Engaging the public with robotic and remote telescopes

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Abstract. Blackrock Castle in Cork, Ireland, houses an interactive science exhibition and astronomical observatory. A key objective of the facility is to raise awareness amongst the general public of the importance of science in modern society. Here we describe our experiences of using robotic and remote telescopes as a means of engaging the public in a two-way conversation that supports this objective. For the most part it is not the technology that poses the biggest challenges, but rather developing an operational framework that takes account of the needs and perceptions of the public. We briefly summarize two case studies that highlight public engagement initiatives in which we are involved. We argue that the time has come to capitals on the maturation of small-telescope technology as applied to changing public perceptions about science.

Keywords: class files: remote telescopes – public outreach – public science engagement

1. A role for public engagement

In recent years public engagement with science has moved center-stage in EU policy-making. In announcing the next framework for research and innovation in Europe, Horizon2020, Science Commissioner Máire Geoghegan-Quinn commented that “the new name marks another step in our endeavor to establish research and innovation where it belongs, at the center of EU policy making. To achieve that in a lasting way, we need to connect with a wider public and give our work a higher profile” (Geoghegan-Quinn 2011).

Public engagement is important for a number of reasons including: (i) it connects

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researchers to the wider society in a two-way dialogue in which both can learn from one another; (ii) it gives confidence to the public that their money is being used in a transparent manner that explains the rationale for, and outputs of, research; (iii) it inspires young people to consider careers in research (including in the humanities and social sciences, not only the traditional sciences and engineering); (iv) it informs parents so they can better understand the role of science in society and convey this to their children, even if they themselves do not have a formal science background; and (v) it provides a feedback mechanism whereby social and ethical issues can influence the research being carried out within a given society and vice-versa. Public engagement can also increase the creativity and innovation of people not only in their daily lives but also in their workplaces and can therefore be seen as fundamental to efficient societal development.

2. Why participate in public engagement?

On a personal level you may ask yourself what encourages you to participate in public engagement. Is it part of your institution’s corporate social responsibility policy; is it a means to garner support from the local community for research; does it satisfy some requirements imposed on you by funding agencies; is it a necessary part of your career development plan; is it purely altruistic? Are you engaging with the public willingly, or do you consider it a bothersome overhead on your time and effort? What return do you get or expect from public engagement? Before engaging, think about why.

More specifically, we can ask whether engagement between the astronomical community and the public can provide a quantifiable benefit to society or is merely of passing interest. For the purposes of this paper we consider this question in the context of using remote or robotic telescopes. Our comments are largely based on our experiences at our science center and observatory in Blackrock Castle, Cork, Ireland (hereafter BCO) and they may not reflect other’s experiences.

3. Public engagement through astronomy and its impact on STEM

In Ireland, as elsewhere across the EU, there has been a gradual and persistent downward trend in the number of students enrolling on science and engineering courses in higher education institutions. This decline in the interest of younger people in Science, Technology, Engineering and Maths (STEM) subjects, and the continuing difficulties with which these subjects are generally perceived amongst the population, is seen as a real threat to the future development of economies that rely on the so-called “knowledge base” for their success. There is much anecdotal evidence to suggest that technology-related companies are finding it difficult to fill vacancies with suit-
ably qualified individuals\(^1\) because the STEM foundations are lacking to a significant degree, and there is a real danger that a poor uptake in STEM subjects will adversely affect the future of the European tertiary education system, the industries that rely on STEM, and the future competitiveness of the associated employment markets.

Astronomy has several advantages as a teaching, learning and motivational tool compared to many other STEM-based disciplines: it is naturally relevant to all STEM subjects, and naturally links to how cultures view their place in the universe, our sense of who we are and how we got here; it is generally well-received by people of all ages and backgrounds, not just specialists, because we all can see the sky to a greater or lesser degree; it is a potent motivational subject in which the concepts of STEM can be explored through inquiry-based techniques; it naturally relies on cutting edge technologies and engineering; it provides an interesting environment for life-long learning for everyone and for continuous professional development of teachers; it extends beyond STEM disciplines to embrace art, culture and music; and it supports major political initiatives such as the Innovation Union for Europe adopted in November 2010 by the EU Commission and the EU strategy for research, Horizon 2020.

