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From e-Science for Children to e-Services for Educators

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Abstract

We provided teachers and young scientists with 'e-Science like' experiences and asked them to reflect on how the technologies employed might be used to support learning at school. Our aim was to scope the kinds of services that might facilitate contact and collaboration between schools and science researchers. We ran five sessions each involving live communication with remote scientists, use of mobile sensing equipment to gather and submit local pollution data for visualisation and analysis and the investigation of a remote sensing device in the Antarctic. On the basis of this experience, we are beginning to define some e-Services, which would help science teachers to bring real research and researchers into the classroom. Such services provide opportunities for learner-directed learning. However, we believe their real value is their potential to bridge the gap between school science and university research – broadening awareness, changing attitudes and possibly motivating learners towards scientific research.

Keywords: learning service requirements, public awareness of science, constructivist learning, motivation

Introduction

Grid Interfaces for Environmental Science

The Equator (Equator, 2004) "Advanced Grid Interfaces for Environmental Science in the Lab and in the Field" e-Science projects are demonstrating how data, captured from remote sensors on an Antarctic lake (Benford et al, 2003) and mobile CO sensors deployed in an urban environment (Steed et al, 2003) can be integrated with other data sources and accessed on a global scale by scientists able to visualize, manipulate and share the data from any location. Henceforth we shall refer to these two as *the Antarctic remote sensing project* and *the urban CO monitoring project*. Both these activities are exploring the ways in which diverse mobile and distributed sensors and devices, connected to a large scale distributed computing infrastructure, can support new forms of scientific enquiry. This vision of e-Science emphasises the need for scientists to be able to manipulate and share data from any location whether in the lab or in the field and also the need to enhance current labour intensive approaches to observation and measurement with automated capture and sensing technologies that deliver more detailed, timely and continuous data.

Public Understanding of e-Science for Schools

Our work forms part of the strategy to support public understanding for the projects described above. We developed materials and activities for 'e-Science' sessions, which we ran at Sussex University with small groups of young scientists (14-16 year olds) and teachers. Although, the content of our sessions related to the Equator e-Science projects our intention with the sessions was to provide teachers and young scientists with an 'e-Science like' experience and prompt them to reflect more generally on the potential roles of the technologies employed both in scientific research and in their own school learning and teaching. We were not evaluating any particular tool, rather increasing awareness of e-Science and investigating the range of activities and technology that might support collaboration, communication and learning between school scientists and research scientists.

The e-Science Sessions

These sessions very much promoted a learner centred constructivist approach; activities were designed to provoke the learners to ask questions and construct answers of their own through interaction with each other, research scientists, teachers, real data and devices. During the sessions, participants communicated live with remote and distributed scientists in the Antarctic, London, Nottingham and Australia, they investigated the remote sensing device on the lake in the Antarctic and accessed data from its 'grid-enabled' sensors, they used mobile Carbon Monoxide and GPS sensing equipment to gather pollution data from the local environment and they investigated advanced representations of their own and others data generated by a spatial visualisation service (Steed et al, 2003). The equipment, data and research scientists involved were drawn from the Equator e-Science projects. After each session we asked teachers and learners how they felt the technology and activities employed in the session might be used to support learning at school.

Services for Educators

Participants in the sessions were enthusiastic about bringing this kind of activity into school; communicating live with real scientists, accessing and contributing to remote research data, and making use of tools for visualisation of the data they collected. However, teachers identified practical difficulties in setting up and running such sessions within the school context. Our experience of setting up and running these sessions has led us to reflect on what it would take to make such experiences more widely available. What kinds of technological services might enable teachers to bring 'real research and researchers' into their classrooms on a regular basis? This paper describes the 'e-Science' sessions we ran, reactions to these sessions and our initial conception of services that could support teachers wishing to provide similar experiences for learners at school. We believe such services have the potential to bridge the gap between school science and university research – broadening awareness, changing attitudes and possibly motivating school children towards scientific research.

