of Meaning*. Altamira, UK

Kimble, G., Scorza, C, & Russo P. (2012). *EU Universe Awareness Programme Evaluation Guide*, ISBN 9789491760037

Liberman, N., Polack, O., Hameiri, B., & Blumenfeld, M. (2012). *Priming of spatial distance enhances children's creative performance*. Journal of experimental child psychology, 111(4), 663-670.

Nobes, Gavin, et al. "*Children's understanding of the earth in a multicultural community: mental models or fragments of knowledge?.*" Developmental Science 6.1 (2003): 72-85.

Museums, Libraries and Archives Council (2008). Generic Learning Outcomes. UK http://www.inspiringlearningforall.gov.uk/resources/

Nichols, B. H., & Zeidler, D. L. (2012). *Teaching earth smarts: A pragmatic, nonpartisan educational construct for socioecological literacy*. Presented at the Annual International Conference of the National Association for Research in Science Teaching, Indianapolis, IN.

Nobes, G., Moore, D. G., Martin, A. E., Clifford, B. R., Butterworth, G., Panagiotaki, G., & Siegal, M. (2003). *Children's understanding of the earth in a multicultural community: mental models or fragments of knowledge?*. Developmental Science, 6(1), 72-85.

OECD Report "Evolution of student interest in science & technology", Global Science Forum (2006) http://tinyurl.com/oecd2006report

Ödman-Govender, C. J., & Kelleghan, D. (2011). *Astronomical Perspectives for Young Children*. Science, 333(6046), 1106-1107.

Panagiotaki, G., Nobes, G., & Potton, A. (2009). *Mental models and other misconceptions in children's understanding of the earth*. Journal of Experimental Child Psychology, 104(1), 52-67.

Peacock, A. (1991). "Science in Primary Schools, The Multicultural Dimension", Routledge

Russo, P., Lindberg Christensen, L., & Shida, R. (2008). The International Year of Astronomy 2009 Websites - Connecting IYA2009 with its Community. In *Bulletin of the American Astronomical Society* (Vol. 40, p. 247).

Rocard M., 2007, *Science Education NOW*", European Commission, Directorate for Research (http://tinyurl.com/rocard-report

Ryan, K. & Cousins, J.B. (2009). The SAGE International Handbook of Educational Evaluation. SAGE, Chicago

Rosen, L. (2010). *Welcome to the iGeneration!.* Education Digest: Essential Readings Condensed for Quick Review, 75(8), 8-12.

Worth, K. & Grollman, S., US National Science Foundation (2003) ISBN 0-325-00573-7

Samarapungavan, A., Vosniadou, S., & Brewer, W. F. (1996). *Mental models of the earth, sun, and moon: Indian children's cosmologies. Cognitive development*, 11(4), 491-521.

Schweinhart, L. J., Montie, J., Xiang, Z., Barnett, W. S., Belfield, C. R., & Nores, M. (2005). *Lifetime effects: the High/Scope Perry Preschool study through age 40.*

Schweinhart, Montie, Xiang, Barnett, Belfield & Nores, (2005). The High/Scope Perry Preschool Study Through Age 40: Summary, Conclusions, and Frequently Asked Questions

Sjøberg & Schreiner (2010). The ROSE project: An overview and key findings

Trefil, J. (2008). Why Science? Teachers College Press & National Science Teachers Association Press.

UNICEF Report: "*Programming Childhood Development*", United Nations Children's Fund (2006) http://tinyurl.com/unicef-childhood-report

Vosniadou, S. (1994). *Capturing and modeling the process of conceptual change*. Learning and instruction, 4(1), 45-69.

Vosniadou, S., & Brewer, W. F. (1994). *Mental models of the day/night cycle*. Cognitive science, 18(1), 123-183.

III

Innovations in Astronomy Education Resources

III.1

Peer-review Platform for Astronomy Education Activities

Hundreds of thousands of astronomy education activities exist, but their discoverability and quality is highly variable. The web platform for astronomy education activities, astroEDU, presented in this chapter tries to solve these issues. Using the familiar peer-review workflow of scientific publications, astroEDU is improving standards of quality, visibility and accessibility, while providing credibility to these astronomy education activities. astroEDU targets activity guides, tutorials and other educational activities in the area of astronomy education, prepared by teachers, educators and other education specialists. The innovative aspect of astroEDU is that each of the astroEDU educational activities is double blind peer-reviewed by an educator as well as an astronomer to ensure a high standard in terms of scientific content and educational value. All reviewed materials are then stored in a free open online database, enabling broad distribution in a range of different formats. In this way astroEDU is not another web repository for educational resources but a mechanism for peer-reviewing and publishing high-quality astronomy education activities in an open access way. This chapter provides an account on the implementation and first findings of the use of astroEDU.

Publication

This chapter is based on Russo, P., Gomez, E., Heenatigala, T. and Strubbe, L., 2015, eLearning journal, 40

1. Introduction

The amount of educational content freely available on the Web is large and growing fast. Many challenges have emerged for educators when looking for and comparing resources available online, most of them related with discoverability, quality and openness of the resources. The Open Educational Resources (OERs) model [1] addressed some of these challenges, offering a new, scalable, and potentially powerful vision of learning. OERs are teaching, learning and research resources that reside in the public domain or have been released under an intellectual property license that permits their free use or re-purposing [2]. This concept has been further developed: making OERs be cost free to the end-user; allowing the end-user freedom to Reuse, Revise/alter, Remix and Redistribute, the 4R framework. This framework was initially presented by Wiley and in expanded in detail by [3] (Fig. 1).

The far-reaching impact of the OERs in society is not widely understood and is full of challenges on creation, use and evaluation [4]. Not all of these challenges derive from the OER model, but from lateral reasons, for example the use of OER is connected with the level of Internet access, knowing that two thirds of the world's population still doesn't have Internet access or the educational policies at different levels, within institutions and in government [5]. Moreover OER is seen as a potential threat to education content held by publishing houses [6].

Nevertheless the number of OER has opened a new way for science education to produce, develop and distribute resources. The number of repositories that store these resources has been growing in recent years, each with a different emphasis. Below we present a summary of repositories, which are specific to astronomy education activities and resources.

2. Astronomy Education Repositories

Although there are thousands of educational repositories, archiving a variety of resource types, there are not many repositories of educational resources specifically for astronomy. The table 1 gives an overview of existing repositories for astronomy education in English.

The information collated on those repositories is mostly well organized and of high quality, however none of those repositories satisfies completely the OER 4R model previously mentioned; sometimes the material cannot be revised or remixed; it can only, in most of the cases, be redistributed and reused. All of these repositories are only available in English and the majority does not provide the original source text of materials, which would facilitate adaptation and translation, essential for an international platform.

The discoverability of resources is also one of the problems. There is no evidence that teachers use the repositories of educational material to find their resources. Some educators use generic search engines, like Google. Results from a Google search provide very little indication of the quality of the resources. However quality is one of the most important criteria for educators when they search for learning resources online [9].

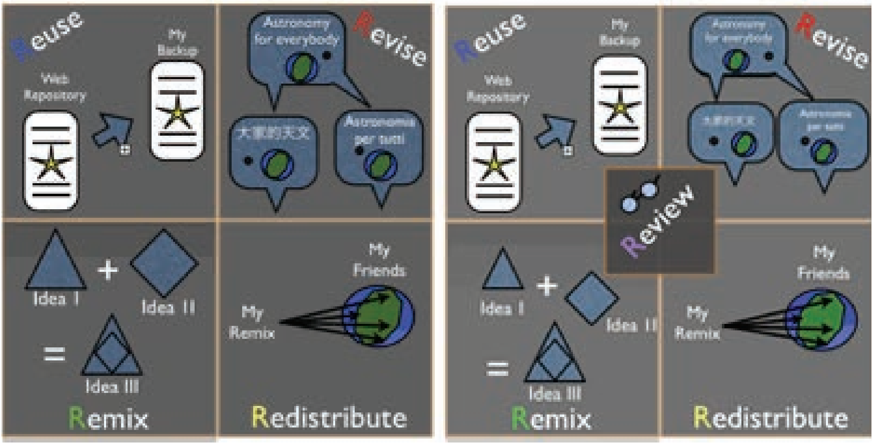

Fig. 1. (Left) Open Education Resources 4R framework: Reuse, Revise (Alter), Remix, Redistribute as presented by [3]. (Right) Proposed new OER framework: 5R: addition of Review of content through scientific and pedagogical quality checked (and improved) by the community peers. The review steps is implemented before and after publication.

Table I Educational Repositories in Astronomy

Repository	**Compadre (Physics and Astronomy Education Activities)**	**Galileo Teachers Training Program**	**Astronomical Society of the Pacific**	**NASA Wavelength**	**astroEDU**
URL	www.compadre.org	www.galileoteachers.org	www.astrosociety.org/education/	www.nasawavelength.org/	www.iau.org/astroEDU
Type of review	Internal review	Internal review	Internal review	Internal review	Peer-review review
Open to submissions?	Yes	No	No	No	Yes
Multilingual Support?	No	No	No	No	Planned
User registration required?	No	No	Yes	No	No

Library Type	Repository (Resource records)	Repository (Resources in PDF)	Listing (lists of links to resources)	Repository (Resource records)	Library
License	Various (from no license to copyrighted)	Various (from no license to copyrighted)	Various (from no license to copyrighted)	Various (from no license to copyrighted)	Creative Commons Attribution 3.0 Unported
Resource Types	Student resources, Teaching resources, Games, A/V material, Tools, Datasets, Reference materials	Teaching resources, Tools, webpages.	Reference materials, Courses, Webpages	Student resources, Teaching resources, Datasets, Reference materials, News & events, Webpages	Lessons Plans.
Connection to the Curriculum	None	None	None	US National Science Education Standards	Yes (English version: UK, Australia, US)
Collection growing?	N/A	N/A	N/A	Yes	Yes
Reference	[7]	N/A	N/A	[8]	This chapter

Although OERs offer a good solution for sharing knowledge, particularly when putting open educational resources on the internet, ensuring these OERs are also of high quality remains a challenge. To address this we propose astroEDU (www.iau.org/astroedu) an online platform for sharing astronomy OERs. astroEDU conforms to the 4R framework but which adds a new component, review, to ensure the resources are of the highest quality. In this respect astroEDU has enhanced the 4R model to a 5R model where Review becomes the fifth 'R'. To address the need to review the resources we propose a review system similar to that used in the academic knowledge creation and dissemination; the peer-review model.

Peer review was introduced to scholarly publication more than 280 years ago, as a process to evaluate any work by one or more people of similar competence to the producers of the work (also called peers). In academia this constitutes a form of self-regulation by qualified members of a profession within the relevant field. *Peer review methods are employed to maintain standards of quality, improve performance, and provide credibility. In academia, peer review is often used to determine an academic paper's suitability for publication* in [10]. Interestingly the peer-review process hasn't been widely used for the evaluation of science education products such as educational activities. Early attempts of using this methodology have been done by [11] and [12] with varying levels of success.

More recent attempts have been made by NASA Wavelength and Climate Literacy and Energy Awareness Network (CLEAN) to integrate peer-selection and internal peer-review. The resources are selected by a panel or by team members and then reviewed by a pre-appointed review board. These review methodologies enhance the quality of the resources, but do not provide a system for any educator to submit their resources, which is a limitation of both platforms.
The innovative aspect of astroEDU is the use of peer-review in a similar way to its use in scholarly publication. The suitability for publication of the activity is evaluated by the two stakeholders peers; an educator and an astronomy researcher. In this way both educational and scientific accuracy of the activity is checked and reviewed. For astroEDU the methodology used is anonymous peer review, also called blind review. In this system of pre-publication peer review of scientific articles or papers for journals by reviewers who are known to the journal editor but whose names are not given to the article's author. The reviewers do not know the author's identity, as any identifying information is stripped from the document before review. In this respect astroEDU's form of peer-review is double blind and free from bias. Moreover the same way that peer-reviewed scholarly articles are the main metric for performance evaluation of scholars, astroEDU will provide a new metric to assess the quality of the work developed by educators.

Table II astroEDU educational activities taxonomy

Sections of astroEDU activities.	**Description**
Activity title	Full title of the activity.
Keywords	Any words that relate to the subject, goals or audience of the activity. Note that most submissions will get variety of keywords and editor must ensure to select and add relevant keywords. Important for on-line search.
Age range	All age categories the activity applies to. The categories may change depending on the reviewers' and editorial board's input

Education level	The education level will change depending on the reviewers' and editorial board's input.
Time	The time taken to complete the activity.
Group size	Defines whether the activity is for individual or group use. Can also provide information like how many students per teacher
Supervised for safety	Determine whether the activity has steps that require adult supervision for safety. E.g.: using scissors.
Cost	Estimated cost of any materials needed for the activity. For astroEDU as a currency we use Euro (€).
Location	Suitable location to conduct the activity (for example indoors or outdoors).
List of material	List of items needed for the activity. Try to find materials which are easily and cheaply available in most countries (or offer alternatives)
Overall Activity Goals	A short list of points outlining the general purpose of the activity, and why these are important for students to learn. For example, "The overall goals of the activity are for students to understand why we experience seasons, and to improve their ability to communicate scientific findings. Seasons are important to understand because they affect daily life and involve concepts about light that are important in other contexts as well." (More specific learning objectives are entered in the field "Learning Objectives")
Learning Objectives	Learning objectives are specific statements that define the expected goals of an activity in terms of demonstrable skills or knowledge that will be acquired by a student as a result of instruction. These are also known as: instructional objectives, learning outcomes, learning goals. The demonstration of learning should be tied directly to "Evaluation". On the following page you can find some additional information on how to formulate good learning objectives: http://edutechwiki.unige.ch/en/Learning_objective. Use terminology listed on the page. For example, "Students will use the concept of solar flux as a function of incidence angle to explain why it is hot in summer and cold in winter in Toronto."
Evaluation	Include ways to test the goals, learning objectives and key skills learned by the audience. A way to assess the implementation of the activity and your performance should also be included.

Background information	This section contains information that teachers will read prior to beginning the activity. Necessary scientific background information needed to implement this activity. Limit each topic to one paragraph and keep in mind what is actually necessary for the activity. Also keep in mind the background of the teacher (e.g., explain concepts clearly, and do not use inappropriately technical vocabulary).
Core skills	Determine whether the activity is; Asking questions, Developing and using models, Planning and carrying out investigations, Analysing and interpreting data, Using mathematics and computational thinking, Constructing explanations, Engaging in argument from evidence, Communicating information or a combination of these.
Type of learning activity	Enquiry models are a pedagogical methodology for learning activities where the educational activity "starts by posing questions, problems or scenarios, rather than simply presenting established facts or portraying a smooth path to knowledge". There are several approaches to enquiry-based instruction. These approaches include; Open-ended enquiry, Guided enquiry, Structured enquiry, Confirmation or Verification, Fun Learning.
Brief Summary	One-paragraph short description of the activity. The description should give an introduction to the activity as well as what to expect from completing the activity.
Full description of the activity:	Detailed step-by-step breakdown of the activity. Use graphics where possible to show the steps.
Connection to school curriculum	Add the curriculum connection from the relevant country or region. The astroEDU editorial board will help find further connections.

To ensure a rigorous peer-review of educational activities an activity template was established and designed by the astroEDU editorial board. For that specific learning outcomes need to be identified, which enable the logic of the activity and the evaluation structure. For astroEDU educational taxonomy was established based on [13]. astroEDU activities follow the standard components defined by several authors in science education [13]. The components can be broken in four main areas: Objectives (What will your students learn?), Materials (What are the teaching instruments?), Processes (How will you teach your students?) and assessment (How will you assess your students' learning?). In Table 2 you can find a detailed explanation for the relevant different sections of astroEDU activities.

3. astroEDU Technical Implementation

The publication workflow of astroEDU was designed to remove barriers to the creation, submission use and re-use, and sharing of high-quality content. To achieve these goals, astroEDU uses off-the-shelf web technologies for the production and publication workflows

Table III Web technologies used to develop and implement astroEDU

Web Technology	Use in astroEDU	Reference
Django	Django is a high-level Python Web framework that encourages rapid development and clean, pragmatic design. Django was designed to handle two challenges: the intensive deadlines of a newsroom and the stringent requirements of the experienced Web developers who wrote it. It lets you build high-performing, elegant Web applications quickly.	J. Forcier, P. Bissex, & W. Chun, Python Web development with Django, 2009 Upper Saddle River, NJ: Addison-Wesley.
Python	Python is a dynamic object-oriented programming language that can be used for many kinds of software development. It offers strong support for integration with other languages and tools, comes with extensive standard libraries, and can be learned in a few days.	G. van Rossum, An Introduction to Python for UNIX/C Programmers *in Proceedings of the NLUUG najaarsconferentie* 1993.
MariaDB	MariaDB is a robust, scalable, and reliable SQL server. MariaDB is a drop-in replacement for MySQL.	MariaDB An enhanced, drop-in replacement for MySQL. (n.d.). Retrieved May 22, 2014, from https://mariadb.org/en/
NGINX	NGINX is a high performance, open source web application accelerator that helps websites deliver more content, faster, to its users.	Nginx news. (n.d.). Retrieved May 22, 2014, from http://nginx.org/

Mem-cached	Memcached is a high-performance, distributed memory object caching system, generic in nature, but intended for use in speeding up dynamic web applications by alleviating database load.	Nginx news. (n.d.). Retrieved May 22, 2014, from http://nginx.org/
Elasticsearch	Elasticsearch is a search server based on Lucene. It provides a distributed, multitenant-capable full-text search engine with a RESTful web interface and schema-free JSON documents.	Elasticsearch. (n.d.). Retrieved May 22, 2014, from http://www.elasticsearch.org/overview/
Markdown and Report-Lab	PDF and EPUB are digital formats optimised for printing and e-books, respectively. AstroEDU activities are available in these formats to enable broader use, leveraging technologies such as Markdown and ReportLab.	Markdown: Syntax. (n.d.). Retrieved May 22, 2014, from http://daringfireball.net/projects/markdown/syntax ReportLab open-source PDF Toolkit. (n.d.). Retrieved May 22, 2014, from http://www.reportlab.com/opensource

Submission is done via e-mail or a web form (typeform). Google documents and spreadsheets are used as collaborative tools within the editorial workflow, as described in Figure 3. Central to the philosophy of astroEDU is disseminating the best astronomy education resources. The majority of educator interaction with astroEDU will be searching and browsing for resources on the website. After review, activities are made available in many different formats: PDF, .doc, HTML, and epub, including the source files (RTF) for future translations and remixes. These successful activities are then syndicated through educational resources repositories and sharing sites (example: Scientix [16], TESconnect [17] and OER [18]. One of the main goals of the astroEDU is to promote the use of excellent activities worldwide. That is the reason why all the astroEDU activities will be licensed through the Creative Commons Attribution 3.0 Unported license. All the astroEDU activities are labeled with a Digital Object Identifier (DOI), to provide a form of persistent identification for future reference and an easy way to educators to reference their activities just like in scholarly paper. The front-end website uses different web technologies, mainly open-source software. The table 3. gives you an overview of the different web technologies.