Astronomy’s potential to address the relative lack of interest in STEM, makes it of direct relevance to both the European educational and enterprise systems. To unlock the potential, however, we need to be sure that the methods we use to communicate with our target groups - be they primary or secondary students, teachers, community groups, local authorities, etc. - have a real and measurable impact on them. Knowing who you are communicating with, and what it is you want to communicate, are essential for successful public engagement. The methods you use must be continually assessed and as technologies change, so too must your communication methodologies. This requires you to understand not only your own area of expertise, but the changing face of the society with whom you are attempting to interact in a meaningful way. Not everyone finds this interesting, but it is crucial. And if you get involved in engagement you should be prepared to listen to your audience - they may not always share your excitement and enthusiasm for the subject. Think about that which is UNIQUE about YOUR communication channel. How do your efforts get seen - website, Facebook, Twitter? How do you generate interest in science without intimidating your audience - excellence in science might be seen to be the ultimate measure of success, but not everyone can be 'excellent' and so you have to ask how people who are 'average' feel about being constantly told of the importance of being excellent. An objective of public engagement should be to help everyone to achieve their own potential - not to discourage participation. Engagement is not about dealing only with the brightest, most motivated and hard working sections of society and therefore when measuring 'impact' one needs to remember it is a relative, not absolute, term.

\(^1\)ICT Ireland quotes 3,500 vacancies for IT professionals in Ireland in June 2011, despite the economic conditions and high unemployment rate.
4. Public engagement at Blackrock Castle Observatory

Blackrock Castle is situated on the shores of the river Lee in Cork and dates back to approximately 1593. Conservation and restoration work began in 2003 when Cork City Council bought the Castle’s lease after years of disrepair in private hands. The Council sought ideas for using the castle in a way that would be make it relevant to both locals and visitors, and which portrayed Cork as a city that embraces its cultural past and believes in its technological future. A team from Cork Institute of Technology (CIT) proposed the installation of an interactive science center and astronomical observatory and this was accepted by the Council in 2004. In our view, this was a brave decision by the Council who could have gone with a more traditional use for a (small) castle. Yet they saw the sense in highlighting the connection between science and the life of the city by using an iconic landmark building to promote science in society. The purpose and vision of BCO is: “to affect positive attitudes toward science, engineering and technology in Ireland and be recognized and respected as a center of excellence in scientific research, education and outreach”. Central to the BCO experience is a state-of-the-art exhibition that invites interactive debate on mankind’s ultimate place in the Universe. A laboratory-styled classroom allows groups to prepare and debrief before and after the exhibition experience. An on-site Education Officer facilitates all visits and workshops.

To date, approximately 180,000 people have visited BCO and 26,000 people (mostly students up to age 16) have been involved in our outreach program to schools. Some 6,000 pupils have participated in our on-site schools’ workshops and a further 5,000 have taken our on-site public workshops. (For more information see http://www.bco.ie).

5. BCO target audience

Whilst the many workshops we run are targeted at specific age groups, the target audience for the interactive science center is very broad. It includes:

- People of all ages, national and international, who can walk into the facility at any given time. The motivation for visiting the facility is varied, but the objective from the center’s point of view must be for them to have a fun, educational and rewarding experience.
- Teachers and their classes, for whom curriculum relevancy is a prerequisite for visiting the site.
- Corporate and other specialized groups for whom the exhibition needs to be customized.
- People who interact with BCO by (possibly repeatedly) visiting the website and people who engage with our social media initiatives (notably Facebook and Twitter).
6. The observatory at Blackrock Castle

BCO houses a small astronomical observatory (BCOLabs), staffed by researchers from CIT engaged in developing and applying new technologies for high precision photometry and networks of small telescopes. The close integration of the public exhibition and the astronomical observatory - facilitated by the display of research content which is updated regularly, and by a host of regular public events - gives a dynamic feel to the exhibition. Having the research team on-site means the facility is not just a place where information and experiences are recalled, but where new ideas are generated. The public have the opportunity to talk to “real” scientists, to see that the progress of research or the scientific method is not a linear predictable one, but one which can lead to blind alleys. Our experiences tell us that this is one of the most rewarding aspects of our public engagement because it brings the scientific method to life and shows the human side of research, complete with all the highs and lows of life that we are all familiar with. It also customizes the visitor experience by their individual interactions with the scientists.