The e-Science Sessions

Overview of the Sessions

We ran five 3-hour sessions in a laboratory and outdoors on the University campus with a total of 43 'gifted and talented' young scientists (14-16 year olds) from two schools. 'Gifted and talented' refers to the fact that these students are selected as being in the top 10% of their year group for science. The sessions were run in two periods of approximately one and a half hours with a 15-minute break between periods. The first period focused on *the Antarctic remote sensing project* and involved interacting with remote experts and data and the use of web-based materials to support the learners' research. The second period focussed on *the urban CO monitoring project* and involved learners collecting local CO readings with handheld sensors and location data with GPS devices and generating visualisations of this data using software and equipment from *the urban CO monitoring project* strand of the Equator e-Science project. The overall intention of the sessions was to involve the learners not only in thinking about the technology involved in these projects but also in using the technology within the context of their own 'e-Science' like experience. A guiding principle throughout the sessions was that we would not give learners details about the e-Science projects. Rather we challenged them to think about what these projects might be trying to do, to find out as much as they could for themselves and to decide for themselves what e-Science might be. We wanted their own interest to drive their research and construction of ideas and knowledge about the projects and technology involved. To support this process, we developed structured tasks, web-based materials (Underwood et al, 2003) and set up practical activities.

e-Science Session Activities	Time
Antarctic Remote Sensing • Discussion of images relating to e-Science • Web-based investigation of Antarctic remote sensing device and formulation of questions for experts • Questions & Answers using MSN Messenger text chat with (1-3) researchers • Make predictions about Antarctic data. Access, retrieve and plot the device data.	1.5 hours
Break	

Mobile Sensing • Speculation about how 5 *the urban CO monitoring project* images might be related. • Investigation of CO pollution around campus using handheld mobile sensing device (CO sensor / GPS / PDA). • Web-based investigation about the effects of CO and standard monitoring data available online for the local area. • Upload and visualisation of young scientists CO & GPS data. Reflection on the activity and representation of the data. • Text chat with an *urban CO monitoring* project researcher. • Reflection on the session and possible uses of the technology and activities in school.	1.5 hours

Table 1. Outline of e-Science Sessions.

Remote Sensing in the Antarctic

In order to stimulate interest and motivate the learners to find out about the e-Science projects we deliberately used 'ambiguity' (Gaver et al, 2002). At the start of the session we used ten images (of equipment, locations, scientific activity and data representations) related to *the urban CO monitoring project* and *the Antarctic remote sensing project* as stimuli to engage learners. Pictures were not captioned or explained in anyway. We asked the learners to talk to each other about what the images might show, how they might be related and how the technology pictured might be used for research. We also asked them to separate the images in to two groups of five, one group relating to each of the two e-Science projects. We challenged them to create their own understanding of these projects. They began to formulate and ask their questions and discuss how they might find answers. They then worked in pairs at PCs using our structured web-based investigation about the Antarctic device to find answers to their initial questions (e.g. where is it? what does it do? who put it there?). The web-based materials (Underwood, 2004) for this part of the activity show interactive images of the Antarctic device and gradually reveal details about the sensors it houses. These materials also link to web pages relating to *the Antarctic remote sensing project* research. During this part of the session the learners were prompted to note down any new questions arising from their gradually increasing understanding of the device. We also told them that they would have the opportunity to ask their questions to research scientists involved in the project. We identified some of the researchers they would have the opportunity to 'chat' to in photographs taken in the Antarctic.