4. Conclusions & Future Work

astroEDU is an open-access platform for peer-reviewed astronomy education activities and makes the best astronomy activities accessible to educators around the world. As a platform for educators to discover, review, distribute, improve, and remix educational astronomy activities, astroEDU tries to solve some past issues with educational activities in astronomy, namely that high-quality educational activities are difficult to find. As a proof-of-concept, the whole astroEDU process demonstrates that through peer-review and publication in a simple, elegant website, high-quality educational materials can be made available in an open-access way. The initial results and feedback is positive: "*[AstroEDU is] off to a promising start, with a pleasing range of activities suited to children of all ages and abilities*" [15].

The pedagogical impact of astroEDU will be measured in the next years, when more activities will populate the repository and more educators will use the materials. In the near future astroEDU will also explore new ways to review its content, mainly through classroom evaluation and post-publication evaluation. For classroom evaluation some randomized evaluations will be run in schools in Wales (UK) and the Netherlands. The different educators can also use the comments box for each activity so who use the activity can discuss how it worked when they used it, testing, etc. astroEDU will also test new models of peer-review in contrast with the current anonymous peer-review, some existing models like open peer-review will be tested. The discoverability of educational material is another issue that will be addressed in the next developments steps. Using techniques like Search Engine Optimization we expect to increase the number of users for the astroEDU activities. astroEDU is currently available in English, although astroEDU currently welcomes submissions in any language. It is anticipated the platform will be offered in other languages in early 2015. Only a truly cross platform and cross-language experience will be useful for educators and teachers around the world and astroEDU will try to achieve that.

5. References

[1] J. Hylén, Open educational resources: Opportunities and challenges. *Proceedings of Open Education*, 2006, 49-63.

[2] D. E. Atkins, J. S. Brown & A.L. Hammond, A review of the open educational resources (OER) movement: Achievements, challenges, and new opportunities*). Creative commons, 2007,* pp. 1-84

[3] J. Hilton III, D. Wiley, J. Stein & A. Johnson, The four 'R's of openness and ALMS analysis: frameworks for open educational resources. *Open Learning*, 2010, 25(1), 37-44.

[4] M.S. Smith & C. M. Casserly, The promise of open educational resources. *Change: The Magazine of Higher Learning*, 2006, 38(5), 8-17.

[5] M. Morley, Open Policy. *Squire Morley, 'Open Policy' for Openness in Education course*, 2012.

[6] Organisation for Economic Co-operation and Development, Giving knowledge for free: The emergence of open educational resources. Paris: *OECD - Educational Resources Centre for Educational Research and Innovation*. Available from: http://www.oecd.org/dataoecd/1/53/38484866.pdf [Accessed June

2014], 2007

[7] S. E. Deustua, ComPADRE: Communities of Physics and Astronomy Digital Resources in Education, Mercury, 2004 33.2 (2004): 19.

[8] D.A. Smith, T.G. Schwerin, L. M. Peticolas, D. Porcello, E. Kansa, S. S. Shipp & L. Bartolone, NASA Wavelength: A Full Spectrum of NASA Resources for Earth and Space Science Education. In *AGU Fall Meeting Abstracts*, 2013, 1, p. 07-05

[9] I. Brent, G. Gibbs, A. Katarzyna, Defining openness: updating the concept of “open” for a connected world in *JIME2012: JIME Special Issue on Open Educational Resources*, 2012

[10] S. Scanlan, NANO: New American Notes Online: An Interdisciplinary Academic Journal for Big Ideas in a Small World, Intro Peer Review, 2013 Retrieved 20 June 2014, from http://www.nanocrit.com/issues/issue-3-peer-review-new-possibilities/

[11] R. Cafolla, Project MERLOT: Bringing peer review to web-based educational resources, *Journal of Technology and Teacher Education* 14.2, 2006, 313-323.

[12] A. U. Gold, T. S. Ledley, S. M. Buhr, S. Fox, M. McCaffrey, F. Niepold, C. Manduca, and S. E. Lynds (2012) Peer-Review of Digital Educational Resources—A Rigorous Review Process Developed by the Climate Literacy and Energy Awareness Network (CLEAN). *Journal of Geoscience Education,* 2012, Vol. 60, No. 4, pp. 295-308.

[13] L. W. Anderson & D. R. Krathwohl, A Taxonomy for learning, teaching and assessing: A Revision of Bloom’s Taxonomy of Educational Objectives. New York: Longman. 2001

[14] Physics World, Web life: AstroEDU Review in Physics World, March 2014

[15] D. Aguirre-Molina & Á. Gras-Velázquez. Scientix, The Community For Science Education In Europe i*n EDULEARN11 Proceedings*, 2011, 4763-4768.

[16] Tes.co.uk, About Us - Information - TES . [online] Available at: http://www.tes.co.uk/article.aspx?storyCode=6000208&navCode=285 [Accessed 13 Aug. 2014].

[17] Commons, O. E. R. “About OER Commons.” *Reference: http://www. oercommons. org/about Accessed* 25 (2008).

III.2

Design, Development, and Impact of Physical Resources for Science Education

Physical educational resources provide a useful supplement for educators to demonstrate abstract or complex concepts. There has been considerable research on the benefits of resources based on inquiry-based learning for scientific and technical subjects. Universe in a Box is one such astronomy kit developed as part of the Universe Awareness (UNAWE) programme coordinated by Leiden University. It is designed to explain difficult and abstract astronomical concepts to young children (4 to 10 years old) by providing practical activities as well as the materials and models required to do them. The innovative approach to a collaborative development across the UNAWE network has made Universe in a Box the first international astronomy education resource produced and used globally. We consider the advantages and disadvantages of different models for the production and distribution of global science education kits. The preliminary social and educational impact and potential of such an educational kit are also presented and discussed.

Publication

This section is based on with Russo *et al.*, 2015, Journal of Science and Mathematics Education (Submitted)

1. Introduction

An educational kit is a product that can be used by teachers or their pupils to explain a concept, idea or theme. Educational kits cover a variety of subjects. This article will focus on practical, hands-on education kits covering scientific topics. Practical activities are a necessary element of promoting the understanding of scientific principles for children of all ages. The importance of practical activities was highlighted in a World Bank report, which stated that "practical work in science education increases comprehension of scientific principles and their application in the real world" (Musar, 1993). It is much easier for children to understand phenomena such as "the seasons" with a visual three-dimensional model rather than a two-dimensional diagram in a book or on the blackboard.

2. Educational Kits in Astronomy

Astronomy is an engaging theme for educational kits because children have a natural fascination with the night sky and because astronomy can be used as an umbrella for a wide range of topics, both scientific and cultural.

In 2010, a Relevance of Science Education (ROSE) survey asked school pupils from countries all around the world questions about science and their interest in it (Sjøberg & Schreiner, 2010). Much of the study focussed on finding ways to motivate students to follow science subjects for longer periods. The researchers found many differences in attitudes between developing and developed countries and between boys and girls. Generally, students from developing countries appeared to find science more interesting and wanted to study more of it, whereas students from developed countries were less enthusiastic about science. Boys seemed to like studying explosive chemicals more than girls, whose interest lay more in body and health than boys. One surprising outcome was that, overall, boys and girls from 40 countries surveyed find space the most interesting scientific topic (particularly, questions about "The possibility of life outside Earth")(Sjøberg & Schreiner, 2010).

The International Astronomical Union (IAU) has developed and ratified a strategic plan called "Astronomy for Development 2011 - 2020" (Miley et al., 2012), which demonstrates that astronomy can be a unique tool for global capacity building and highlights the fact that astronomy provides an inspirational gateway to technology, science, and culture. The rationale of this ambitious document is that, because astronomy links science and technology with inspiration and excitement, it has the potential to enable technological capacity building and education, thereby as well as be a tool to furthering sustainable development throughout the world.

As part of an initial investigation for the Universe Awareness project in 2012, Ramchandani (2012) researched astronomy kits that were available at the time. She found that most of these astronomy kits were restricted to the Solar System and did not cover the broad range of modern astronomy. Also, because they were usually heavily linked to local curricula, most available astronomy kits were unsuitable for a wide global audience.

Many primary school teachers experience science as a difficult subject and are, therefore, reluctant to teach it in their classes. Universe in a Box was developed to be a high-quality, easy-to-use astronomy resource that would help combat a teacher's fear. The following section describes the various stages of development of Universe in a Box.

3. Design of a Global Astronomy Educational Kit

3.1 Initial concept

Universe in a Box was an original concept of the House of Astronomy in Germany (www.haus-der-astronomie.de). It was developed under the MINT Box program for STEM education, supported by a grant from the Baden-Württemberg Foundation. Development of the box began in 2010, and the prototype was tested during seven pilot projects in February 2011 (Bwstiftung, 2014).

The authors developed the toolkit based on several pedagogical resources (Goswami (2008), Nobes et al. (2003) and Pauen (1996)) in order to ensure educational goals and activities were suitable for the age groups recommended. Universe in a Box has been designed as a didactic tool for teachers with inquiry-based learning (Bell, Urhahne, Schanze, & Ploetzner, 2010) for primary education students. The material offers the opportunity to work out the answers to questions on astronomy. It encourages hands-on learning, discussing, drawing conclusions, and presentation. The materials required for the activities are, with a few exceptions, low cost and also easy to hand-make.

Universe in a Box helps teachers in a variety of ways. Its main goal is to assist teachers overcome the hurdle of initial preparation for teaching astronomical topics by choosing appropriate focus areas and providing appropriate learning content and materials. The activities are designed to help make the connection between astronomy and other fields of science, art, religion, and culture and can be used by both 'beginner' and 'advanced' teachers.

Universe in a Box has a modular design and comes with three modules: The Earth-Moon-Sun System, The Planets, and The World of Constellations. The central theme starts by focusing on a topic that children are familiar with: the Earth. Questions include the following: (a) Why do we have day and night? (b) What shape is the earth? and (c) How can I tell? It then shifts on to the sun and the concepts of year and seasons come into play. Then it shifts to the moon: (a) Why does the moon change its form? (b) What is a month? (c) How long is a lunar day? and (d) What can we learn from the shapes of the moon craters? It then emphasises that planet Earth is not just a planet, but a special one, and asks questions such as Can we live on another planet? and What do we need to live? Finally, it introduces stars and identifies constellations.

Questions such as Is the life of a star eternal? and Do they all have the same colour? are addressed and answered.

Either individual activities or entire modules can be used in the classroom, both with large and small groups. Add-on modules on the life of a star, galaxies, and the "Earth-Human" system are currently in development. Educators are encouraged to customize the box with additional activities and material of their own. Apart from the relevant background and activity descriptions, the activity handbook also offers ideas for teaching astronomy integrated with other disciplines, guidance on further experimentation, and photocopy-friendly craft templates to extend and apply the newly learned knowledge.

Universe in a Box is also a product that resonates with Article 29 (1) of the Convention on the Rights of the Child, U.N. Doc. CRC/GC/2001/1 (2001), which states that the education of the child should be directed to the following:

1. The development of the child's personality, talents, and mental and physical abilities to their fullest potential;
2. The development of respect for human rights and fundamental freedoms and for the principles enshrined in the Charter of the United Nations;
3. The development of respect for the child's parents, his or her own cultural identity, language and values, for the national values of the country in which the child is living, the country from which he or she may originate, and for civilizations different from his or her own;
4. (d) The preparation of the child for responsible life in a free society, in the spirit of understanding, peace, tolerance, equality of sexes, and friendship among all peoples, ethnic, national and religious groups, and persons of indigenous origin;
5. (e) The development of respect for the natural environment.

3.2 Mint Box & Educational Development

Table 1 details the design elements including the educational features of the original prototype for Universe in a Box, the Mint Box (based on Fisher 2011). Eighteen MINT boxes were assembled, 15 of which were distributed to schools; another 10 DIY (Do-It-Yourself) kits were also given to schools. The

MINT team implemented the box through several workshops, reaching a total of 307 children and 44 teachers.

Table 1. Design elements of the original prototype for Universe in a Box.

Educational Goals	Promotion of numerous primary education competencies through astronomical themes (Baxter, 1995). Linking astronomical topics with other subjects (mathematics, art, religion, science fiction etc.) to support interdisciplinary learning and sustainability. (Saunders, Brake, Griffiths, & Thornton. 2004). Awareness of children to respect others' cultures, the origin of life, and to protect the earth by the realization that we are all inhabitants of a small, blue planet Earth. (Arends, 2015).
Audience	Use in both elementary school (4- to 10-year-old children) and extracurricular activities at science centres, observatories, planetariums, museums, outreach programs, amateur astronomy centres, etc. Ideal student-to-teacher ratio of 1:20.
Educational Approach	Pre-selection of topics forming three modules: Earth-Moon-Sun System, The Planets, and The World of Constellations. The topics follow a didactic order, and activities have an interdisciplinary / cultural focus. Inquiry-based learning educational activities.

Flexible Educational Design	Educational models provided for teaching. Add-on modules on galaxies, stars, and the Earth-Human system currently in development. A complete description of the materials and the activities, Astronomy background information on the science behind the activity. Suggestions for interdisciplinary activities. Suggestions for further reading and experimentation. Guide in loose-leaf folder format for customization and easy updating. Photocopy-friendly craft templates. Educators can use the box in a modular fashion depending on topic. Educators can customize with additional activities and material. Educational materials are low-cost and can be easily reproduced or purchased Teacher training. Teachers with no experience in astronomy benefit from a teacher training workshop.

Training feedback was positive and both teachers and students were enthusiastic about the workshops. Many participants felt more confident after a first introduction to the subject. Teachers with no experience in astronomy benefitted particularly from an associated teacher-training workshop. The feedback led to the consolidation of the modules and respective materials (Table 2).

Table 2. Educational activities sorted by modules including the materials and the corresponding activities, which are covered in the handbook.

Materials	Educational Activities
Module 1: Earth-Moon-Sun	
Globe Three small figures Patafix Small ship Bulb holder Bulb Styrofoam moon Moon and Earth masks	Characteristics of the moon, moon distance, lunar laboratory, lunar landscape games, reflected light, 3D visualization of the phases of the moon, moon phase box, moon phases, mosaic pictures of the moon from other countries and cultures, pictures and stories about the moon, mini research project: The lunar orbit Round Earth, dialogue between children at opposite ends of the Earth, Earth mosaic, our planet, day and night, seasons, tilted Earth's axis Sun's Apparent Size I, Apparent Size II, Invisible Light, Path of the sun across the sky, sun shade, construction of a sundial, solar surface convection, mini research project: Sun: Solar rotation
Module 2: The Planets	
2m string Planetary system of wooden balls Card game Laminated pictures of the planets Origami rocket	Card game on the sun and planets, model of our solar system , when can I see planets, ellipses, construction of a planetary path, construction of rockets
Module 3: The World of Constellations	

Zodiac band Constellation projector with time cards Images of the zodiac Zodiac book 10 stars Blue cloth Planisphere (handmade) Planisphere (sourced)	Zodiac band with planets and constellations, visibility of the constellations, function of a Planisphere, the constellation Cassiopeia, constellations of the year, constellation viewer

3.3 EU Universe Awareness: Consolidation

Figure 1. Universe in a Box content.

The MINT box was identified by the EU Universe Awareness project (Schrier, Nijman, & Russo, 2012) as a potential global product with local reach, one that could be globally standardised to an extent to gain economies of scale and scope but localised to meet local requirements. The “*glocalisation*” of educational resources has been discussed by Willems and Bossu (2012). Universe in a Box was considered suitable because its content fits with the required educational curricula of many countries and because the activity book and materials come in a format that is easy to localise and reproduce. Feedback was gathered from educational experts and astronomers on ways to further improve the kit. Handbook content and layout were changed, and the materials for several of the components were changed in order to make them more durable and better quality (Ramchandani, 2012).

3.5 Prototype

Four companies were contacted to request quotations for the production of Universe in a Box. Curion Education Pvt. Ltd. was selected to be the main producer of the international version. The production and shipping of 50 prototype Universe in a Boxes (Figure 1) to 30 countries was then arranged. These were selected from 100 requests from schools received via the UNAWE website and favoured requests from those most likely to maintain future involvement in production, distribution, and/or educational input. Proposed production costs were 30 EUR, although this increased to 45 EUR per box due to the small scale of production and various improvements to materials. On average, each box shipping cost was 45 EUR.

All 50 prototypes were well-received. Educators from 45 countries found most of the materials attractive and easy to implement for children between 4 and 10 years old. Handbook activities were easily understood, with the guide being described as "*rich*" and "*well-explained*", although more translations were requested (French, Arabic, and Hindi translations were suggested). The evaluation from an educator training session in South Africa seemed to sum up the overall feedback when session administrators stated that "*educators have concluded that Universe in a Box will have a significant impact on their teaching of astronomy in the classroom and will enable their learners to apply their content knowledge using various activities in the toolkit*". They further suggested that the box will *"stimulate interest in space science"*. By August 2013, the first large-scale production (1000 boxes) of the English international version of Universe in a Box was commissioned. Feedback from users of the 50 prototypes was used to improve the production version Universe in a Box.

4. Production and Distribution

There are several approaches to supplying and distributing educational equipment widely (Musar, 1993):

- Production by teachers and students
- Establishing central production units
- Central development and assembly of kits
- Decentralised development and production
- A combined approach

Although teachers and students know well what is needed in their special environments, quality can be better ensured by a wider approach that allows input from external specialists. Some countries have central units for production of teaching aids (including equipment for science education), often as part of the responsible Ministry or a not-for-profit organisation. There is a risk, however, that when a unitary system produces equipment for the whole national education system, monopolisation costs and political issues will arise. Buying certain materials in stock (on the domestic or international market) and repackaging them in small lots exploits economies of scale and is a potential attraction of the central development and assembly of such kits.

However, this requires significant infrastructure or initial effort, and shipping costs are lowest when production is closer to demand. Global shipping can cost more than the products themselves.

In general, a hybrid approach is optimum and allows for development of locally relevant, high quality resources in economically efficient ways. After careful deliberation, it was decided to produce Universe in a Box using the hybrid approach.