BCO houses two optical telescopes, a 40-cm RCT by Meade on a Paramount ME robotic mount and a 25-cm SCT by Meade. The 40-cm will be housed in a new 4m dome in Autumn 2011 and the 25-cm is presently housed in a 4’ Robo-Dome carbon-fibre dome. Both are controlled in scheduled or unscheduled mode using standard software by Software Bisque and DC3 (ACP) along with a Davis weather station. We use different CCD cameras (Andor iXon+, Andor Luca, QSI) along with a range of standard accessories including filters and focal reducers. BCO receives approximately 70 clear nights per year.

7. Robotic or remote telescope operation and public outreach?

7.1 Robotic operation

There is no doubt that robotic telescopes are very efficient for observations where the quality and perhaps quantity of the science data gathered is the crucial factor. They can respond rapidly to targets of opportunity and are ideal for making repeated observations. Robotic telescopes are now relatively commonplace with a number of excellent “off the shelf” solutions. Our own experiences with the Paramount ME robotic mount over the past three years have shown it to be a robust and reliable system for scheduled observations.

When the observatory at BCO first opened we initially set up a routine system whereby users could select an object from a list via a web interface, make decisions about exposure times and filters (based on advice given about the magnitude of the target in different wavebands), request the observation and receive the results when they had been taken. The images benefited from the usual pre-processing (zero-biasing,
flat-fielding), though these were optional, and by more advanced possibilities, such as image stacking to improve the S/N or generating RGB color images. Our experience was, however, that these latter manipulations were rarely carried out by users from schools as they were perceived by most teachers and pupils to be too difficult and/or time-consuming. A small number of schools, with a strong science teaching ethos and an enthusiastic teacher completed the more difficult tasks, but the majority completed only the imaging (often without pre-processing). Feedback from participating schools showed that most found the selection of targets both educational and fun, but they also found the software intimidating and in those cases where the final images had been processed, the teacher was likely to have spent a considerable amount of time understanding the software before providing significant help to the students. Furthermore, the pictures had been taken at a time that was determined by the local meteorological conditions and this was often a number of weeks after the request had been made (which may not be a problem elsewhere where the meteorology is more favorable to optical observing). Consequently, the students were often unaware that it was happening. Comments such as: “like posting a request for a picture on google”, or “I was asleep when the observation was made where’s the fun in that” were too commonplace to make this a satisfactory approach. Furthermore, it was mostly the dedicated schools with a history of strong support for science, that faired better, and these were not the only schools we wanted to engage with.

7.2 Remote operation

Based on these experiences, and the fact that the vast majority of casual visitors to the interactive exhibition want to interact with a real telescope themselves, we decided to embark on a series of initiatives where telescopes were used “live” via remote operation - be that at BCO or elsewhere. Using this mode of operation we found the feedback to be much more positive. Operating the telescope in real-time, seeing it move to user generated commands is seen as “cool” and many students commented that they ‘didn’t believe I was actually moving the telescope’! Remote operation is, to date, performed by schools coming to BCO where they can be tutored by experts. This could be done via Skype with the students in their school, but we have not yet used this approach. On occasions where the observing conditions are poor, it is important to have archival images to work with, but it is also important for the students to be able to prepare the telescope and the instrument suite for observing, to select the targets, and then to physically control the telescope even if the dome is closed. Students can still take zerobias frames and dome flats in such circumstances. In addition, we have recently begun a programme to add sensors to the telescope and will do so to the new 4m dome when it is installed. These sensors - temperature, humidity, acceleration, strain - provide additional data that can be used as part of the telescope session and as part of teaching the curriculum. (For example, a slewing telescope accelerates and decelerates and has a damping period and this can be visually correlated with a contemporaneous webcam video). We have found that the critical element to success
is to actually allow the students to control the telescope and to have experts to talk them through the process. Returning groups can engage in more challenging observing or post-processing, building on knowledge previously gained. Observations made in this way give a greater sense of ownership to the observer, providing them with a unique and memorable experience.

Perhaps surprisingly, the size of the telescope does not feature highly in the feedback from the students. When asked about whether they would like to control a 2-m or a 10-m, instead of a 0.4m, the students were equivocal. The location of the telescope, however, is of interest. Telescopes that are far away, or in exotic locations, are favored and all the more so when there is the possibility of an observer to talk to at the remote telescope (see section 8 for a case study of our “Web of Stars” programme). Success rests on being able to control a real telescope in real-time. This seems to us to be a crucial point and one which should give us all great encouragement. It appears that is not necessary to use large and expensive telescope facilities for public engagement - indeed small telescopes may be just as exciting if used in the correct way. This is an example of ‘frugal innovation’ - the key is not in the financial investment as much as in how that investment is tailored to the meet the needs and expectations of the target audience(s). Students comment that they are less interested in virtual worlds, even ones which could have avatars of astronomers that guide them through the observing process, if they were not actually connecting to a real telescope. These young people - ‘digital natives’ - are very familiar with virtual world environments (e.g., Xbox, Kinect) and with gaming across continents, but they rarely get to control something tangible and this is something they understand clearly. In that sense, “real” can be more fun than “virtual” if “real” is a unique experience.