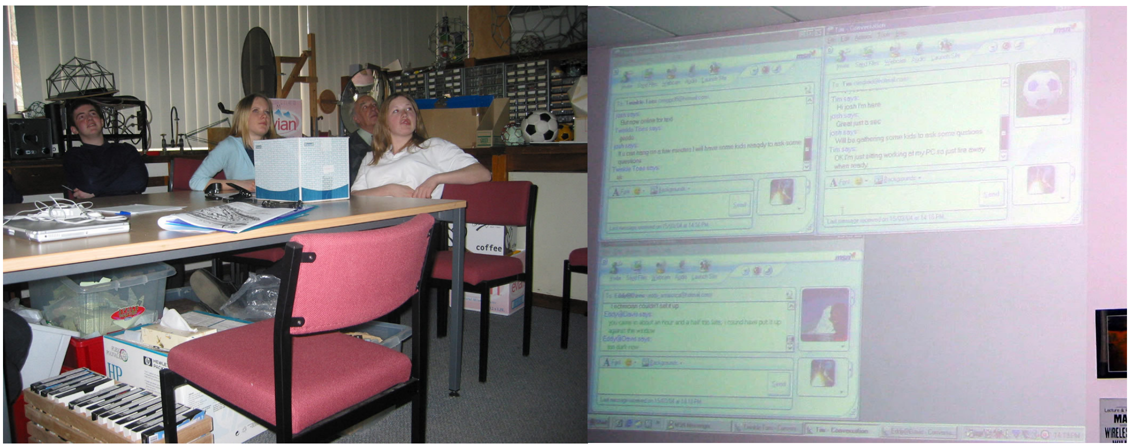

Figure 1. Learners engaged in 3 text chats with researchers in Nottingham, Antarctica and Australia

Communication with Science Researchers

We then used MSN Messenger™ to establish live text conversations with 'globally distributed researchers' during the sessions. The researcher arranged times, checked availability, and clarified expectations with the expert participants well in advance. Typically, we had two or three chats running simultaneously and projected these on a large screen (see figure 1). We used multiple simultaneous chats so that whilst students were waiting for an answer to be typed by one participant an incoming answer from another participant might arrive, different areas of expertise could also be covered by this strategy and learners could get more than one perspective on questions such as 'What's it like living in the Antarctic?' The experts were located in the Antarctic, Nottingham and Australia at the time of the sessions. Our young scientists were made aware of the location and area of expertise of each participant. The learners sat as a group around a large table and discussed and shouted out their questions, indicating whom they would like to ask. As conversations developed they formulated and asked new questions. Teachers were also present and occasionally interjected with suggestions, prompts and questions of their own. All questions were typed into MSN Messenger™ at the learners' end by one of the authors.

Antarctic Device Data

Time permitting and after the chat with experts, learners had the opportunity to download and investigate data from the grid-enabled Antarctic device via a web interface (Egglestone, 2004). Typically, we asked learners to predict the shape of a graph showing data from the device (e.g. change in ice thickness over the year or variation in UVb intensity over time). They would then acquire suitable data from the web interface to the device, use Excel™ to graph this, compare this graph with their prediction and then try to explain any differences. Often, this period finished with learners, teachers and researchers exchanging ideas about the possible benefits of the device for Antarctic research.

Mobile Local Pollution Sensing

In the second half of sessions, learners returned to the original stimulus images and re-examined the five that related to *the urban CO monitoring project*. We asked them to explain how they thought these images might be related. Having identified that the project involved collecting and representing Carbon Monoxide pollution data, they studied a map of the campus and decided where they thought it would be most interesting to take CO readings. They also discussed the factors they felt might influence CO levels (e.g. proximity to roads, wind speed, etc). We then organised the learners into groups (2, 3 or 4 people) and equipped each group with an integrated sensing device (GPS, PDA & CO sensor – left-hand side of figure 2), a video camera, an anemometer (for wind speed measurement) and a map for recording their observations. The sensing devices record location and CO levels every second. A researcher and/or teacher accompanied each group. If necessary, the adult participant in the group prompted the learners to reflect on the significance of the readings they were getting and to record observations. Video was recorded continuously during the approximately 20-30 minutes each group was out.