Universe in a Box is only one of several educational resources being developed by the UNAWE project, and one of the main aims when considering how to proceed with Universe in a Box was to create a framework through which future resources generally can also be distributed and improved.

The production and distribution of Universe in a Box is evolving towards a regional production hub model to take advantage of benefits discussed later in this report, with a substantial fraction of boxes being produced and distributed from a central point.

4.1 Centralised production

Production costs can be reduced by scaled-up production. One of the benefits of centralised production is that, by producing a greater quantity, the cost per unit decreases. Centralised production also assures an element of consistency and quality control of the resource.

In January 2014, the UNAWE International Office (based at Leiden University) commissioned the production of 1000 International English versions of Universe in a Box. These were produced by Curion Education, the same company who produced the 50 prototypes. These boxes were shipped to Leiden, the Netherlands, where the International Office assumed responsibility for the distribution.

Drawbacks of centralised production are that it limits localisation opportunities. All boxes have to be identical. For example, all 1000 boxes had the English handbook, and substituting this for another language could only be done at additional cost. Also, because the socket for the included lamp stand had a European two-pin plug, adjustments needed to be made for use in many countries (examples: the UK or USA).

4.2 Localised production

An innovative aspect of the Universe in a Box is the Do-It-Yourself Guide (Ramchandani, 2014). This guide gives instructions on how to replicate the box from locally sourced components as an alternative to ordering from the

International UNAWE Office. Localised production of educational resources has the following benefits:

- Affordable and locally suitable costs
- Better availability of spare parts
- Higher relevance to curriculum (and flexible adaptation)
- Higher local content (including translations of material)
- Direct marketing
- Savings on distribution costs

UNAWE national coordinators Ivo Dzhokin (from Bulgaria) and Arif Bayirli (from Turkey) used the DIY version of the Universe in a Box handbook to produce the kit locally. The Bulgarian kit was constructed using cardboard and Styrofoam balls. It also included an additional activity on constellations involving constructing models of Ursa Major constellation from small Styrofoam balls and wooden skewers. Dzhokin presented the original kit (ordered and shipped from UNAWE International Office) at the annual Bulgarian Astroparty and donated 17 locally produced versions of the kits to schools participating in this event. During the astronomy event, he explained several of the activities to teachers in Bulgarian.

All teachers in this session gave good feedback and showed great interest in the UNAWE-Bulgaria project in general. Articles were published in local and national media, as well as information sent to the Ministry of Education and Science. Dzhokin's session in Bulgaria had 14 teacher participants, 46 students, and nine guests.

In Turkey, Bayirli and colleagues built two boxes using the DIY guide. They used the opportunity of a teacher training workshop in a 2014 conference called "Best Practices in Education" in Istanbul to put together and promote the idea of the DIY kits. Due to customs issues and costs, they preferred to construct their own Universe in a Box. Bayirli also pointed out that "building the box familiarises the users with the materials", aiming to give workshop participants the message that they can easily "go and get the materials provided from the UNAWE website and print them on a cardboard and go to a local craft store and gather the materials you [they] need and like!" He estimated that producing the box in Turkey costs almost one-fourth of ordering directly from the UNAWE International Office (which covers shipping costs as well).

The DIY guide and the print package were translated into Turkish and are now available on the UNAWE-Turkey website for download (http://www.evrenianlayalim.org/p/bir-kutu-evren.html). Translation of the Activity Guide into Turkish is an ongoing process. Some items from the DIY guide were not easily available in the local market, so several changes and alternatives were implemented; these were then suggested in the Turkish translation of the DIY guide. The model of the solar system proved particularly difficult to locate. The translated Turkish version of the DIY guide has been distributed to 100 teachers during teacher training events, which are the main part of UNAWE-Turkey's astronomy activities. Overall Bayirli says they prefer to order the box from the International Office despite the difference in price because most UNAWE members in Turkey are voluntary and building the DIY version is quite time-consuming. He has said, "*We are planning to promote building the box or if they can afford it to buy, just purchase from the UNAWE; it is much more manageable*".

4.3 Centralised distribution model (through the International UNAWE Office)

As mentioned in the Production section, the first large-scale production of Universe in a Box (the 1000 boxes produced by Curion) was stored and distributed from the International UNAWE Office at Leiden University. These boxes were distributed globally to more than 40 countries.

Shipping costs of centralised distribution are relatively high (see Table 1 for accurate shipping cost estimates from August 2014 from www.post.nl/tarieven/), and it requires one central distributor.

Table 1. Shipping costs for Universe in a Box

Destinations **(From Leiden, Netherlands)**	**Costs of sending one unit by regular mail (49 x 39 x 25 cm weight 8 kg)**
Netherlands	6.95
Germany	25.00
Portugal	31.00
Iceland	32.30
Nepal	58.30
Australia	58.30

Centralised distribution allowed the implementation of a BuyOne-DonateOne scheme for distribution of Universe in a Box. Under this scheme, a school or organisation that can afford to do so, pay the costs of production and shipping for the equivalent of two boxes, though they only receive one. The other box is sent to a school or organisation in an underprivileged community that otherwise could not afford it. This scheme had limited success; in total only 17 boxes were donated this way. It was this lack of uptake that persuaded us to undertake a Kickstarter crowdfunding campaign (see Crowdfunding campaign section).

4.4 Regional distribution model

Regional distribution can be combined with centralised production or it can be coupled with regional production. Regional production means that the pricing of the resource is more consistent with regional prices, thereby ensuring that the resource is more affordable for the regional market. Also, regional production contributes to the economic development of the region. Furthermore, by reducing the distribution costs, production of the kits in the region or shipping them in bulk to a central regional node minimises one of the major contributions to the cost of the kits.

Regional distribution requires several people in different places and one central coordinator to ensure consistent quality of production and to provide support where necessary. Therefore, it is proposed to optimise the future production and distribution of the kits. The boxes should be produced at regional nodes and distributed from each node. This would replace the current model where boxes are produced in India and then shipped to where they are required. The individuals or organisations who take on the role of producing and distributing the kits will become 'localisation, production, and development' partners of Universe in a Box. These partners will be trained to use the box and trained in how to train others in its use. They will be given a DIY Universe in a Box kit with additional resources to enable them to source and reproduce Universe in a Box. These hubs will train local users in the resource and be responsible for distributing the boxes they have produced to these newly trained and enthusiastic local users.

The process of finding localisation, production, and distribution partners is ongoing as these will enable Universe in a Box to develop its distribution nodes on a regional basis. The organisation must also coordinate the process of becoming a partner (e.g., peer review, setting price, etc.). Country/region-specific information should be created concerning business plans (and their implementations) and advice on how to obtain funding. The International UNAWE Office should also assist in the actual production and distribution setup where necessary as well as provide seed loans for prototyping.

5. Crowdfunding campaign

In May 2014, the UNAWE International Office undertook a successful Kickstarter crowdfunding campaign and raised more than €17,000 to send Universe in a Box around the world to underprivileged communities and to produce online training videos. The following sections describe the steps involved in developing and carrying out the campaign as well as a few things learned from organising a crowdfunding project.

5.1 Development

An important goal of the Universe Awareness team was to share the astronomy education resources with underprivileged communities, but by early 2014, the purchase of boxes under BuyOne-DonateOne had been less successful than hoped. The use of a crowdfunding campaign was an alternative method to support sharing the Universe in a Box kits and increasing their internation-

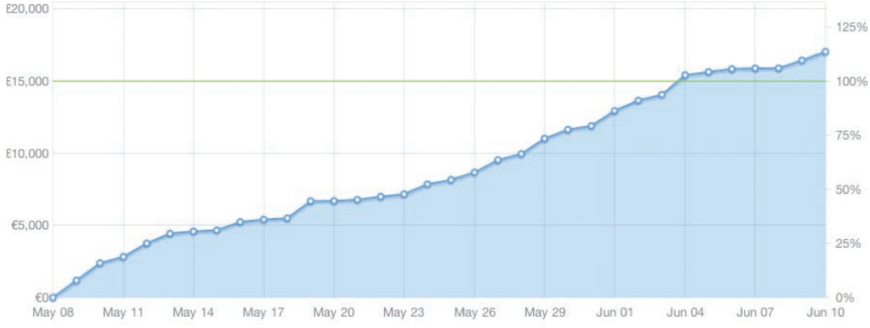

Figure 2. Evolution of the donations during the campaign period

al recognition. The plan for this campaign was to distribute boxes as 'rewards' for backers of the project as well as raise the funds necessary to send a number of boxes to underprivileged communities who otherwise could not afford them. The large publicity and campaign effort that must accompany crowdfunding raises international awareness of projects and products. The campaign used the equivalent of two months of full-time work by a UNAWE employee (before and during the campaign) as well as €800 to produce a campaign video (mostly rental of equipment and specialists). After careful budgeting and planning, the financial target for the campaign was set at €15,000. This was to cover the costs of distributing 160 Universe in a Box kits around the world to underprivileged communities and the costs of producing online training videos to support the implementation of Universe in a Box. Calculated within the target was the amount it would cost to ship campaign rewards and the commission that Kickstarter takes from the total amount raised.

UNAWE has an extensive international network (The UNAWE Facebook page was liked by 2,343 people, and the Twitter page was followed by 4,627 people before the campaign launched), which gives a strong foundation from which to launch a crowdfunding campaign, but thorough preparation is also important for success. Almost one month full-time equivalent was spent before the launch date in preparing content for the Kickstarter page (words, photos, and video) and developing a plan of action for the campaign itself. We raised awareness about the campaign on the UNAWE web pages before launch to allow and encourage a "hype" to build.

5.2 Implementation

The campaign page can be viewed online at https://www.kickstarter.com/projects/unawe/universe-in-a-box.

The campaign was promoted through email and social media, contacted several journalists, and had phone calls or conversations with personal friends and contacts. The UNAWE team contributed to several blogs about the campaign, and other people also blogged about us.

Updates were posted on the UNAWE Twitter and Facebook accounts at least twice daily during the campaign. The website Peerreach was used to identify high-impact Twitter users, particularly within the relevant fields of Science and Education. These people were then sent personalised messages with a link to the campaign. Emails were sent out to various groups of potentially interested people throughout the campaign and to the UNAWE mailing lists at the beginning, middle, and end of the campaign. The UNAWE International mailing list has 1,749 subscribers, and the UNAWE NL mailing list has 844 subscribers. We prepared press releases and had media coverage through a variety of outlets. The results and lessons learned from this campaign were published in Ashton, Russo, and Heenatigala (2014).

5.3 Results

At the end of our 31-day campaign, €17,037 was pledged, exceeding our €15,000 goal. €15,463.56 was received from Kickstarter after its commission had been deducted. Figure 1 shows how the number of pledges varied during the campaign.

The campaign resulted in 235 backers (average backing: €72.50), was shared 1,395 times on Facebook, and the video viewed 2,664 times (45.14% of plays were completed). The table below is a direct product from the Kickstarter page and shows where pledgers arrived at the Kickstarter page from. The largest amount was direct traffic, but a significant proportion of pledgers arrived at the site from the Twitter and Facebook links. Blog articles (University Today and astronomie.nl) and a widget embedded on the UNAWE website also contributed a reasonable amount to the campaign.

Figure 2. Global distribution of Universe in a Box. Interactive map available on: http://unawe.org/resources/universebox/

Table 2. Overview of the pledges' sources

Source	Number of backers	% Pledged	Amount Pledged (€)
Direct traffic (no referrer information)	97	42.46%	7,234
Facebook	26	8.74%	1,545
Twitter	24	9.07%	1,490
universetoday.com	14	5.52%	941
Other sources	14	15.0%	345
Embedded Kickstarter widget on www.unawe.org	9	5.05%	860
Advanced Discovery on Kickstarter	8	3.09%	526
Google searches	7	14.0%	695
unawe.org	5	3.44%	586

phys.org	4	1.12%	190
scienceblogs.de	4	0.82%	140
astronomie.nl	3	1.76%	300
Leiden University	3	0.56%	95
allesoversterrenkunde.nl	2	1.17%	200

Upon successful completion of the campaign, there were three main obligations: shipping of rewards to projects backers, fulfilling the targets set out by the campaign, and continuing to build and strengthen the community.

Evaluation & Discussion

At the time of writing, 700 international versions of Universe in a Box have been distributed to 40 countries (Figure 2). Teacher training sessions involving Universe in a Box have taken place in numerous countries. Feedback from these sessions after teachers have taken Universe in a Box activities back into the classroom has been resoundingly positive. Professional evaluation of all the boxes and the associated training sessions still have to be done, but preliminary anecdotal evidence shows that the children's understanding of concepts included in Universe in a Box increases after activities.

This chapter is a description of the processes and trade-offs that governed the development, production, and distribution of the flagship UNAWE educational resource, Universe in a Box. Many of the issues discussed are generic, but are relevant and should be taken account of when considering the development, production, and distribution of other educational resources, particularly those with an international focus.

Science and technology literacy is of crucial importance in education globally and has been recognised as essential by the United Nations Educational, Scientific and Cultural Organisation (UNESCO) since 1984 in its series "Innovations in Science and Technology Education". The general view is that if we are to solve current and future social and environmental problems, then we need a generation of scientifically and politically literate people. Scientific literacy also has the potential to have huge impacts on underprivileged communities, either equipping people with practical solutions to everyday problems, by giving them passion and drive to pursue scientific careers, or by basically enabling people to think in different ways and make informed decisions.

Astronomy is a powerful tool for science education. Often communities in otherwise resource-poor countries have the clearest views of the night sky and, thus, an instant gateway into the study of astronomy and space sciences. These early exposures can inspire and engage people in studies of science and technology.

Bottom-up education resources in particular should be a major part of plans to develop or improve education in underprivileged communities. It is important that resources are locally relevant and sensitive and include cultural content where possible. Training is also an important part of resource development if these are to be employed effectively and not abandoned for something that educators find easier or more relevant. Universe in a Box aims to take all of the above considerations into account.

An important result of UNAWE's work with Universe in a Box is a new framework for the development of future global educational resources (Ramchandani, 2013) based on the following principles:

- Co-development and collaboration (multiple partners) over single organization
- Co-production and distribution (with local partners) over top-down
- Co-ownership and branding (with smaller amounts) over licensing/franchising
- Co-funding (with smaller amounts) over large capital requirement
- Co-profiting (each partner benefits) while meeting a common goal

These principles form a new framework for the development of a "glocal" physical educational kit: one that could be globally standardised to an extent to gain economies of scale and scope, but localised to meet local requirements. This framework will be applied and exploited in future global educational projects, e.g. EU Space Awareness, a project funded by the European Commission between 2015 and 2017, that will use space to inspire children and teenagers and encourage them to embark on careers in the space industry.

References

Arends, E. (2015) Blue Marble in empty space. astroEDU, 1412. doi:10.14586/astroedu.1412

Ashton, A., Russo, P., and Heenatigala, T., (2014). *Crowdfunding astronomy outreach projects: Lessons learned from the UNAWE crowdfunding campaign*. Communicating Astronomy with the Public Journal, 15, 24-27.

Baxter, J. (1995). *Children's understanding of astronomy and the earth*. In S. M. Glynn & R. Duit (Eds), Learning science in the schools: Research reforming practice (155-177). Mahwah, NJ: Lawrence Erlbaum.

Bell, T., Urhahne, D., Schanze, S., and Ploetzner, R. (2010.) *Collaborative inquiry learning: Models, tools, and challenges*. International Journal of Science Education, 3(1), 349-377.

Bwstiftung.de, (2014). *Baden-Württemberg Stiftung: MINT-Box*. Retrieved December 2014 from http://www.bwstiftung.de/forschung/laufende-programme-und-projekte/wissenschaft-oeffentlichkeit/mint-box.html

Goswami, U. (Ed.). (2008). *Blackwell handbook of childhood cognitive development.* John Wiley & Sons.

Miley, G., & et al. (2012). *The IAU Astronomy for Development Strategic Plan 2010 – 2020* (Revised ed.). International Astronomical Union. Available online at http://iau.org/static/education/strategicplan_2010-2020.pdf

Miley, G. (2012). *The IAU Astronomy for Development programme*. In A. Heck (Ed.), Organizations, people and strategies in astronomy (Vol. 1, pp. 93-111). Duttlenheim, France: Venngeist.

Musar, A. (1993). *Equipment for science education: Constraints and opportunities* (Discussion Paper No. 11). Washington, DC: The World Bank, Education and Social Policy Department.

Nobes, G., Moore, D. G., Martin, A. E., Clifford, B. R., Butterworth, G., Panagiotaki, G., & Siegal, M. (2003). *Children's understanding of the earth in a multicultural community: mental models or fragments of knowledge?*. Developmental Science, 6(1), 72-85.

Pauen, S. (1996). *Children's reasoning about the interaction of forces*. Child Development, 67(6), 2728-2742.

Peerreach.com. (2014). *Top 100 science worldwide.* Retrieved December 7, 2014, from http://peerreach.com/lists/science/

Ramchandani, J. (2012). *Internship report: Universe in a Box*. Available online at http://www.unawe.org/resources/reports/universe_box_jaya_report/

Ramchandani, J. (2013). Prototype production and distribution report. Available online at http://www.unawe.org/resources/reports/unibox_protoproduction/

Ramchandani, J. (2014). *Universe in a Box: Do-it-yourself guide*. Available online at http://unawe.org/resources/guides/universeinaboxdiyguide/

Ramchandani, J. (2013). *A Collaborative Model for Astronomy Educational Resources for Global Outreach*, communication at Communicating Astronomy with the Public Conference 2013

Willems, J., & Bossu, C. (2012). *Equity considerations for open educational resources in the glocalization of education*. Distance Education, 33(2), 185-199.
Saunders, D., Brake, M., Griffiths, M., & Thornton, R. (2004). Access, astronomy and science fiction: A case study in curriculum design. Active Learning in Higher Education, 5(1), 27-42.

Schrier, W., Nijman, I., & Russo, P. (2013). *Universe awareness: Inspiring every child with our wonderful cosmos*. In Communicating Science: A National Conference on Science Education and Public Outreach (Vol. 473, p. 141).

Sjøberg, S., & Schreiner, C. (2010). *The ROSE project: An overview and key findings.*

IV

Impact of Astronomy Education and Public Outreach on Astronomical Research

IV.1

A Survey of Astronomical Research: A Baseline for Astronomical Development

Measuring scientific development is a difficult task. Different metrics have been put forward to evaluate scientific development; in this chapter we explore a metric that uses the number of peer-reviewed, and when available non- peer-reviewed, research articles as an indicator of development in the field of astronomy. We analysed the available publication record, using the Smithsonian Astrophysical Observatory/NASA Astrophysics Database System, by country affiliation in the time span between 1950 and 2011 for countries with a gross national income of less than 14,365 USD in 2010. This represents 149 countries. We propose that this metric identifies countries in "astronomical development" with a culture of research publishing. We also propose that for a country to develop in astronomy, it should invest in outside expert visits, send its staff abroad to study, and establish a culture of scientific publishing. Furthermore, we propose that this chapter may be used as a baseline to measure the success of major international projects, such as the International Year of Astronomy 2009.