Not surprisingly, teachers require resource packs before/during/after the observing session to aid them with the experience and to enable them to answer most of the students’ questions. The content must have curriculum relevancy and must therefore be tailored to the age of the students. We have found that the context in which curricular material is presented is all-important and can assist greatly with the enthusiasm in which it is greeted. For example, teaching the electromagnetic spectrum is more stimulating to many students if they understand it in the context of the filter set they have used at the telescope and how that makes an object appear differently when they take a picture.

One lesson we have learned that appears to cross all age groups, gender and socioeconomic backgrounds is the importance of having the right people. A good tutor who accompanies an observing session, answering questions and showing enthusiasm, is hard to surpass for impact. The tutor can be drawn from a pool of volunteers who are carefully selected and trained to interact in a somewhat hands-off manner whilst giving advice on performing the observations. This allows the students to take ownership of the process as far as possible and this is well received. The volunteer pool should ideally include a number of teachers, but the general requirement remains that all volunteers should be selected as much for their people skills as their astronom-
ical knowledge. Indeed, in our experience an overly enthusiastic amateur astronomer may be inclined to take over proceedings and this is not well received.

Remote operation of telescopes is not without its drawbacks of course. It requires additional resources (mostly in terms of personnel) compared to robotic operation. The volunteers can greatly assist here in reducing the resource burden, but it still requires much greater logistical planning. And when schools are involved it is difficult for them to participate outside of school hours (which generally means they would be taking data during local daylight hours if the telescope is sited locally). Our solution to this is to use telescopes in a timezone that is roughly 6-12 hours behind our own and to take advantage of the relative ease of connecting telescopes via the Internet. The critical success factor for this to be effective seems to be to build networks of people who are willing to share their telescope time with users from another country. Long term sustainability of such networks requires there to be some advantage for everyone, possibly through a reciprocal observing arrangement. In cases where this is not possible, there may be other options such as sharing of other types of data, including data derived from cultural interactions between participants.

8. Case Study I - Web of stars

For the last two years we have been running a pilot programme called Web of Stars in partnership with the Chabot Space & Science Center, CA, USA (http://www.chabotspace.com). This is a remote astronomy project, designed to teach astronomy using a live video link and also to enable us to learn how to do remote astronomy in a way that maximizes its impact on generating interest in STEM. It was conceived to celebrate the 2009 International Year of Astronomy, as well as the 25th anniversary of San Francisco and Cork becoming sister cities. The programme takes advantage of the eight-hour time difference between Cork and the San Francisco Bay Area.

Students start preparing for their observing session in their own classroom some weeks before the session itself, which is conducted at BCO. They use the free offline software Stellarium (http://www.stellarium.org) to select targets that are observable from Cork at the time of the proposed observation. They also make decisions about exposure times, filters, etc., using a manual that we have prepared to assist the students and their teachers. This information is then relayed to Chabot Space & Science Center. On the day of the observation, the students come to BCO. Astronomers at Chabot work with the students via a Skype link to discuss the observing session strategy and use the previously uploaded information from the students to take the target images in near-realtime using their 1m telescope “Nellie”. The images are downloaded from the Chabot FTP server and analyzed locally in Cork using the free offline software Salsa J (www.euhou.net). Some of the images taken by one school can be seen on their school’s astronomy club website: http://www.mundiastronomy.ie/archives.html. In late 2010 we added teacher training workshops to Web of Stars using inquiry-based learning techniques with their
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students. Inquiry-based learning is an ideal way to create better engagement of students in a subject, and it has been shown to lead to better understanding and retention of material than traditional lecture-style instruction. The teacher workshop is designed to help them develop awareness in active learning by giving them real astronomical data, and the tools to analyze it simply and easily in their own classroom. These workshops are government accredited and count towards the professional development portfolio of teachers. Web of Stars benefits significantly from the experience of actually working in real-time with an astronomer on the far side of the world. Conversations between students and the astronomer in Chabot often begin on a technical level, but as students become more comfortable they ask questions about why the astronomer took up such a career, what it entails, what it is like to work in Oakland, CA, leading into more general questions that are driven by the interests of the students themselves. This interaction with the astronomer is a unique one for the students, thereby making the experience more memorable. There is also evidence that it positively affects the attitudes of the students towards STEM. For example, students reported:

- A better understanding of the scientific method;
- Less of a feeling of being intimidated by scientists;
- Clearer understanding of topics in the curriculum;
- More interest in taking up science subjects at second and third level;
- More interest in science generally.