Publication

This chapter is based on Ribeiro, V., Russo, P. & Cárdenas-Avendaño, A., The Astronomical Journal, 146:138 , 2013 DOI: 10.1088/0004-6256/146/6/138

1. Introduction

Astronomy is a fascinating subject, with a unique ability to inspire and to stimulate curiosity in human beings about the wonders of science and technology. This makes astronomy a useful tool for bringing science to the general public to inspire, to show the scientific method, and to open their eyes to a new perspective. Astronomy has been shown to have wide-reaching applications in many different sectors of society. Immediate examples are the technological developments that came from the building of the ESA/NASA Hubble Space Telescope,[1] such as the use of mirror technology to increase semiconductor productivity and performance, and CCD technology being adapted for more efficient biopsies[2] (Astronomy & Astrophysics Survey Committee 2001). These examples demonstrate that astronomy not only aims to answer fundamental questions about how the universe works and to stimulate curiosity, but it can also aid technological development and economical growth. Although it is difficult to quantify the return of investment in astronomy, some reports show spin-off technological development to return as much as ten-to-one.[3]

One project that aimed to stimulate and inspire people's curiosity with the wonders of the universe was the International Year of Astronomy in 2009 (IYA2009). This project reached over 815 million people in 148 countries (Russo & Christensen 2010) through various activities from star parties and school programs to the use of IYA2009 to launch university programs (e.g., Ribeiro et al. 2011). The success of IYA2009 was no mean feat. However, truly understanding and evaluating its impact, at least in astronomy, will be a difficult task. Project evaluations are applied for numerous reasons,[4] for example, (1) to determine if the project goals were reached, (2) to obtain information on the outcomes of an event, along with suggestions for improvement, (3) to identify the changes resulting from the implementation of a project, (4) to identify ways in which the project could have been more effective and efficient, (5) to identify unexpected results, (6) to crystallize ideas about the event and what it is intended to achieve, and (7) to provide encouragement by demonstrating that efforts have been worthwhile. Measuring this impact may be done in various forms.

Developing Astronomy Globally (DAG), a cornerstone project of IYA2009 which was fed into the International Astronomical Union (IAU) Strategic Plan,[5] was designed to develop astronomy professionally (at universities and at the research level) worldwide.6 As part of DAG, a survey was conducted as a self-evaluation of the countries participating in IYA2009 (Naicker & Govender 2009). The survey was completed by the IYA2009 Single Point of Contact from each country and therefore may suffer some bias and the data may be incomplete. Naicker & Govender (2009) proposed that each country would fall into one of four separate phases of astronomical development, and presented some recommendations for development accordingly. In summary, these phases were (1) well established, (2) in need of support, (3) nonexistent with strong potential, and (4) non-existent with limited potential.

Hearnshaw (2007) extracted statistical information from the Smithsonian Astrophysical Observatory/NASA Astrophysics Data System (hereafter ADS) to obtain an overview of the state of astronomical development for each country. Hearnshaw found that the number of publications per IAU member correlates strongly with gross domestic product (GDP) per capita. However, this concentrated only on IAU member states and a select few non-member countries. This chapter looks at a sample of peer-reviewed research articles for a number of countries, most not included in Hearnshaw (2007), to measure countries in astronomical development and to identify those with a culture of publishing using ADS, which is used by the entire astronomical community (Henneken et al. 2009), and is therefore a good database for determining the astronomical research being carried out throughout the world. Other means are possible for this study, e.g., the World of Science. However, two major factors played a role in the decision to use ADS instead: (1) it is free and (2) as mentioned above, it is used by the entire astronomical community. From this viewpoint, counting the number of publications in astronomy by each country provides, to a first approximation, a good indicator of astronomical development.

Due to the sheer amount of data and different sociological reasons for a country to be in astronomical development, we only concentrate on providing a quantitative, rather than qualitative, discussion and invite the community to draw their own conclusions for their particular regions.

2. Methods

When publishing in a refereed journal, authors are required to provide their institution address with the article. In the majority of cases this is also indexed for searching, alongside coauthors, title, and other key information that makes searching for a journal article simple. We therefore used the ADS affiliation field to count astronomical publications by country from 1950 up to and including 2011. We only queried the astronomical database for these studies. However, this query returns journals not only related to astronomy but also to the geosciences. Particular care was taken for countries that may conflict with other words in the affiliation. For example, Niger is easily confused with Nigeria and Guinea is easily confused with Equatorial Guinea, Guinea-Bissau, and Papua New Guinea. The search returned the number of papers for each country in a given year. We then selected papers, based on the biased view of the authors, that we consider to be in mainstream astronomical journals. These were The Astronomical Journal, Astronomy and Astrophysics, The Astrophysical Journal (including Letters and Supplements), Monthly Notices of the Royal Astronomical Society, New Astronomy (including Reviews), and Physical Reviews. The first four journals were described by Henneken et al. (2009) as the core journals read regularly by active astronomers. We searched, using the ADS Mighty Search,[7] both refereed and non-refereed papers, although the latter are very difficult to quantify due to the fact that, in the majority of the cases, the affiliations are not given in the ADS abstract. Furthermore, counting the number of papers per country was based solely on whether the country name appeared in the affiliation field. As an example, in the current chapter each of the countries in the affiliation field would receive a count of one paper. This is not uncommon in astronomy, where 55% of papers are suggested to arise from authors from different countries (Abt 2007).

The number of papers published per year was used to identify which countries are in astronomical development. The selection of countries we considered was based on their gross national income (GNI).[8] We considered those countries that have a GNI of less than 14,365 USD (based on the average world GNI for 2010).We should note that a country's GNI can be very dynamic. However, for the purpose of these studies, just considering the 2010 number is sufficient for the majority of the world's countries. This search retrieved 149 countries (Appendix A), including all the least developed countries (LDCs; Appendix B).

3. Results

Figures 1–6 show the results for the number of papers per year, as well as the GNI per country per year, divided into Africa, South and Latin America, Asia, Europe, Oceania, and LDCs, respectively. Thewhite histograms are all of the results as queried on ADS while the black histograms are for the selected mainstream astronomical journals, as mentioned above. Only countries with paper counts greater than five in total are shown in the figures, while excluded countries are shown in Table 1 along with their total number of papers in brackets. Furthermore, only the time span from 1970 onward is shown, as before this date the number of papers is generally very low and will not aid our discussions.

Table 1. Countries with Five or Fewer Publications Over the Time Span of Our Studies. The number in parentheses is the number of publications.

Country	**Country**	**Country**
Afghanistan(1) Angola(2) Anguilla(0) Antigua and Barbuda(0) Belize(1) Bhutan(1) Burundi(2) Cambodia(1) Cape Verde(3) Central African Republic(2) Chad(1) Comoros(0) Cook Islands(1) Cote d'Ivoire(0) Djibouti(3) Dominica(0) Dominican Republic(2)) DPR Korea(3) El Salvador(4) Equatorial Guinea(0)	Gabon(2) Gambia(0) Georgia(0) Grenada(2) Guatemala(5) Guinea-Bissau(0) Guinea(0) Guyana(1) Haiti(2) Kiribati(0) Kosovo(4) Lao(0) Liberia(0) Madagascar(2) Malawi(1) Maldives(0) Mali(0) Marshal Islands(1) Mauritania(1) Micronesia(1)	Mozambique(3) Nauru(0) Niger(0) Palau(1) Rwanda(1) Saint Kitts and Nevis(0) Saint Vicent and the Grenadines(0) Samoa(2) São Tomé and Principe(0) Seychelles(1) Sierra Leone(1) Solomon Islands(3) Somalia(4) Suriname(0) Timor-Leste(0) Togo(0) Tonga(0) Tuvalu(0) Vanuatu(1)

We only considered results from the astronomical database within ADS, which also retrieves articles from the field of geosciences. The search did not

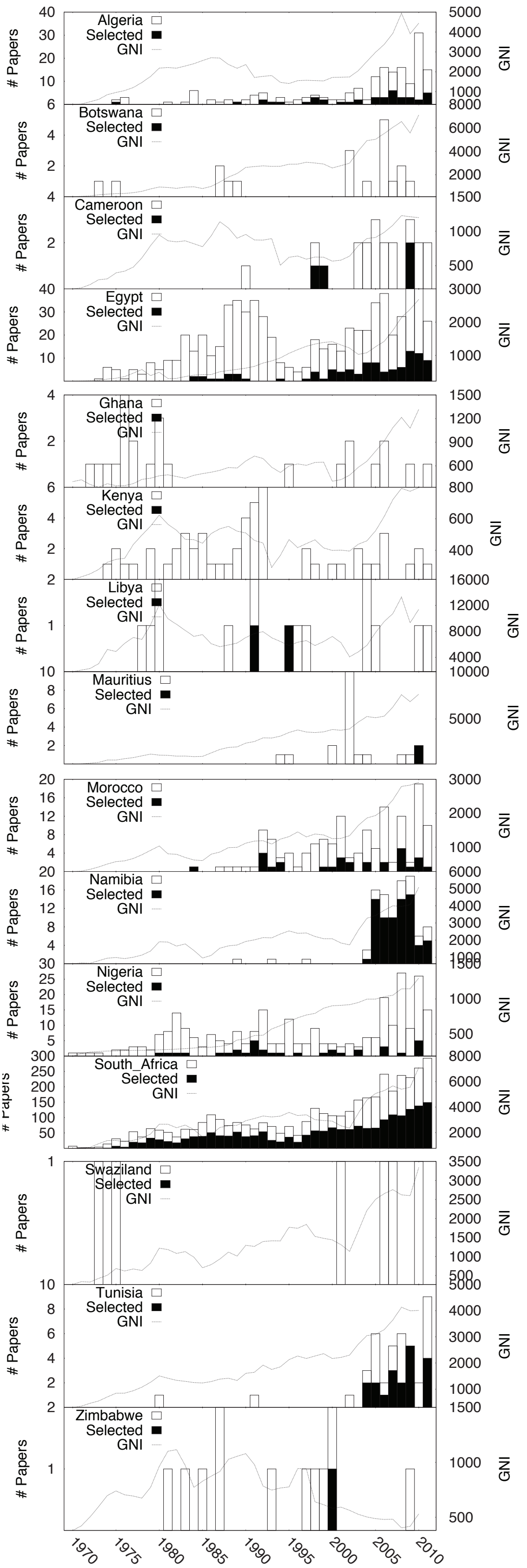

Figure 1. Results for the African continent. Shown are all the results from the ADS search (white histograms) along with the journals identified as mainstream (black histograms), and for comparison, the country's GNI (dashed line).

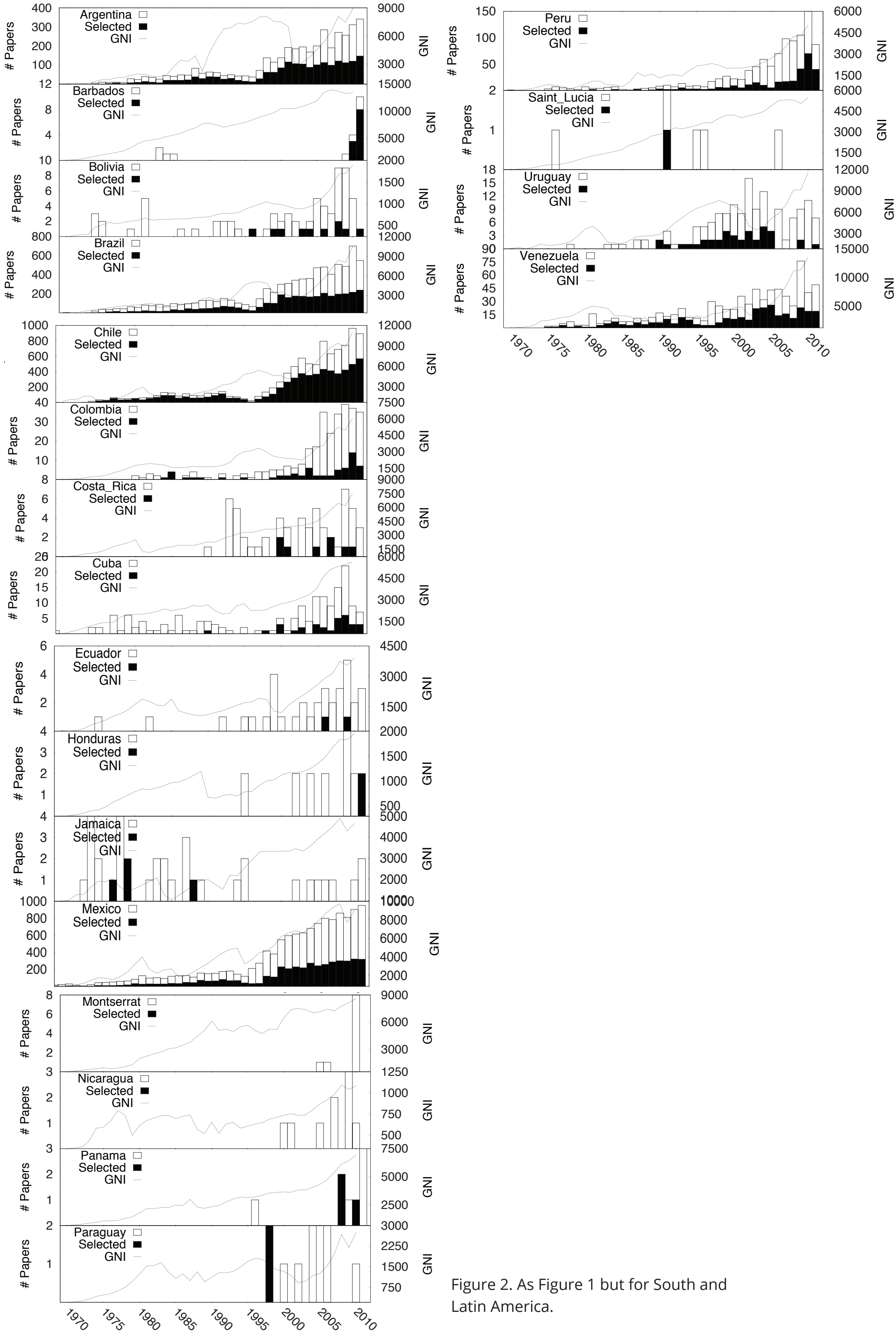

Figure 2. As Figure 1 but for South and Latin America.

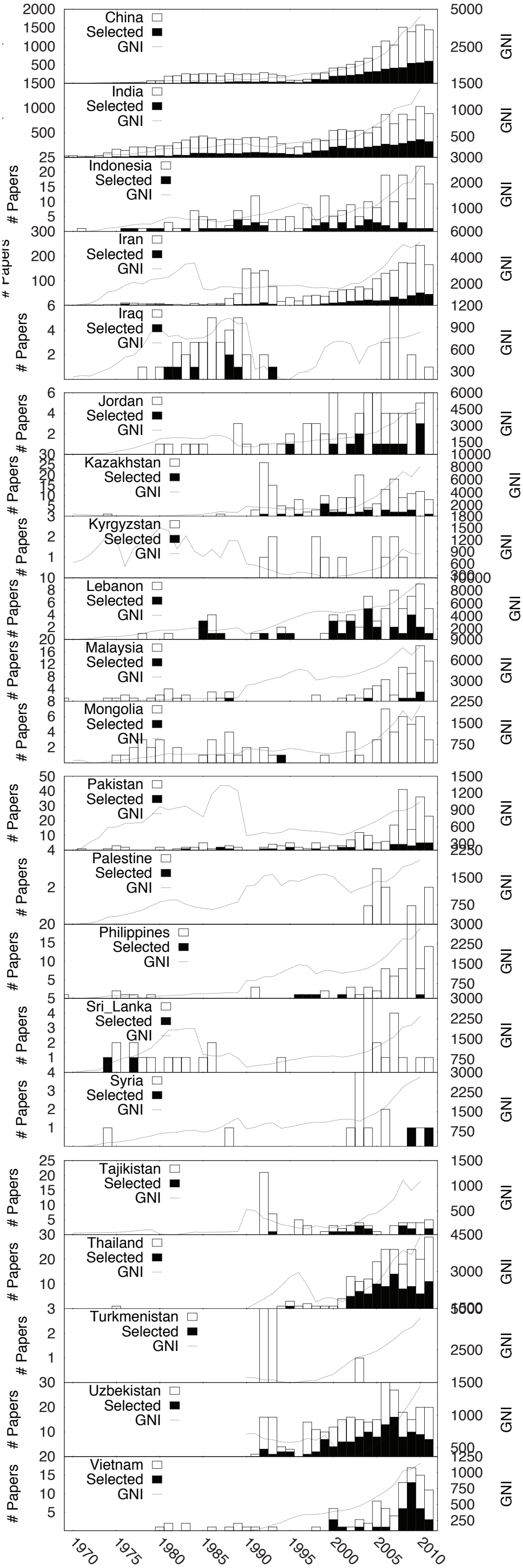

Figure 3. As Figure 1 but for Asia.

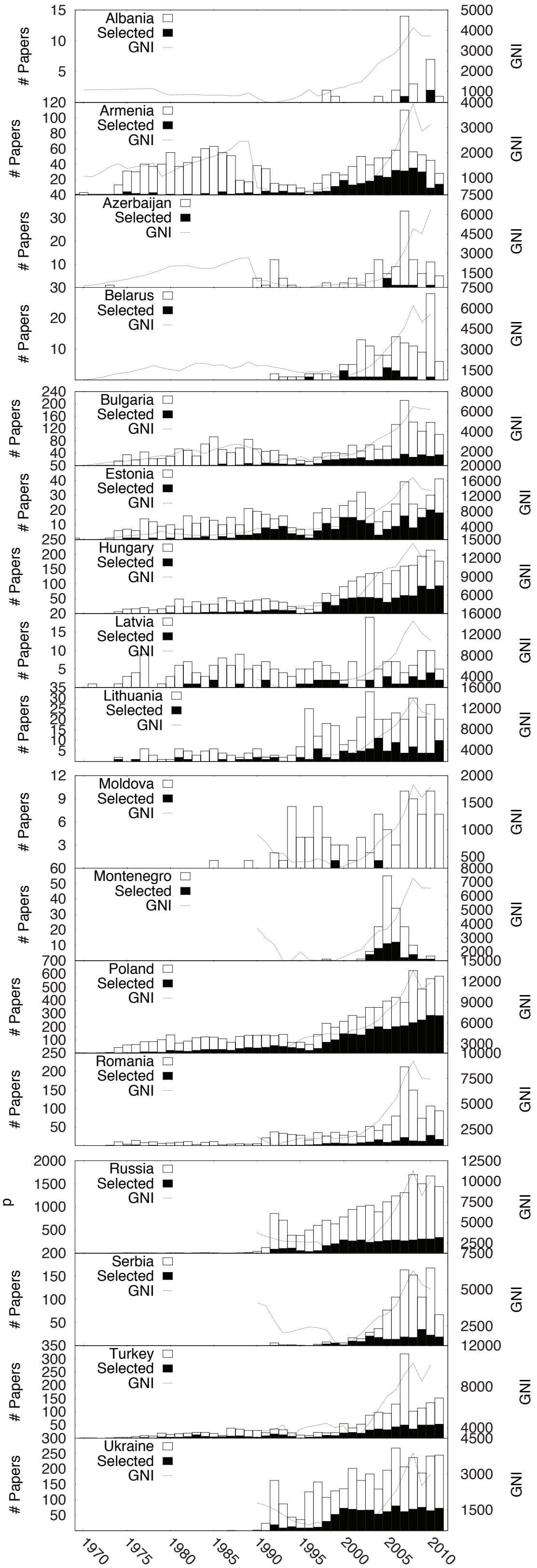

Figure 4. As Figure 1 but for Europe.

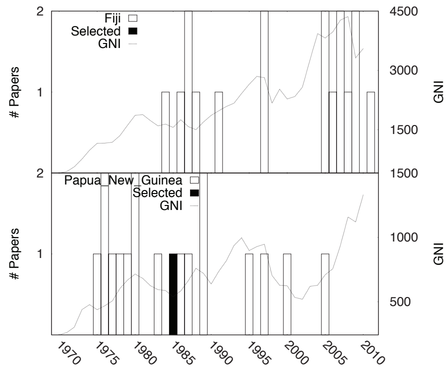

Figure 5. As Figure 1 but for Oceania.

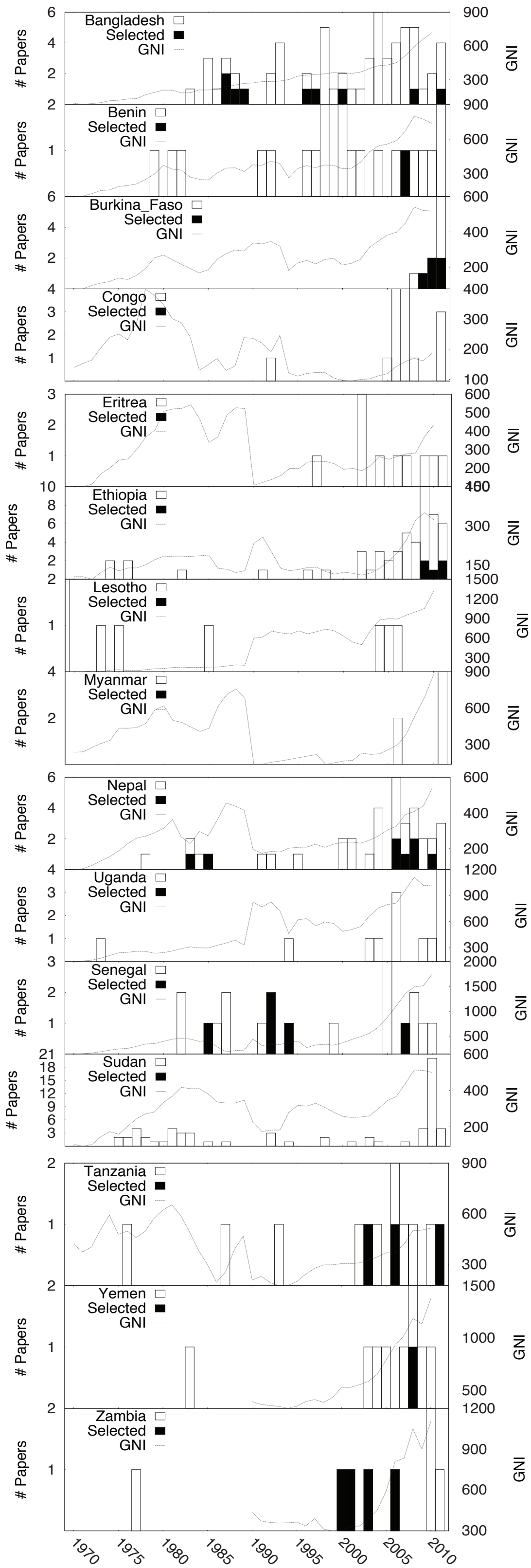

Figure 6. As Figure 1 but for the LDCs.

include results from the physics database query within ADS, which would undoubtedly increase the number of publications for any given country. Several descriptions can be made upon visual inspection of Figures 1–6, which fall into five general categories that may complement the phases described by Naicker & Govender (2009), described below:

1. Countries with a history of publishing research articles, both in astronomy and other sciences.
2. Countries with a history of publishing in refereed journals, not including astronomy.
3. Countries where the majority of research output is in astronomy.
4. Countries with little history of research publishing.
5. Countries that are difficult to place in the categories above, either due too little information and/or recent publishing activity.

4. Discussion and Conclusion

Based on the general descriptions above,most of the countries in Europe have a good history of publishing both in astronomy and other sciences, while in Africa it is difficult to say anything quantitatively except in the cases of Egypt, Namibia, and South Africa. In terms of the LDCs, more investment should be made in the general sciences and the culture of publishing. The Asian continent presents some interesting results, with countries like China and India that have a good history of publishing, both in astronomy and other sciences, and emerging countries like Thailand and Uzbekistan that publish very few papers in any of these fields. In South and Latin America, many countries have a history of publishing in both astronomy and other sciences, for example, Argentina, Brazil, Chile,Mexico, Peru, and Venezuela. Emerging countries with potential for developing astronomy further, due to an already existing culture of publishing, include Colombia and Uruguay.

We believe that the most successful country in developing astronomywill be one that already has a culture of publishing. In a number of countries, there appears to be a correlation between the country's GNI and the number of published papers. This may be related to an overall investment in science and technology, via job creation and making a country attractive to foreign scientists who may bring their expertise. To put this in the context of major projects such as the IAU Office of Astronomy for Development,[9] we believe that for a country to be successful in developing astronomy, within the lifetime of the office it should have a well-established publishing record (not necessarily in astronomy) or invest in bringing in outside expertise, which can play a leading role in implementing courses at universities to help push for more papers to be published. One immediate example is that of Burkina Faso, where the University of Ouagadougou partnered with the University of Montreal in 2006 to develop an astronomy degree and build an observatory (Carignan et al. 2011). Also, a level of investment from the country in science and technology would improve the culture of publishing and encourage individuals to disseminate their research and think critically about others' research. Similarly, Bilir et al. (2012) outlined Turkish astronomical output from 1980 to 2010, with further information about their astronomical community, including the impact of their publications. However, examples where an ethical conundrum about acquiring foreign expertise can be interpreted as a means of exchange for academic prestige (Bhattacharjee 2011, see also the various comments about the article online and in Science Magazine on 2012 March 02) tell us more about how impact factors guide general research foundations in funding an institution and/or individual. Indeed, no metric is foolproof, and important strides are being done by various groups.[10,11,12]

Education and Public Outreach (EPO) programs both on global scales, such as the IYA2009, and locally can play a key role in the development of astronomy in a country. For example, Mozambique used the momentum of the IYA2009 to develop local EPO programs and as a launching platform to develop astronomy at the university level (Ribeiro et al. 2011). Similarly, with the future construction of the Square Kilometer Array, decided between Australia and New Zealand, and South Africa and its partner countries (Botswana, Ghana,Kenya, Madagascar, Mauritius, Mozambique, Namibia, and Zambia), the African continent is gearing up for the construction of an African Very Long Baseline Interferometer.[13]

In future work we would like to quantify the role each country has played on paper, as a means to determine "leadership."Afirst indication, as mentioned above, is that a few of the countries are not leading any projects. However, we should determine what leading really means. In the era of large projects we find more and more author lists in alphabetical order, while normally the first author is the person who has played a leading role in the research. For example, the Research Excellence Framework[14] in the United Kingdom, requests that for papers with more than 10 authors, the author should explain what their contribution to the paper was regardless of whether or not they are the first author. No justification is required if the paper has fewer than 10 authors. We only concentrated on the number of published papers to identify the global level of astronomical development. However, the ADS system has a number of other outputs that may be used for various studies, for example, the number of citations, the number of authors, and their collaborations (e.g., Newman 2001). This may also be an interesting project to visualize research collaborations.[15]

5. Acknowledgements

This research has made use of NASA's Astrophysics Data System. The authorswould like to thank Alberto Accomazzi and Edwin Henneken for bringing to our attention the ADS Mighty Search. V.A.R.M.R. acknowledges the Royal Astronomical Society, UK, for various travel grants. The South African SKA Project is acknowledged for funding the postdoctoral fellowship position at the University of Cape Town.We would like to thank the community who supported the paper for their comments, in particular, Mattia Fumagalli, George

Miley, and Robert Simpson. We thank the anonymous referee for constructive comments on the original manuscript.

Appendix A: World Countries

The countries listed below are those considered for this study. These decisions were made based on a GNI of less than 14,365 USD in 2010. Those in italic are the LDCs (see also Appendix B).

Africa: Algeria, *Angola, Benin*, Botswana, *Burkina Faso, Burundi*, Cameroon, Cape Verde, *Central African Republic, Chad, Comoros*, Cote d'Ivoire, *Democratic Republic of the Congo, Djibouti,* Egypt, *Equatorial Guinea, Eritrea, Ethiopia*, Gabon, *Gambia*, Ghana, *Guinea, Guinea-Bissau,* Kenya, *Lesotho, Liberia,* Libya, *Madagascar, Malawi, Mali, Mauritania*, Mauritius, Morocco, *Mozambique*, Namibia, *Niger*, Nigeria, *Rwanda, Uganda, São Tomé and Principe, Senegal,* Seychelles, *Sierra Leone, Somalia*, South Africa, *Sudan*, Swaziland, *Togo, United Republic of Tanzania,* Tunisia, *Zambia*, Zimbabwe.

Asia: *Afghanistan, Bangladesh, Bhutan*, *Cambodia*, China, Democratic People's Republic of Korea, India, Indonesia, Iran, Iraq, Jordan, Kazakhstan, *Kiribati*, Kyrgyzstan, *Laos*, Lebanon, Malaysia, Maldives, Mongolia, *Myanmar, Nepal*, Pakistan, Palestine, Philippines, *Samoa, Solomon Islands*, Sri Lanka, Syrian Arab Republic, Tajikistan, Thailand, *Timor-Leste*, Turkmenistan, *Tuvalu*, Uzbekistan, *Vanuatu*, Vietnam, *Yemen*.

Europe: Albania, Armenia, Azerbaijan, Belarus, Bulgaria, Estonia, Georgia, Hungary, Kosovo, Latvia, Lithuania, Moldova, Montenegro, Poland, Romania, Russian Federation, Ukraine, Serbia, Turkey.

Latin America: Anguilla, Antigua and Barbuda, Argentina, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, *Haiti*, Honduras, Jamaica, Mexico, Montserrat, Nicaragua, Panama, Paraguay, Peru, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Uruguay, Venezuela.

Oceania: Cook Islands, Fiji, Marshall Islands,Micronesia, Nauru, Palau, Papua New Guinea, Tonga.

Appendix B: Least Developed Countries

The concept of LDCs represents the poorest and weakest segment of the international community.[16] The list includes 48 countries: 33 in Africa, 14 in Asia and the Pacific, and 1 in Latin America. In 2003, the Economic and Social Council of the United Nations used the following three criteria for the identification of the LDCs, as proposed by the Committee for Development Policy (CDP).

1. A low-income criterion, based on a three-year average estimate of the GNI per capita based on the World Bank Atlas method (under 992 USD for inclusion, above 1190 USD to be removed from the list).
2. A human resource weakness criterion, involving a composite Human Assets Index based on indicators of (1) nutrition, (2) health, (3) education, and (4) adult literacy.
3. An economic vulnerability criterion, involving a composite Economic Vulnerability Index based on indicators of (1) the instability of agricultural production, (2) the instability of exports of goods and services, (3) the economic importance of non-traditional activities (share of manufacturing and modern services in GDP), (4) the merchandise export concentration, and (5) the handicap of economic smallness (as measured through the population in logarithm) and the percentage of population displaced by natural disasters.

To be added to the list, a country must satisfy all three criteria. To qualify for graduation, a country must meet the thresholds for two of the three criteria in two consecutive triennial reviews by the CDP. In addition, since the fundamental meaning of the LDC category, i.e., the recognition of structural handicaps, excludes large economies, the population must not exceed 75 million.

Notes

[1] http://spinoff.nasa.gov last accessed 2012 November 02.

[2] http://spinoff.nasa.gov/pdf/Hubble_Flyer.pdf last accessed 2012 November 02.

[3] http://www.ic.gc.ca/eic/site/cprp-gepmc.nsf/vwapj/Coalition_ Canadian_Astronomy.pdf/%24FILE/Coalition_Canadian_Astronomy.pdf last accessed 2012 November 02.

[4]http://www.astronomy2009.org/static/resources/iya2009_evaluation_ guide_spocs.pdf last accessed 2012 July 20.

[5] http://www.iau.org/static/education/strategicplan_091001.pdf last accessed 2012 July 20.

[6] Developing Astronomy Globally, http://www.developingastronomy.org/ last accessed 2012 July 20.

[7] http://adsabs.harvard.edu/mighty_search.html

[8] http://data.un.org/ last accessed 2012 October 2012.

[9] http://iau.org/education/oad/ last accessed 2012 October 07.

[10] http://www.cwts.nl/ last accessed 2013 July 01.

[11] http://info.scival.com/ last accessed 2013 July 01.

[12] http://researchanalytics.thomsonreuters.com/incites/ last accessed 2013 July 01.

[13] http://www.aerap.org/africanradioastronomy.php?id=32 last accessed 2013 July 01

[14] http://www.ref.ac.uk/ last accessed 2013 August 11.

[15] http://orbitingfrog.com/post/34755190022/mapping-collaboration-inastronomy last accessed 2012 November 02.

[16] http://www.unohrlls.org/en/ldc/164/ last accessed 2012 July 20.

References

Abt, H. 2007, Scim, 72, 105

Astronomy&Astrophysics Survey Committee, Board on Physics&Astronomy, S. S. B. N. R. C. 2001, Astronomy and Astrophysics in the New Millennium (Washington, DC: The National Academies Press)

Bhattacharjee, Y. 2011, Sci, 334, 1344

Bilir, S., Gogus, E., Onal, O., Ozturkmen, N. D., & Yontan, T. 2012, Scim, arXiv:1211.4574

Carignan, C., Turbide, L., & Koulidiati, J. 2011, in IAU Symp. 277, Tracing the Ancestry of Galaxies:On the land of our ancestors, ed. C. Carignan, F.

Combes, & K. C. Freeman (Cambridge: Cambridge Univ. Press), 220

Hearnshaw, J. 2007, IAUSS, 5, 9

Henneken, E. A., Kurtz, M. J., Accomazzi, A., et al. 2009, J. Infometrics, 3, 1

Naicker, L., & Govender, K. 2009, CAPJ, 7, 14

Newman, M. E. J. 2001, PhRvE, 64, 016131

Ribeiro, V. A. R. M., Paulo, C. M., Besteiro, A. M. A. R., et al. 2011, in IAU Symp. 260, The Role of Astronomy in Society and Culture, ed. D. Valls-Gabaud & A. Boksenberg (Cambridge: Cambridge Univ. Press), 522

Russo, P., & Christensen, L. L. 2010, International Year of Astronomy 2009–Final Report (Garching: International Astronomical Union)

IV.2

The Influence of Social Movements on Space Astronomy Policy

Public engagement (PE) initiatives can lead to a long term public support of science. However most of the real impact of PE initiatives within the context of long-term science policy is not completely understood. An examination of the National Aeronautics and Space Administration's (NASA) Hubble Space Telescope, James Webb Space Telescope, and International Sun/Earth Explorer 3 reveal how large grassroots movements led by citizen scientists and space aficionados can have profound effects on public policy. We explore the role and relevance of public grassroots movements in the policy of space astronomy initiatives, present some recent cases which illustrate policy decisions involving broader interest groups, and consider new avenues of PE including crowdfunding and crowdsourcing.

Publication

This chapter is based on Harris, H. & Russo, P., Space Policy (2014); DOI: j.spacepol.2014.08.009

1. Introduction

The role of public opinion on space policy has dramatically evolved over the last half-century. The public movements discussed here illustrate a trend away from the "technocratic" view that the public is an obstacle to progress [1]. Rather, within the framework of NASA-led space-telescope missions, a new model is forming in which the "power of the people" slowly approaches that of the government.

The relationship between science, technology, and the public is complex. The innovations resulting from space exploration, research, and development are not only generally accepted, but taken for granted, by the public [2]. Yet the public remains overwhelmingly uninformed about both the workings of NASA and the federal budget dedicated to space science. While the majority of Americans rated NASA as doing a "good" or "excellent" job during the space age, fewer than half believed the Apollo program was worth the cost [3]. Most Americans additionally overestimated the budget for NASA as a percentage of the total federal budget, and believed tax dollars could be better spent elsewhere [4]. As NASA Historian Roger Launius explains, "*the American public is notorious for its willingness to support programs in principle but to oppose their funding at levels appropriate to sustain them*" [3]. While still generally true, in recent years support by the public has grown markedly more vocal. Public interest in the Hubble and James Webb Space Telescopes surpassed casual levels of curiosity – a dedicated following of space enthusiasts and citizen scientists went so far as to directly challenge the government when both telescopes faced cancellation.

Even the opposition to funding is slowly fading as is illustrated by the public adoption of the ISEE-3 mission, due in part to the rising popularity of crowd-funding for space exploration. Crowdfunding presents the public with a unique opportunity to directly impact real research and personally benefit through rewards given at various funding levels.

The three cases discussed here epitomize this evolving dynamic between space astronomy research, the public, and the government.