One school commented: “Last year, after hearing about our visit to BCO and our participation in the video link up with Chabot Space & Science Centre at Blackrock, the intake of transition year physics students at Regina Mundi College doubled!” - John Murphy Physics Teacher, Regina Mundi College, Cork.”

Teachers are also positive about the advantages of participating in a Web of Stars Teacher Training Programme:

- Significant benefits from working with other teachers in an inquiry-based environment;
- More motivated to teach STEM concepts using non-standard approaches;
- Resource material that they can use in the classroom subsequently;
- Feeling less intimidated about the scientific method and how enjoyable it can be at the same time as being educational.

There is no doubt but that the Web of Stars programme achieves many of its objectives, but it is not without its own issues. Despite our best efforts, imaging and post-processing is still seen as technically challenging and requires teachers and students to spend a not inconsiderable amount of time studying the process if they are
to learn from it. Having tutors involved is resource heavy, and it is not always easy
to arrange to have an astronomer/operator/volunteer at the telescope. It may be that
controlling the telescope with the help of an avatar astronomer to guide the user(s), for
example, might be a more practical way forward if the Web of Stars concept is to be
extended to more schools, so long as the students really are controlling the telescope
in real-time.

9. Case Study II - Send a message to space

Remote or robotic astronomy can also be carried out with radio telescopes. Given
the rather poor meteorology in Cork, we considered this as a possible supplement to
using optical telescopes and it has the added advantage from a public engagement
perspective that radio telescopes can operate day and night. We have an exhibit in our
interactive science center called “send-a-message-to-space”. The basic idea behind
this exhibit is simple. Using a touchscreen interface, users get the opportunity to
learn about transmitting radio signals. They then get to select a star which is known to
have an exoplanet planet orbiting it and to send a radio message (which they compose)
towards that planet in real-time using a small radio telescope at BCO. We continuously
assess the response of visitors to the various elements of the exhibition and noticed
the popularity of this exhibit. It gave us the idea to extend the basic concept so that
it could be used by students from their classrooms, and to begin the development of
educational modules with curriculum relevancy to go with it.

The new application is composed of multiple hardware and software components
as shown in Fig.1. For an antenna we use a standard 0.9m satellite dish commonly
used in household and business for both satellite TV or Satellite Internet solutions
on an industrial mount usually used in the security industry for outdoor cameras.
The transmitter is a Wi-Fi dongle, which avoids possible ComReg issues, and is a
reliable and inexpensive off-the-shelf solution. Users see the radio telescope slew to
the location of the chosen exoplanet via a simple live webcam linkup, and an optical
flash signals the moment at which the radio signal is sent.

Users who send a message can track their signal by connecting to a URL on the
BCO website. They are asked to input (i) the planet to which they sent the message,
(ii) the time/date they sent their message. The website then displays (i) the time since the message was sent, (ii) the distance the message has traveled and (iii) the time to reach the target exoplanet. This element to the exhibit encourages continued interest and interaction between the student and the exhibit, long after they have sent their message. We are further developing the concept to include additional information on the webpage, for example upcoming events at BCO, breaking science news, new curriculum-relevant material, etc. The list of potential options is extensive.

9.1 The science underlying the radio telescope exhibit - not intimidating your audience

Many scientific concepts underpin sending a radio message to space, not all of which need to be introduced to the end-user for their session as too much information can be intimidating and the experience loses its impact. We have been experimenting with different interfaces which are customized for different age groups and/or different levels of background knowledge (e.g., different school groups). For most groups a rigorous explanation of the science underlying radio transmission is not necessary, but for some we can introduce challenging concepts which they can discuss subsequently, perhaps back in school. For example, although the message is beamed towards a target star, we explain that the radio signal must “compete” with the general radio frequency noise that permeates the universe. At some distance the signal strength is equal to that of the background noise and at farther distances it is less. While this does not make it impossible to detect, it does pose challenges for the “person” receiving the signal to extract it from the background noise. This introduces the very important area of signal extraction from noise, which has applications in many industries, not just space-related ones. The most important point is that the exhibit catalyses debates about signal propagation in the interstellar medium, the nature of exoplanets, the likelihood of life evolving on those exoplanets and so forth. By acting as a catalyst, we encourage teachers and their students (or the general public when they participate) to engage in a science-based discussion.