2. Hubble Space Telescope

In the late 1960s the astronomy community in the United States recognized the need for a large telescope positioned above Earth's atmosphere and thus plans for the Large Space Telescope were born. Later renamed after the renowned astronomer Edwin Hubble, the Hubble Space Telescope experienced a series of setbacks before attaining the celebrity status it enjoys today [5]. Particularly in Hubble's later years, the role of the public became instrumental in securing the telescope's continued success.

In 1975, the House of Representatives Appropriations Subcommittee originally denied funding for Hubble due to the project's large ticket price of $500 million [6]. Between lobbying by the astronomical community and a budget reduction of almost 50% through collaboration with the European Space Agency (ESA), NASA was able to secure funding for the telescope by 1977. As a result of a series of launch delays and the Space Shuttle Challenger accident in 1986, the telescope waited another four years before deployment into low Earth orbit by the Space Shuttle Discovery in 1990 [5].

When news of a spherical aberration in Hubble's main mirror reached the media in 1990, Hubble was painted as a failure and national embarrassment [7]. After the first servicing mission to replace the defective mirror, NASA launched a highly successful nationwide outreach campaign to rehabilitate Hubble's reputation in the public eye. The Hubble Heritage Project, beginning in 1998, oversaw the online dissemination of some of Hubble's more spectacular images of the cosmos [8]. Such images have been instrumental in increasing public awareness and interest in the fields of astronomy and astrophysics.

In the year following the 2003 Columbia explosion, NASA Administrator Sean O'Keefe announced the decision to cancel the fifth servicing flight to Hubble, citing the mission as too risky [9,10]. Without the necessary repairs, Hubble, and all scientific research reliant on the instrument, faced a bleak future.

The public, who originally mocked the faulty instrument, emerged to fight for the telescope through a public grassroots movement of "Hubble Huggers" [11]. Numerous online petitions highlighted the ways in which abandonment of Hubble would not only damage America's future as a scientific powerhouse but also tarnish public pride and interest in astronomy [11]. NASA opened an unprecedented direct dialogue with the public to explore options to keep the telescope in orbit and operational [11,12,13]. As national concern for the fate of "the people's telescope" reached an all-time high, the American Astronomical Society and bipartisan efforts by the US Senate successfully revived the servicing mission [14, 15,16]. In 2006 Michael Griffin, who succeeded O'Keefe as NASA Administrator, announced to a standing ovation that a manned servicing mission would happen in 2009, leaving the telescope functional beyond 2014 and possibly into 2020 [5,14,17].

The public's instrumental role in saving the telescope was the focus of the 2012 documentary, Saving Hubble [14,18]. The film's premiere was well timed, as another social movement echoing that which saved Hubble had just taken root. The next generation of Hubble Huggers, united under the moniker "Science Warriors," launched a campaign to save another instrument - the James Webb Space Telescope.

3. James Webb Space Telescope

In 1996, following the successful mission to correct Hubble's mirror and the long-awaited public release of Hubble's spectacular images of space, NASA turned its sights towards the future of space telescopes. The Academy of Sciences National Research Council crowned the then-called Next Generation Space Telescope as the top scientific priority of the 2001 Astronomy Decadal Survey [19].

The telescope, renamed the James Webb Space Telescope (JWST) after the Apollo-era NASA Administrator, was originally projected for launch in 2007. A series of delays pushed back the launch date by eleven years and the estimated total cost ballooned from $0.5 million in 1997 to $8.7 million in 2011, prompting the US House of Representatives Committee on Appropriations to end all funding for the telescope for fiscal year 2012 [20,21]. Massive overspending and "poor management" were cited as reasons to completely defund the project and send a strong message to NASA that there would be "clear consequences for failing to meet... expectations" [18].

This series of budget increases and launch delays risked JWST's credibility in the public eye, just as Hubble's defective mirror led the media to question NASA's competence. Of particular concern to the astronomical community was that JWST not amass negative attention as the futures of both the telescope and subsequent space astronomy missions were perceived to be at stake. The American Astronomical Society and The Planetary Society released statements in defence of JWST, setting in motion a wave of public support as the issue gained visibility in the press [22].

Reminiscent of the "Hubble Huggers" effort in 2004, a new, largely internet-led movement of "Science Warriors" [23] voiced their dismay at the project cancellation. Social media users, employing the hashtag #saveJWST, launched movements on Facebook, Twitter, Change.org, and numerous blogs and forums to remind elected officials that the public wanted JWST to succeed [24,25,26]. A large facet of the movement focused on spurring a large-scale letter-writing campaign to government representatives [23]. The efforts proved successful when a Senate Panel voted to restore funding for the JWST, allowing the telescope to continue development with a current expected launch date of 2018 [27].

4. New Trends: ISEE-3 and Crowdfunding as a Public Support Tool

The influence of the public on astronomy and space exploration extends beyond serving as a mechanism to ensure financial backing from the government. Sufficient public interest in a particular space mission can entirely replace the government as the funding agent, as has recently been witnessed.

In 1978, NASA launched the International Sun-Earth Explorer 3 (ISEE-3) spacecraft, the third satellite in a NASA, ESA, and European Space Research Organisation collaboration to study solar winds and the Earth's magnetic field [28]. After being repurposed in 1985 to execute the world's first encounter with a comet and subsequently renamed the International Cometary Explorer, the spacecraft retired to make the almost 30-year journey around the sun [29].

ISEE-3 remained operational and broadcasted continually during its orbit around the Sun, prompting NASA to consider reviving contact in 2014 as it became clear the satellite could still perform scientific research [29]. Despite the opportunity, NASA deemed the cost to resuscitate the spacecraft too large to justify the project, prompting the public and astronomical community to intercede.

To save their respective telescopes, the Hubble Huggers and Science Warriors focused on convincing government representatives to restore federal funding to NASA. However, successfully saving ISEE-3 was contingent on the citizen scientists' and space enthusiasts' willingness to completely take over the space mission.

Based out of an abandoned McDonald's building, a "Reboot Team" of citizen scientists working in partnership with private space company Skycorp approached NASA with a proposal to resurrect the spacecraft [29]. With NASA's cooperation, they planned to redirect ISEE-3 to the Lagrangian 1 stable orbit point between the Earth and Sun [28]. Once there, the probe would resume its original 1978 mission goal to study the flow of solar wind from the Sun [29,30]. In May 2014, NASA issued an unprecedented Non-Reimbursable Space Act Agreement with Skycorp to hand over the space probe to the Reboot Team [29,31].

The mission was not without challenges. NASA abandoned the capability for communication with the spacecraft in its 1999 decision to upgrade the transmitters on the Deep Space Network of radio telescopes. However, in May 2014, the Reboot Team acquired the necessary hardware and worked with the Arecibo Observatory in Puerto Rico to communicate with ISEE-3. Upon successfully redirecting the probe, a large tracking antenna and radio telescope at Morehead State University would be used for the rest of the mission, with extra support provided by the Bochum Observatory in Germany [32].

NASA additionally would not provide any funding toward the mission. Consequently, the Reboot Team launched a social media campaign to increase awareness of the unique opportunity presented to citizen scientists. With the support of space enthusiasts online, they raised nearly $160,000 for the mission through crowdfunding - $35,000 more than the original goal [30].

On July 2, 2014, the Reboot Team successfully fired the ISEE-3's thrusters for the first time since 1987 [33]. Six days later, however, they were unable to adjust the trajectory of the probe to enter Earth orbit [34]. On July 10, the team turned to the public for help, stating on the Space College website, "we have a crowdsourced research project for our ISEE-3 Reboot fans" [35]. The call for assistance caught the attention of professional propulsion engineers at large aerospace firms who offered their expertise [36]. The team resolved to let ISEE-3 resume its original orbit around the Sun and instead focus entirely on their citizen science objectives, which remained unaffected by the probes trajectory. The ISEE-3 Interplanetary Citizen Science Mission begins on August 10 as the first "citizen science, crowd funded, crowd sourced, interplanetary space science mission" [37].

As in the previous cases, blogs and social media were instrumental in amassing support for the project, and perhaps most notably reaching a public largely unfamiliar with movements supporting space science. The Reboot Team estimated that over 95% of donors to the crowdfunding campaign were “new to overt participation in a public space effort” [38].

The successful movement to save ISEE-3 is undoubtedly an accomplishment for citizen scientists and the public. The Space Act Agreement between NASA and Skycorp, the first of its kind in which a government-funded spacecraft was handed over to citizen scientists and the public, epitomizes the evolving way in which the government and public participate in and share in space science [29]. Mirroring the Reboot Team’s successful crowdfunding campaign, space enthusiasts elsewhere are adopting crowdfunding as a strategy for saving space science instruments, as is shown in Section 5.

5. Looking Ahead: Emerging Cases

Beyond these three examples, early 2014 has seen a growing number of public engagement initiatives to directly involve the public in policy issues. The University of California Office of the President announced its intention to terminate funding for the ground-based Lick Observatory by 2018 [39,40]. Often it is the case that a previous movement inspires the next, revealing the interconnectivity of these communities. Just as the Hubble Huggers set a precedent for the saveJWST Science Warriors, the recently emergent Save Lick Observatory movement benefited from support by the Science Warriors [24]. The Save Lick campaign to keep the observatory alive is simultaneously challenging the university’s decision and raising its own money through private donations [41]. A growing number of international examples following this trend have also surfaced, including Canada’s first space telescope mission, the Microvariability and Oscillations of STars (MOST) Telescope. MOST will be retired due to funding cuts to the Canadian Space Agency [42]. Like ISEE-3, MOST is still fully operational, sparking discussions of crowdfunding as a potential strategy to sustain the telescope [43].

6. Conclusions

These examples illustrate that public opinion and organized social movements do influence space policy and government funding. The trends explored here suggest that in recent years there have indeed been changes in the government-public-science dynamic, which lend themselves, upon further investigation, to a new model of understanding these relations. Social media and blogs have revolutionized space astronomy communications both between the government and the public, and among the various communities of space enthusiasts. The advent of crowdfunding has additionally opened new venues through which the public can directly engage with, and change, space policy. At present we must rely solely on anecdotal evidence from specific cases; additional work and data are necessary to fully understand the mechanisms of public opinion and grassroots movement on space-related policies.

Acknowledgements

This research was done within the framework of the Leiden/ESA Astrophysics Program for Summer Students hosted by Leiden Observatory and European Space Agency. We would like to thank George Miley, Jos van den Broek, Sophie A. Jones, Dilovan Serindag, and S. R. J. Walton for their comments on this chapter.

References

[1] Irwin, Alan. The Politics of Talk: Coming to terms with the "new" scientific governance. Social Studies of Science. 2006; 36(2): 299–320. DOI: 10.1177/0306312706053350.

[2] Irwin, Alan. Constructing the scientific citizen: Science and democracy in the biosciences. Public Understanding of Science. 2001; 10(1): 1–18. DOI: 10.1088/0963-6625/10/1/301.

[3] Launius, Roger. Public opinion polls and perceptions of US human spaceflight. Space Policy. 2003; 19(3). DOI: 10.1016/S0265-9646(03)00039-0.

[4] Alan Steinberg. Influencing Public Opinion of Space Policy: Programmatic Effects Versus Education Effects, Astropolitics: The International Journal of Space Politics & Policy, 2013; 11(3):187-202, DOI: 10.1080/14777622.2013.841534.

[5] Okolski, G. A Brief History of the Hubble Space Telescope [Online]. NASA History Division, http://history.nasa.gov/hubble/; April 18, 2008 [accessed 27.6.14].

[6] Dunar, A. J., & Waring, S. P. Power To Explore -- History of Marshall Space Flight Center 1960-1990. Washington, DC: National Aeronautics and Space Administration, NASA History Office, Office of Policy and Plans; 1999.

[7] Malik, Tariq. How the Hubble Telescope Survived Eye Surgery to Win Our Hearts [Online]. SPACE.com, http://www.space.com/8285-hubble-telescope-survived-eye-surgery-win-hearts.html; April 24, 2010 [accessed 28.7.14].

[8] The Hubble Heritage Project [Online]. STSci, http://heritage.stsci.edu/; [accessed 30.6.14]

[9] NASA Cancellation of the Fifth (SM-4) Hubble Servicing Mission [Online]. NASA Whitepaper. http://www.nasa.gov/pdf/56670main_HSM_Cancellation_whitepaper.pdf; 2004 [accessed 27.6.14].

[10] Hubble Servicing Mission SM4 Cancelled by NASA Headquarters (Internal Memos) [Online]. SpaceRef, http://www.spaceref.com/news/viewsr.html?pid=11540; January 16, 2004 [accessed 28.7.14].

[11] McKee, Maggie. Save Hubble campaign gaining momentum [Online]. New Scientist, http://www.newscientist.com/article/dn4607-save-hubble-campaign-gaining-momentum.html#.U60pU66a55R; January 27, 2004 [accessed 28.7.14].

[12] Lawler, Andrew. Attention Hubble Huggers [Online]. Science Magazine, http://news.sciencemag.org/2004/03/attention-hubble-huggers; March 9,

2004 [accessed 28.7.14].

[13] Hubble Huggers: NASA asked the public to submit ideas for saving the Hubble telescope [Online]. The Osgood File, CBS Radio Network, ACF Newsource, http://acfnewsource.org.s60463.gridserver.com/science/hubble_huggers.html; July 29, 2004 [accessed 28.7.14].

[14] Gaynes, David (Director). Saving Hubble [Documentary]. United States: American Ideal Pictures, 2012.

[15] Fienberg, R. T. How to Help Hubble [Online]. Sky & Telescope, http://www.skyandtelescope.com/astronomy-news/how-to-help-hubble/; January 28, 2004 [accessed 28.7.14].

[16] Public Law 109-155, 119 STAT. 2895 NASA Authorization Act of 2005. (December 30, 2005). 109th Congress. (Sec. 302). URL: http://www.gpo.gov/fdsys/pkg/PLAW-109publ155/pdf/PLAW-109publ155.pdf; [accessed 28.7.14].

[17] Morgan, Daniel. RS21767 Hubble Space Telescope: NASA's Plans for a Servicing Mission [Online]. The Library of Congress. Congressional Research Service Report for Congress, http://fas.org/sgp/crs/space/RS21767.pdf; May 23, 2008 [accessed 28.7.14].

[18] Saving Hubble: a new independent documentary directed by David Gaynes [Online]. International Astronomical Union, http://iau.org/scientific_meetings/iau_ga_2012/special_events/saving_hubble/; 2012 [accessed 28.7.14].

[19] National Research Council. Astronomy and Astrophysics in the New Millennium. Washington, DC: The National Academies Press, 2001.

[20] Wolf, Frank. Report 112-?? Commerce, Justice, Science, and Related Agencies Appropriations Bill, 2012. 112th Congress, 1st Session. House of Representatives. (p.72). URL: http://appropriations.house.gov/uploadedfiles/cjs_report.pdf; 2011 [accessed 28.7.14].

[21] Appropriations Committee Releases the Fiscal Year 2012 Commerce, Justice, Science Appropriations [Online]. The U.S House of Representatives Committee on Appropriations, http://appropriations.house.gov/news/documentsingle.aspx?DocumentID=250023; July 7, 2011[accessed 28.7.14].

[22] Feinberg, Rick. AAS Issues Statement on Proposed Cancellation of James Webb Space Telescope. American Astronomical Society Press Release, July 7, 2011.

[23] Sullivan, Kyle. Save the James Webb Space Telescope [Blog]. http://savethistelescope.blogspot.com/; 2012 [accessed 28.7.14].

[24] Save the James Webb Space Telescope [Online]. Facebook [Community Page], http://www.facebook.com/SaveJWST; July 7, 2011 [accessed 30.6.14].

[25] JWST [SaveJWST]. Tweets [Twitter page], https://twitter.com/SaveJWST; July 2011 [accessed 30.6.14].

[26] Sulivan, Kyle. DO NOT cancel funding for the James Webb Space Telescope [Online]. Change.org [Petition], http://www.change.org/petitions/do-not-cancel-funding-for-the-james-webb-space-telescope; 2011 [accessed 28.7.14].

[27] Leone, Dan. Senate Panel Restores James Webb Space Telescope Funding [Online]. Space News, http://www.spacenews.com/article/senate-panel-restores-james-webb-space-telescope-funding; September 14, 2011 [accessed 28.7.14].

[28] ISEE-3: An Old Friend Comes to Visit Earth [Online]. NASA, http://www.nasa.gov/content/isee-3-an-old-friend-comes-to-visit-earth/; April 14, 2014 [accessed 28.7.14].

[29] Release 14-144: NASA Signs Agreement with Citizen Scientists Attempting to Communicate with Old Spacecraft [Online]. NASA Press, http://www.nasa.gov/press/2014/may/nasa-signs-agreement-with-citizen-scientists-attempting-to-communicate-with-old/index.html; May 21, 2014 [accessed 28.7.14].

[30] ISEE-3 Reboot Project by Space College, Skycorp, and SpaceRef [Online]. Rockethub [Crowdfunding Campaign, http://www.rockethub.com/projects/42228-isee-3-reboot-project-by-space-college-skycorp-and-spaceref; 2014 [accessed 28.7.14].

[31] SAA2-402926: Nonreimbursable Space Act Agreement Between The National Aeronautics and Space Administration and Skycorp, Inc for ISEE-3 Reboot Project [Online]. NASA, http://sservi.nasa.gov/wp-content/uploads/2014/05/ISEE-3-Space-Act-Agreement.pdf; May 2014 [accessed 28.7.14].

[32] Cowing, Keith. ISEE-3 Reboot Project Status and Schedule for First Contact [Online]. Space College, http://spacecollege.org/isee3/isee-3-reboot-project-status-and-schedule-for-first-contact.html; May 15, 2014 [accessed 28.7.14].

[33] Leone, Dan. ISEE-3 Propulsion System Awakens at 11th Hour [Online]. Space News, http://www.spacenews.com/article/civil-space/41133isee-3-propulsion-system-awakens-at-11th-hour; July 3, 2014 [accessed 28.7.14].

[34] Chang, Kenneth. Space Probe Might Lack Nitrogen to Push It Home [Online]. New York Times, http://www.nytimes.com/2014/07/10/science/space/space-probe-might-lack-nitrogen-to-push-it-home.html?_r=0; July 9, 2014 [accessed 28.7.14].

[35] Cowing, Keith. ISEE-3 Reboot Project Seeks Your Help To Solve a Technical Problem [Online]. Space College, http://spacecollege.org/isee3/isee-3-reboot-project-seeks-your-help-to-solve-a-technical-problem.html; July 10, 2014

[accessed 28.7.14].

[36] Cowing, Keith. ISEE-3 Status Report 10 July 2014 [Online]. Space College, http://spacecollege.org/isee3/isee-3-status-report-10-july-2014.html; July 10, 2014 [accessed 28.7.14].

[37] Cowing, Keith. Announcing the ISEE-3 Interplanetary Citizen Science Mission [Online]. Space College, http://spacecollege.org/isee3/announcing-the-isee-3-interplanetary-citizen-science-mission.html; July 24, 2014 [accessed 28.7.14].

[38] Cowing, Keith. Education and Public Outreach: Lunar Orbiter and ISEE-3 [Online]. Space College, http://spacecollege.org/isee3/education-and-public-outreach-lunar-orbiter-and-isee-3.html; July 20, 2014 [accessed 28.7.14].

[39] Overbye, Dennis. A Star-Gazing Palace's Hazy Future. The New York Times, New York Edition; 2014, June 3 (pp. D3).

[40] Jaworski, Rob. SJAA Speaker Series - Save Lick Observatory. Bay Area Physics and Astronomy Society [Online]. Meetup.com, http://www.meetup.com/physicists/events/182014912/; 2014 [accessed 28.7.14].
[41] How You Can Help [Online]. Save Lick Observatory, http://www.ucolick.org/SaveLick/help_save_lick.html; 2014 [accessed 28.7.14].

[42] Canada's MOST astronomy mission comes to an end [Online]. Canadian Space Agency, News Release, http://www.asc-csa.gc.ca/eng/media/news_releases/2014/0430.asp; April 20, 2014 [accessed 28.7.14].

[43] MOST space telescope eyes crowdfunding to stay in orbit [Online]. Canadian Broadcasting Corporation. CBC News Technology & Science, http://www.cbc.ca/news/technology/most-space-telescope-eyes-crowdfunding-to-stay-in-orbit-1.2629994; May 2, 2014 [accessed 28.7.14].

V

Closing Remarks

This thesis has presented a study of several aspects of the design, implementation and evaluation of transnational collaborative programmes in science education and public outreach (EPO). The study is based on experiences with two large transnational innovative astronomy EPO programmes, the International Year of Astronomy 2009 (Chapter II.11) and Universe Awareness (Chapter II.2). Taken together, these projects allow several conclusions to be drawn about optimum approaches to massive science communication projects (MSCPs).

1. Summary of Results

Massive science communication projects should be based on strong and relevant science cases. They should engage with a large number of stakeholders, not only in research, academia, policy, funding and governance but also in less traditional communities, such as the arts field. It is important that the organisers of the projects at local level — usually volunteers — be given a sense of ownership and pride and appreciate the importance of the MSCP. The establishment of a centralised coordination body is essential to design, implement, manage and evaluate the MSCP and manage the volunteers. This centralised coordination body should establish a framework that can be standardised globally to gain economies of scale and scope, but should also be localised to meet local requirements and needs. Planning (including evaluation) should start as soon as the concept for the MSCP is developed. Experts in the evaluation of science communication programmes should be included in the global coordination team from the start and provide input to the MSCPs. New sources of funding also need to be sought, for example crowd funding. Crowd funding campaigns should aim to build awareness among the public, as well as to raise funds. An additional aspect of the UNAWE project has been the development of a robust framework for the relevant educational resources that incorporates peer review of both scientific accuracy and educational quality. The principles described above can usefully be extended from astronomy to other scientific disciplines.

2. Changing Aspects of Science Communication

As mentioned in the introduction to this thesis, communicating science and the results of scientific research with the public has become increasingly important for scientific researchers. We have demonstrated that the International Year of Astronomy 2009 (IYA2009) provided a new standard for transnational collaborative science EPO programmes and gave a substantial impetus to astronomy EPO activities throughout the world. The field of astronomy education and public outreach has evolved rapidly since 2009, and new techniques and technologies continue to be exploited. The community has become more organised and connected. Global programmes and projects, such as Universe Awareness have grown. The collaborative approach laid out in the IYA2009 project has persisted and the astronomical EPO community continues to cooperate in tackling important issues regardless of nationality, culture or language, mimicking the internationalisation of astronomical research.

A dramatic change of the media landscape has qualitatively changed the connection between researchers and the global public. The number of available communication channels, social media networks like Facebook, Twitter, Instagram and other similar networks are proliferating. Not only do these new media channels provide effective tools for science communicators, but they have also resulted in increased interest and a degree of active participation from large numbers of non-expert individuals (the "crowd') throughout the world and distribution of scientific results to the public at an unprecedented speed. Further research is necessary to understand the impacts of these changes (boyd 2015). While these media channels are not the first genre of technology used to engage large groups of the public, they have grown from obscurity to near ubiquity rapidly in the last years. Social media has become the favoured knowledge-sharing tool among these new information "gatekeepers", particularly young people. Furthermore, the advent of crowd-support and –funding (as discussed in chapter III.2) has opened new venues through which the public can directly engage with, and influence research.

As astronomy education and public outreach has grown and become professionalised, it has also become more diverse. It now includes such topics as teacher training, citizen science, content for science centres and museums, as well as the development of online resources. Many innovative projects presently carried out at a local level have great potential for global dissemination, but are presently limited for wider dissemination by language issues and cultural boundaries.

Although English is the lingua franca of research, it is not the dominant language of EPO. The availability of resources and training in local languages is particularly important for activities with pre-university students or the training of primary school teachers. Yet another challenge is adapting courses and resources to fit within sometimes highly rigid national and regional school curricula. This requires considerable intervention at a local level to ensure that global programmes and resources are most effectively delivered at a local scale. To overcome these problems, a balance between local and global input is needed in the development of suitable educational materials. This has been demonstrated to work effectively in the production and distribution of the Universe Awareness Universe in a Box (as discussed in Chapter III.2).

There are different levels at which to meet these challenges. One is the creation of global-wide “light-house” projects, to provide a framework for both content and activity development based on a common standard, and to address adaptation and dissemination needs. The other strategy would be to create service structures, to support the numerous individual projects taking place at a local level, with translation, adaptation, and dissemination, enabling such local projects to have a global impact. Examples of these approaches include the UNAWE educational programme (discussed in chapter II.2) and the IAU platform for peer-reviewed resources, astroEDU (discussed in chapter III.1). Service projects — particularly repositories like IAU astroEDU — need long-term support to gain long-term acceptance in the target community and achieve the desired reach.

An important goal of the IAU Office of Astronomy for Development for the next few years is to select and adapt the most innovative local astronomy EPO projects to a global scale. The potential, visibility and effectiveness of such programmes in demonstrating the social relevance of science are high and it is likely that the lessons learned by astronomers will be extended to EPO in other research fields.

Recent initiatives from the European Commission (EC) have advocated stimulating an open and flexible learning experience through the use of information and communications technology to improve education and training systems (EU Open Education Initiative), aligning them with the current digital world. In parallel, the EC has (justifiably) been demanding a more open publication process for research (Open Access) and for the production of educational resources (Open Educational Resources). These initiatives will provide easy and open access to resources and training aids, such as Massive Open Online Courses (MOOCs) and will have an impact on future science education initiatives. As discussed in chapter III.2, the development of “glocal” physical educational resources – ones that could be globally standardised to gain economies of scale and scope, but localised to meet local requirements – can also improve science education.

The need for coordination and consolidation of efforts in education and public outreach is stronger than ever before. It is important to create opportunities, and find sufficient funding, to enable key aspects of science EPO to be implemented. These include: (a) the creation of an integrated approach to science education, with joint high-level science-related literacy goals; (b) the consolidation of experiences, lessons and best practices for pre-university education in astronomy and other sciences; (c) the creation of standardised open-access science-related educational resources, including kits that can be mass-produced and localised with images, videos, educational activities, presentations and content for exhibitions and planetariums. Among possible measures that can be taken to stimulate such activities are (a) devoting a small fixed percentage of science research budgets to public education and communication; and (b) extending the one-dimensional measure of publication impact in citations to a second dimension for the measurement of EPO activities in the career development of researchers.

In summary, public engagement is critical to the future of research: a society that does not care about science will not fund it, and society will not care about science unless it engages with the subject matter. In the vision document, Vision for Science Choices for the Future – 2025, the Dutch government set the tone for the importance of public engagement for research:

A fascination for science should not be confined to scientists themselves. Appropriate communication about science and technology will keep the general public in touch with the field and abreast of developments. It will promote an understanding of the scientific process. Everyone, young and old, will be well-informed and enthusiastic about all aspects of science and technology. Science must be visible."
— Vision for Science Choices for the Future – 2025, Ministry of Education, Culture and Science, Government of the Netherlands, 2004

The astronomy community, like other research communities, must engage with the public, not only by communicating knowledge of our Universe that they derive from research, but also by contributing to culture, philosophy and economic growth through scientific and technical innovation. It also needs to promote the processes and values of science — including rational inquiry, scientific method, global citizenship and the paramount importance of evidence.

References

boyd, d. (2015), Social Media: A Phenomenon to be Analyzed, Social Media + Society, (1) 1.

Netherlands Ministry of Education, Culture and Science 2014, Vision for Science Choices for the Future – 2025, Government of the Netherlands.

Nederlandse samenvatting

Introductie

Dit proefschrift presenteert een studie naar hoe wetenschap op de meest effectieve manier kan worden gebruikt om het grote publiek te betrekken en te onderrichten. In het bijzonder wordt de rol van sterrenkunde in dit proces beschreven.

Sterrenkunde heeft een speciale plek in de wetenschapscommunicatie en het betrekken van het publiek bij de wetenschap. Het heeft een grote aantrekkingskracht voor grote delen van het publiek om een aantal redenen. Ten eerste zijn de hemel en de sterren toegankelijk voor iedereen. Ten tweede zijn astronomische afbeeldingen bijzonder mooi en spectaculair, zoals met name is gedemonstreerd door de *Hubble Space Telescope* en de *Very Large Telescope*. Ten derde gaat sterrenkundig en kosmologisch onderzoek over het ontstaan en de evolutie van het heelal – een onderwerp met een breed filosofisch karakter. Ten vierde wekt het idee van ruimtereizen wijdverbreid veel enthousiasme op over exploratie en avontuur. Ten vijfde is de gedachte dat wij niet alleen zijn in het heelal, diep ingebed in maatschappelijke denkbeelden.

Ook andere aspecten maken sterrenkunde bijzonder geschikt voor grote wereldwijde initiatieven om het publiek bij wetenschap te betrekken. De afgelopen halve eeuw is sterrenkunde een big science geworden, met observatoria die zoveel kosten, dat samenwerking tussen landen – zelfs op wereldschaal – nodig is om deze te kunnen financieren. Sterrenkunde brengt landen samen in internationale organisaties en collaboraties. Ook voor educatie en *public outreach* of publieksbereik (afgekort EPO) over sterrenkunde is een mondiale inspanning nodig, waarbij duizenden organisatoren betrokken zijn die vele miljoenen individuen bereiken.

In dit proefschrift worden de mogelijkheden, kenmerken, beperkingen en uitdagingen onderzocht met betrekking tot dit ontwerp: de implementatie en de evaluatie van internationale samenwerkingsprojecten die zich richten op wetenschapseducatie en publieksbereik (EPO). Onze sterrenkunde-case studies illustreren verschillende innovaties en het belang van een centrale coördinatie die ervoor garant staat dat grote mondiale EPO-projecten resulteren in duurzame resultaten. Tabel 3 geeft een overzicht van de onderwerpen en innovaties die worden behandeld.

In Deel II worden in detail ontwerp, implementatie en evaluatie onderzocht van twee grote sterrenkundige EPO-initiatieven: het Internationale Jaar van de Astronomie 2009 (Hoofdstuk II.1) en het educatieprogramma *Universe Awareness* (Hoofdstuk II.2). Het Internationale Jaar van de Astronomie 2009 (IYA2009) was een platform om de nieuwste astronomische ontdekkingen met de maatschappij te delen. Het benadrukte ook de essentiële rol van sterrenkunde in wetenschapseducatie. IYA2009 zal behandeld worden als een voorbeeld van een grootschalig en enorm succesvol wetenschapscommunicatieproject, waarvan we veel kunnen leren voor het ontwerp en de implementatie van toekomstige grote wereldwijde wetenschapscommunicatieprojecten.

Universe Awareness (UNAWE) is een wereldwijd wetenschapseducatieprogramma dat gebruik maakt van de schoonheid en de grootsheid van het heelal om jonge kinderen, met name met een kansarme achtergrond, aan te moedigen om zich te interesseren in wetenschap en technologie, en om hun gevoel van mondiaal burgerschap te bevorderen. We zullen verschillende innovaties in wetenschapseducatie bespreken die zijn ontwikkeld gedurende de uitvoering van dit programma, zoals *Space Scoop* – een astronomie-nieuwsservice voor kinderen – en duo-stages – een lerarentraining die gezamenlijk door een sterrenkundestudent en een pabostudent wordt verstrekt.

In Deel III bekijken we ontwerp en implementatie van twee andere innovaties in educatiemiddelen over sterrenkunde: astroEDU van de *International Astronomical Union* (Hoofdstuk III.1) en UNAWE's *Universe in a Box* (Hoofdstuk III.2). Er bestaan honderdduizenden middelen voor educatie over sterrenkunde, maar hun vindbaarheid en de kwaliteit ervan varieert sterk. Als een webplatform voor onderwijsactiviteiten in sterrenkunde pakt astroEDU dit probleem aan. Met behulp van de bekende peer-review werkstroom van wetenschappelijke publicaties, verbetert astroEDU kwaliteitsnormen, zichtbaarheid en toegankelijkheid. astroEDU richt zich op activiteitengidsen, handleidingen en andere educatieve activiteiten die zijn voorbereid door leraren, en onderwijs- en educatiespecialisten. Het innovatieve aspect van astroEDU is dat iedere educatieve activiteit van astroEDU dubbelblind is ge-peer-reviewed door zowel een docent als een sterrenkundige; dit om een hoge standaard voor zowel wetenschappelijke inhoud als educatieve waarden te garanderen. Met additionele fysieke educatiemiddelen kunnen docenten vervolgens abstracte of complexe concepten laten zien. Er is al veel onderzoek gedaan naar de voordelen van leermiddelen voor wetenschappelijke en technische onderwerpen die zijn gebaseerd op onderzoekend leren.

UNAWE's *Universe in a Box* is een sterrenkunde-leskist die is ontwikkeld om moeilijke en abstracte sterrenkundige concepten aan jonge kinderen uit te leggen door ze praktische activiteiten aan te bieden, evenals de bijbehorende materialen en modellen. De gezamenlijke ontwikkeling binnen het UNAWE-netwerk is innovatief: Universe in a Box is het eerste internationale educatiemiddel voor sterrenkunde dat wereldwijd zowel wordt geproduceerd als gebruikt. We onderzoeken de voor- en nadelen van verschillende modellen voor wereldwijde productie en distributie van dit paket voor wetenschapseducatie. We laten ook de voorlopige sociale en educatieve impact zien van een dergelijke educatiepakket, en bediscussiëren deze.

In Deel IV bestuderen we de impact van de EPO-initiatieven op sterrenkunde-onderzoek. Ook leveren we het bewijs dat gepaste initiatieven op het gebied van publieke betrokkenheid kunnen leiden tot een maatschappelijk draagvlak voor wetenschappelijk onderzoek op de lange termijn. Er is echter nog geen volledig inzicht in de impact van deze initiatieven binnen de context van wetenschapsbeleid op de lange termijn. We laten zien dat initiatieven voor publieksbereik zoals IYA2009 of grote bottum-up- of grassroots-bewegingen, geleid door burgerwetenschappers en atronomiehobbyisten , aanzienlijke lange-termijneffecten kunnen hebben op onderzoeksfinanciering en de productiviteit van onderzoek. Om dit aan te tonen, verkennen we veranderingen in onderzoekscapaciteit in ontwikkelingslanden (Hoofdstuk IV.1) en de rol en het belang van publieke grassroots-bewegingen voor het beleid van grote ruimtevaart initiatieven, zoals NASA/ESA's *Hubble* en *James Webb* (Hoofdstuk IV.2). We presenteren recente gevallen die beleidsbeslissingen rond bredere belangengroepen illustreren en nieuwe wegen van publieke betrokkenheid overwegen, waaronder crowdfunding en crowdsourcing.

Tabel 3. De in dit proefschrift besproken case studies en innovaties.

Hoofdstuk	**Onderzochte cases**	**Beschreven innovaties**	**Bijdrage van de auteur**
II.1. Het Internationale Jaar van de Astronomie als een Grootschalig Wetenschapscommunicatieproject	De noodzaak voor centrale coördinatie om deelname van grote groepen mensen die geografisch verspreid zijn, mogelijk te maken	Exploitatie van niet-professionele sterrenkundigen voor initiatieven op het gebied van publieksbereik	Exploitatie van niet-professionele sterrenkundigen voor initiatieven op het gebied van publieksbereik
II.2. *Universe Awareness* als een Transnationaal Collaboratief Educatieprogramma	Ontwerp, implementatie en evaluatie van een groot, transnationaal collaboratief programma in sterrenkunde-onderwijs	Innovaties in wetenschapscommunicatie: *Space Scoop* (sterrenkunde nieuwsservice voor kinderen) en duostages (“duo” lerarenopleidingen die gezamenlijk gegeven worden door sterrenkundestudenten en pabostudenten)	Coördinatie, ontwerp, implementatie en evaluatie van *Universe Awareness*
III.1. *Peer-review* Platform voor Educatieve Activiteiten in Astronomie	De implementatie van een *peer-review* proces om de educatieve en wetenschappelijke kwaliteit van educatieve activiteiten te verbeteren	Elke astroEDU onderwijsactiviteit is dubbelblind peer-reviewed door zowel een docent als een sterrenkundige om een hoge standaard van wetenschappelijke inhoud en educatieve waarde te garanderen	Ontwikkeling, concept en de redactionele processen van de IAU astroEDU

III.2. Ontwerp, Ontwikkeling en Impact van Fysieke Middelen voor Weten-schapseducatie	Ontwerp en ontwikkeling van een wereldwijde educatieve hul-pbron	Gezamenlijke ontwikkeling bin-nen het UNAWE-netwerk resulte-erde in *Universe in a Box*: het eerste internationale middel in sterren-kunde-educatie dat wereldwijd wordt geprodu-ceerd en gebruikt	Identificatie van de noodzaak voor dergelijke wereldwijde middelen en het toezicht op ont-wikkeling, distri-butie en boorde-ling van *Universe Awareness*
IV.1. Een Vra-genlijst over Sterrenkun-deonderzoek: een Basis voor Sterrenkundige Ontwikkeling	De impact van sterrenkunde EPO-initiatieven op de ontwikke-ling van ster-renkunde als onderzoeksveld in ontwikkelings-landen	Dit is de meest complete studie naar de ont-wikkeling van sterrenkundige onderzoeks-publicaties in de derde wereld	Co-ontwerp en analyse van het onderzoek
IV. 2. De Invloed van Sociale Bewegingen op Beleid van Ruim-tevaart	Initiatieven op het gebied van publieksbereik als katalysator de steun van het publiek voor we-tenschap op de lange termijn	Voor het eerst wordt de rol van sociale/grass-roots-bewegingen in sterrenkunde-beleid onderzocht	Co-ontwerp en analyse van het onderzoek

Samenvatting van resultaten

Dit proefschrift presenteert een studie naar de verschillende aspecten van het ontwerp, de implementatie en de evaluatie van transnationale samenwerkingsprogramma's in wetenschapseducatie en publieksbereik (EPO). De studie is gebaseerd op ervaringen met twee grote transnationale innovatieve astronomie EPO-programma's: het Internationale Jaar van de Astronomie 2009 (IYA 2009, Hoofdstuk II.11) en *Universe Awareness* (Hoofdstuk II.2). Uit deze projecten samen kunnen verschillende conclusies worden getrokken over de optimale aanpak van grootschalige programma's voor wetenschapscommunicatie (GWCP).