10. Response of users

Based on feedback from several thousand users the following observations can be made:

- The idea of sending a real message towards a real exoplanet is almost universally well received.
- The ability to see a real radio telescope slew to its target in real-time is crucial to the impact.
- The ability to track one’s message by connecting to a website address is very popular, with about 30% of users revisiting the website on at least two occasions since sending their message to review its progress. This hit rate could
likely be improved by upgrading the content on the web page which is presently rudimentary.

11. Discussion

Astronomy offers enormous potential to enhance the teaching of STEM subjects, and teaching STEM subjects is possibly more important now than ever. From our experiences, the use of real telescopes, not virtual ones, can unlock this potential because young people, the constituency we need to influence most if we are to educate a new generation to be scientifically literate, are completely familiar with all things virtual. It is easy for them to communicate across the globe in real-time with sound and pictures and video, and it is common to have tens, if not hundreds or thousands, of friends and followers within social media. There is a plethora of virtual sky or planetarium software that can be downloaded as smart phone applications in moments, at little or no cost. But few of them, relatively speaking, own a telescope or have access to one, and fewer still have the expertise to use one to the full. Whenever we have tried engaging the public with telescopes, the most positive feedback has been forthcoming when the telescope control is in real-time. The reason for this seems to be anchored in a sense of direct involvement in the process - being a part of the team and not merely a spectator. This is perhaps not so easy to achieve with robotic telescopes and yet these have a significant role to play in engagement with the public. Indeed there are some very positive examples of robotic programmes that work very well in this regard (e.g., Bradford Robotic Telescope).

On the negative side, remotely operated telescopes are resource hungry and require the availability of personnel to guide the operation and interaction with the telescope users. While this poses significant challenges to the sustainability of a programme (especially if you have to pay for personnel to be present when the telescope is being used), it also results in the most significant returns and from our experiences it is well worth the effort.

Nevertheless, any audiences we reach out to are likely to reach a saturation point very rapidly. Something that impresses today is not so impressive tomorrow. Once users have experienced a certain level of interaction, they expect to see at least that level, if not more, next time. The temptation is to become a slave to the onward march of technology, with bigger telescopes, larger CCDs and more sophisticated graphics. This, however, is not feasible for all of us, but more importantly it may not have the impact we think it will and it may distract us from what really works. As previously mentioned, telescope aperture is not a key discriminant of the success of an observing session, but the creative way we use it is. The saturation point reached by those who use our telescopes occurs whenever we fail to change the way we interface between our technology and the user.

There comes a time when a technology is sufficiently stable and affordable that we no longer have to spend most of our efforts in optimizing, or even fixing it, but
rather in using it. Since automated telescopes are now a mature engineering reality, we need to think about how best we can use them creatively, in a manner that engages the public on their terms, not ours. It is our view that the time is opportune to establish a network of remotely-operated small (inexpensive) telescopes, the operation of which is professionally coordinated so that they address the requirements of the end-users, noting that the requirements may vary considerably from one country to another (e.g., curriculum when dealing with schools). Such a network should:

- Be available via remote control at selected times by schools and public engagement centers in each of the participating countries;
- Be an exemplar programme, and be seen to be so at the social and political level, for increasing the interest in STEM subjects amongst students;
- Be a best-practice example of cooperation in STEM education amongst the participating countries;
- Catalyse the development of educational material that can be customized for use across the participating countries and representing excellent value-for-money;
- Be free to use.

The network should also:

- Facilitate cultural interactions between groups using the telescopes;
- Assess the impact of new initiatives to see what works and what does not;
- Involve local authorities and other local actors.

At the beginning of this paper we asked what the motivation for engaging in public science outreach might be for you or your institution. For us, the reason is simple. If we do not have people who can solve the ever-changing array of challenges that we face, from climate change to healthy aging and energy security then we have little chance to build a strong and equitable society. The stakes could hardly be higher.

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References