Dergelijke grootschalige programma's moeten gebaseerd zijn op sterke en relevante wetenschappelijke cases. Ze moeten een groot aantal van de belanghebbenden betrekken: niet alleen in het onderzoek, de academische wereld, beleid, financiering en bestuur, maar ook in minder gebruikelijke gemeenschappen, zoals in de kunstwereld. Het is belangrijk dat aan de organisatoren van deze projecten op lokaal niveau – normaalgesproken vrijwilligers – een gevoel van eigenaarschap en trots wordt gegeven en dat ze het belang van de GWCP waarderen. Het oprichten van een gecentraliseerd coördinerend orgaan is essentieel om de GWCP te ontwerpen, implementeren, beheren en evalueren en om vrijwilligers te coördineren. Dit centrale coördinatieorgaan moet een kader vaststellen dat wereldwijd gestandaardiseerd kan worden, om een economisch interessante schaalgrootte en een globaal overzicht te bewerkstelligen, maar moet ook worden gelokaliseerd om aan lokale wensen en behoeften te voldoen. Planning (inclusief evaluatie) moet starten zodra het concept van de GWCP is ontwikkeld.

Experts in het evalueren van wetenschapscommunicatieprogramma's moeten vanaf het begin af aan betrokken worden in het wereldwijde coördinatieteam en input leveren voor de GWCP's. Ook moeten nieuwe financieringsbronnen worden gezocht, bijvoorbeeld crowdfunding. Crowdfunding-campagnes moeten behalve het werven van fondsen ook als doel hebben om bewustzijn bij het publiek te creëren. Een bijkomend aspect van het UNAWE-project is de ontwikkeling van een robuust kader voor de desbetreffende educatiemiddelen die worden blootgesteld aan een peer-review van zowel de wetenschappelijke nauwkeurigheid en educatieve kwaliteit. De hierboven beschreven principes kunnen worden uitgebreid van sterrenkunde naar andere wetenschappelijke disciplines.

Veranderende aspecten van wetenschapscommunicatie

Zoals vermeld in de introductie van dit proefschrift, is voor wetenschappelijke onderzoekers het communiceren van wetenschap en de resultaten van wetenschappelijk onderzoek met het publiek steeds belangrijker geworden. We hebben aangetoond dat het Internationale Jaar van de Astronomie 2009 (IYA2009) een nieuw standaard heeft geboden voor transnationale samenwerkende EPO-programma's op het gebied van wetenschap. Ook gaf het een aanzienlijk impuls aan de EPO-activiteiten op het gebied van sterrenkunde over de hele wereld. Het gebied van sterrenkunde-educatie en publieksbereik heeft zich snel ontwikkeld sinds 2009, en nieuwe technieken en technologieën komen tot onze beschikking. De gemeenschap is meer georganiseerd en verbonden geworden. Wereldwijde programma's en projecten zijn gegroeid, zoals *Universe Awareness*. De gezamenlijke aanpak van het IYA2009-project bestaat nog steeds en de sterrenkunde EPO-gemeenschap pakt nog altijd belangrijke kwesties aan, ongeacht nationaliteit, cultuur of taal, als een afspiegeling van de internationalisering van sterrenkundeonderzoek.

Een dramatische verandering van het medialandschap heeft de connectie tussen onderzoekers en het wereldwijde publiek kwalitatief veranderd. Het aantal beschikbare communicatiekanalen, sociale media-netwerken zoals *Facebook, Twitter, Instagram* en soortgelijke netwerken, prolifereren. Niet alleen bieden deze nieuwe mediakanalen effectieve instrumenten voor wetenschapscommunicatoren, ze hebben ook geresulteerd in toegenomen interesse en een zekere mate van actieve deelname van grote aantallen niet-deskundige personen in de hele wereld – de crowd. Ook heeft het gezorgd voor een ongekend snelle verspreiding van wetenschappelijke resultaten. Verder onderzoek is nodig om de gevolgen van deze veranderingen te begrijpen. Hoewel deze mediakanalen niet de eerste technologische ontwikkelingen zijn om grote groepen van de bevolking te bereiken, zijn ze de afgelopen jaren snel uitgegroeid van iets onbekends naar iets wat overal gebruikt wordt. Sociale media zijn favoriete instrumenten geworden om kennis te delen onder deze nieuwe gatekeepers van informatie, met name jonge mensen. Bovendien heeft de opkomst van crowd-support en crowdfunding (zoals besproken in hoofdstuk III.2) nieuwe deuren geopend waardoor het publiek zich direct kan engageren met onderzoek en dit zelfs kan beïnvloeden.

Terwijl educatie en publieksbereik in sterrenkunde groeide en geprofessionaliseerd werd, is het ook meer gevarieerd geworden. Het omvat nu onderwerpen zoals het trainen van leraren, zogenoemde burgerwetenschap (citizen science), inhoud voor wetenschapscentra en musea, evenals de ontwikkeling van online bronnen. Vele innovatieve projecten die op het moment op lokaal niveau worden uitgevoerd, hebben groot potentieel voor globale verspreiding, maar zijn op het moment beperkt voor bredere verspreiding door problemen met taal en culturele barrières.

Engels mag de lingua franca zijn van onderzoek, het is niet de dominante taal van educatie en publieksbereik. De beschikbaarheid van middelen en training in lokale talen is met name belangrijk voor activiteiten met pre-universitaire studenten of het trainen van basisschoolleraren. Een bijkomstige uitdaging is het aanpassen van vakken en bronnen, zodat ze passen in de soms erg rigide nationale en regionale schoolcurricula. Dit vereist een aanzienlijke interventie op lokaal niveau om te garanderen dat wereldwijde programma's en middelen op de meest effectieve manier op lokaal niveau worden afgeleverd. Om deze problemen te overwinnen, moet een balans worden gevonden tussen lokale en globale input in de ontwikkeling van passende educatiematerialen. In de productie en verspreiding van de Universe in a Box van *Universe Awareness* (zoals besproken in hoofdstuk III.2) wordt aangetoond dat dit effectief werkt.

Er zijn verschillende niveaus waarop deze uitdagingen aangepakt moeten worden. Eén niveau is het maken van wereldwijde voorbeeldprojecten (lighthouse projects) om een kader te bieden voor zowel de inhoud als activiteitenontwikkeling, gebaseerd op een gemeenschappelijke standaard en om aanpassingen en verspreiding aan te pakken. De andere strategie zou zijn om structuren te vinden die de talrijke individuele projecten, die plaatsvinden op lokaal niveau, ondersteunen met vertaling, aanpassing en verspreiding, om er voor te zorgen dat dergelijke projecten een wereldwijde impact kunnen hebben. Voorbeelden van deze aanpakken zijn het educatieprogramma UNAWE (besproken in hoofdstuk II.2) en het IAU astroEDU platform voor peer-reviewed educatiemiddelen (besproken in hoofdstuk III.1). Dienstverlenende projecten – in het bijzonder opslagplaatsen zoals IAU astroEDU – hebben ondersteuning op lange termijn nodig om ook acceptatie van de doelgroep op lange termijn te krijgen en om het beoogde doel te halen.

Een belangrijk doel van de *IAU Office of Astronomy for Development* voor de komende paar jaren is het selecteren van de meest innovatieve lokale sterrenkunde EPO-projecten en om deze aan te passen naar een wereldwijde schaal. Potentieel, zichtbaarheid en effectiviteit van dergelijke programma's om de maatschappelijke relevantie van wetenschap aan te tonen, zijn groot: het is waarschijnlijk dat de lessen die door de sterrenkundigen zijn geleerd, gebruikt en uitgebreid kunnen worden voor EPO in andere onderzoeksgebieden.

Recente initiatieven van de Europese Commissie (EC) hebben ervoor gepleit voor een open en flexibele leerervaring, door gebruik te maken van informatie- en communicatietechnologie, om educatie en trainingssystemen te verbeteren (EU *Open Education Initiative*), in lijn met de huidige digitale wereld. Parallel hieraan heeft de EC (terecht) al gevraagd om een meer open publicatieproces voor onderzoek (*Open Access*) en voor de productie van educatieve middelen (*Open Educational Resources*). Deze initiatieven zullen leiden tot een gemakkelijke en open toegang tot materialen en trainingshulpmiddelen, zoals *Massive Open Online Courses* (MOOC's), en zullen een impact hebben op de toekomst van initiatieven in de wetenschapseducatie. Zoals besproken in hoofdstuk III.2, kunnen ook de ontwikkeling van "glokale" (glocal) fysieke bronnen voor educatie de wetenschapseducatie verbeteren, als ze wereldwijd kunnen worden gestandaardiseerd om significante schaalvoordelen te bereiken en de reikwijdte te vergroten, maar ook aan lokale eisen voldoen.

De noodzaak om initiatieven in educatie en publieksbereik te coördineren en consolideren is groter dan ooit. Het is van belang om mogelijkheden te creëren en om voldoende financiering te vinden, om ervoor te zorgen dat de belangrijkste aspecten van wetenschapseducatie en publieksbereik geïmplementeerd kunnen worden. Deze omvatten: (a) het maken van een geïntegreerde aanpak voor wetenschapseducatie, met gezamenlijke hoogstaande doelen voor wetenschappelijke geletterdheid; (b) consolideren van ervaringen, lessen en best practices voor pre-universitaire educatie in sterrenkunde en andere wetenschappen; (c) realiseren van gestandaardiseerde open-access bronnen voor aan wetenschap gerelateerde educatieve middelen, waaronder pakketten die in grote getalen geproduceerd kunnen worden en gelokaliseerd met afbeeldingen, video's, educatieve activiteiten, presentaties en inhoud voor tentoonstellingen en planetaria. Om zulke activiteiten te stimuleren kunnen onder andere de volgende maatregelen genomen worden: (a) een vastgesteld klein percentage van wetenschappelijk onderzoeksbudgetten beschikbaar maken voor publieke educatie en communicatie; en (b) de eendimensionale maat van publicatie-impact in citaties uitbreiden tot een tweede dimensie om EPO-activiteiten te meten in de loopbaan van wetenschappers.

Samengevat: betrokkenheid van het publiek is van kritiek belang voor de toekomst van onderzoek: een maatschappij die niet geeft om wetenschap zal deze niet sponseren, en de maatschappij zal niet geven om wetenschap tenzij ze zich bezig houdt met het onderwerp. In het visiedocument Wetenschapsvisie 2025, Keuzes voor de Toekomst, zet de Nederlandse regering de toon voor het belang van betrokkenheid van het publiek voor onderzoek:

"*De fascinatie voor wetenschap moet niet beperkt blijven tot wetenschappers alleen. Via wetenschaps- en techniekcommunicatie wordt de samenleving in contact gebracht met wetenschap. Dat bevordert begrip van het wetenschappelijk proces. Jong en oud raken geïnformeerd en enthousiast voor wetenschap en technologie. Het is goed als de wetenschap zichtbaar is.*" – Wetenschapsvisie 2025, Keuzes voor de Toekomst, Ministerie van Onderwijs, Cultuur en Wetenschap, de Nederlandse Regering, 2004.

De sterrenkundegemeenschap, net zoals andere onderzoeksgemeenschappen, moet het publiek betrekken. Niet alleen door te communiceren over sterrenkundige onderzoeksresultaten, maar ook door bij te dragen aan cultuur, filosofie en economische groei door wetenschappelijke en technologische innovatie. De gemeenschap moet het proces en de waarde van wetenschap promoten – inclusief rationeel onderzoek, wetenschappelijke methodes, wereldburgerschap en het grote belang van een wetenschappelijke onderbouwing.

Curriculum Vitae

Pedro Russo

Nationality: Portuguese
Date of Birth: 22 September 1977

Work Experience

2011 – present: Leiden Observatory/Leiden University, the Netherlands
International Manager of Education and Public Outreach Projects
Universe Awareness, IAU astroEDU, H2020 EU Space Awareness (2015 -2018), FP7 Teaching Mysteries with Enquiry Incorporated (2012 - 2016) and EU Universe Awareness (2011-2013).

2007 – 2010: International Year of Astronomy 2009 Secretariat, Garching bei München, Germany (ESO education and Public Outreach Department / International Astronomical Union / UNESCO)
International Year of Astronomy 2009 Coordinator / Outreach Scientist

2000 - 2006: Centro Multimeios de Espinho, Portugal
Astronomer. Content Research, Development and Production Department Coordinator.

Education

Feb. 2006 – Jul. 2007: Max Planck Institute for Solar System Research, Germany / International Max Planck Research School on Physical Processes in the Solar System and Beyond at the Universities of Braunschweig and Göttingen.

2005: Faculty of Sciences, University of Porto, Portugal
Master in Geophysics & Licenciatura in Physics/Applied Mathematics (Astronomy) Research thesis: Thermal Inertia and Surface Properties of Mars.

1995: Pêro da Covilhã Secondary School, Covilhã, Portugal
High School Degree

1987: Figueira de Castelo Rodrigo Elementary School, Fig. Cast. Rodrigo, Portugal

Awards

- 2015: Scientix Award for Best Resources in Science, Technology, Mathematics and Engineering for Universe in a Box
- 2015: Finalist of Qatar Foundation's WISE Awards in Innovation in Educations (winners to be announced in Sep. 2015)
- 2014: Scientix Award for Best Resources in Science, Technology, Mathematics and Engineering for IAU astroEDU
- 2011: American Association for the Advancement of Science - Science Magazine SPORE Award for Universe Awareness
- 2010: Portuguese National Multimedia Award for the TV show 1 Minute of Astronomy
- 2009: Seeds of Science 2009: Special Prize.

Selected Publications

Russo, P., Gomez, E., Heenatigala, T., Strube, L., 2015, *Peer-review Platform for Astronomy Education Activities*, eLearning papers, eLearning Papers #40 ISSN: 1887-1542 (article)

Ashton, A., Russo, P., Heenatigala, 2014, *Crowdfunding Astronomy Outreach Projects: Lessons Learned from the UNAWE Crowdfunding Campaign*, Communicating Astronomy with the Public journal 16 (article)

Harris, H., Russo, P., 2014, *The Influence of Social Movements on Space Astronomy Policy*, Space Policy journal (article)

Russo, P. (Ed.), 2013, *Universe in a Box Activity Book*, English ISBN: 978-94-91760-00-6 (book)

Rosenberg, M., Russo, P., Bladon, G., Christensen, L.L., 2013, *Astronomy in Everyday Life*, Communicating Astronomy with the Public journal 14 (article)

Russo, P. (Ed.), 2013, *Stella & Giotto: Kamishibai Storytelling* , ISBN: 978-94-91760-05-1 (book)

Ribeiro,V. A. R. M., Russo P., Cardenas-Avendano, A., 2013, *A Survey of Astronomical Research: An Astronomy for Development Baseline*, Astronomical Journal. (article)

Russo, P., Christensen, L.L, 2010, International Year of Astronomy 2009 — Final Report, International Astronomical Union, ISBN: 978-3-923524-65-5 (report)

Selected Invited Talks

- *IAU astroEDU,* August 2015, Invited Talk, IAU General Assembly, Division C meeting, Honolu, USA
- *The Next Light Wave: why too much light might be an issue,* July 2015, Invited Keynote, Light, from the Earth to the Stars Conference Conference, Lisbon, Portugal
- *Astronomy Education and Public Outreach for Development*, February 2013, Invited Colloquium, National Astronomical Observatory of Japan, Japan
- *Astronomy for Human Capacity Building: Children & Schools,* March 2013, Global Science, European Parliament, Brussels, Belgium

Selected Professional Activities

- President for the IAU Division C Commission C2: Communicating Astronomy with the Public, 2012 – present
- Member of the Expert Space Group for the Netherlands Space Office, 2012 – present
- Chair for Task Force: School & Children, IAU Office of Astronomy for Development, 2012 – present
- Science Advisor for the Ministry of Science and Technology of the Republic of Mozambique, 2010 – 2011
- Member of the International Astronomical Union, since 2009

Acknowledgements

During the last years I have been collaborating with amazing individuals who have influenced me greatly. This thesis wouldn't had been possible without the direct and indirect contributions of uncountable friends, colleagues and collaborators. Any attempt to list their names would be unfair and incomplete. However, I would like to express my very great appreciation to all my co-authors: Lars Lindberg Christensen, Catherine Cesarsky, Grace Kimble, Abi Ashton, Alessandra Zanazzi, Alexandra Stavinschi, Andreas Quirrenbach, Carolina Ödman-Govender, Cecilia Scorza, Deirdre Kelleghan, Eloi Arisa, Erik Arends, Kevin Govender, Jaya Ramchandani, Filippo Mannucci, Franco Pacini, Jaime Fabregat, Lara Albanese, Libby McKearney, Mark Bailey, Natalie Fischer, Sarah Reed, Sarah Roberts, Sivuyile Manxoyi, Troshini Naidoo, Rosa Maria Ros, Wouter Schrier, Ruth Versfeld, Edward Gomez, Thilina Heenatigala, Linda Strubbe, Jaya Ramchandani, Valerio Ribeiro, Alejandro Cardenas-Avendano and Hannah Harris. I would also like to thank Mara van Beusekom and Iris Nijman for the Dutch translation of the summary.

I would also like to extend my appreciation to everyone involved with the International Year of Astronomy 2009, all the members of the UNAWE team and network, the IAU astroEDU team and all the colleagues and friends that have supported me since I came to work at Leiden University, the Leiden Observatory and Science Communication and Society department.