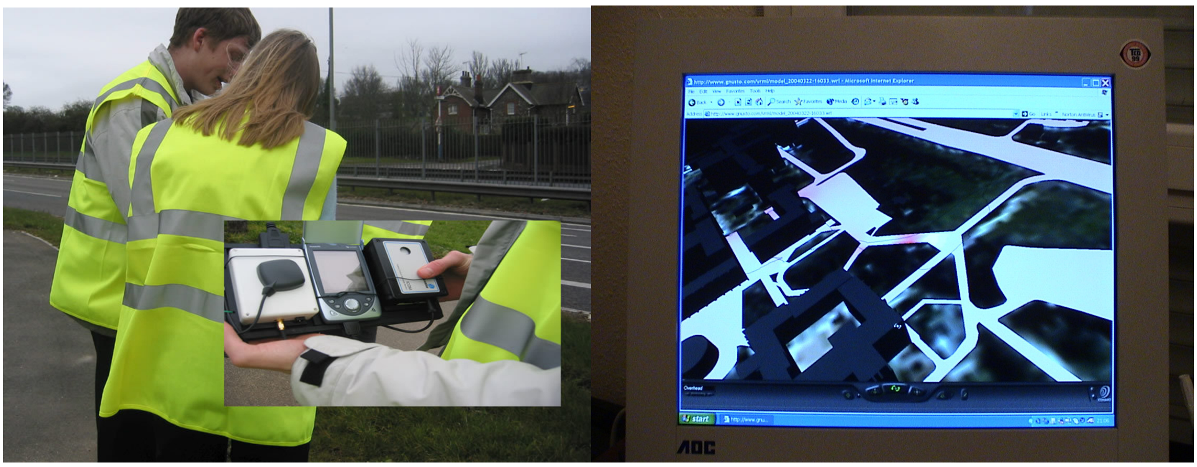

Figure 2. Learners gathering and exploring CO data in the field and in the lab

Pollution Data Visualisation and Analysis

On their return to the laboratory learners followed a worksheet, which asked them to find out more about CO (what are dangerous levels, why is it dangerous, etc) and to investigate the local and national CO monitoring data available online. Meanwhile, we transferred the data they had collected from the sensing device to their PCs. They then used a web interface (Phelps, 2004) to the spatial visualisation software to upload the data. This uses Ordnance Survey data to generate a 3D representation of buildings in the local environment over a photographic map (see right-hand side of figure 2). It also draws the path the CO sensing device has travelled along (a blue line) and represents the variation in CO levels as shades of red on roads and paths (redder for high levels, whiter for lower levels). Learners explored this visualisation of their data using a web-browser with a VRML plug-in. They naturally compared this to their own experience and observations. Time permitting; learners were able to ask a researcher from *the urban CO monitoring project* questions about the sensing device and the visualisation software, again using MSN Messenger™.

Reflecting on the Sessions

Finally, we asked learners to complete a feedback form and to reflect on what they now thought 'e-Science' might be and how they thought the technology might be used in school science teaching and learning. We also explained that the data they had collected, 3D representations, their work and transcripts of conferences would be collated on a website which they and other learners could access at a later date. This website would also include a web-based forum on which they could ask any remaining and new questions asynchronously. Our intention with this website is to prompt learners to re-visit and reflect on this e-Science experience at a later stage and to allow us to access thoughts on how this kind of technology might be used to support their education. We also believe that by providing the kind of resource the learners might visit from home we may broaden the impact of our public understanding work to include not just the young scientists we are working with but also their parents and friends. After each session we talked to the teachers who had been at the sessions, topics covered included perceived benefits to participants and issues teachers felt might be involved in running similar sessions in school. We also recorded interaction with the web-based resources, participation during the chat with remote experts, the outdoor CO sensing activity and some of the discussions during the sessions.

Results

We have a rich data set, but are still in the early stages of transcription and analysis of much of this material. Data include video recordings of the CO sensing activities and some of the classroom discussions and activities, transcripts of all the MSN Messenger™ chat sessions, and written feedback from many of the learners. We cannot at this stage offer any detailed analysis of learning interactions during the session. However, we can comment on teachers' and learners' reactions to the activities and to the sessions overall. We also summarise learners' written explanations of what they felt e-Science to be and how they felt similar technology might be used in school.

The Teachers' View

Four teachers attended the sessions. One very experienced teacher was present at all five sessions, another was present at two sessions and the other two attended one session each. All teachers expressed general enthusiasm for the sessions and the activities involved. Two mentioned that they felt that learners had been engaged and challenged throughout the three-hour session and that given the length of the session this was a significant achievement. When asked what they felt participants had learnt two teachers identified one possible benefit of the sessions to be that some learners might remember and apply the data collection methodologies employed (automated remote sensing and mobile location sensitive data collection and visualisation) to similar but unrelated problems at some future stage in their careers. In support of this two learners explicitly stated that they felt they had learnt how GPS and other sensing data could be used together. Teachers also suggested that the learners' awareness of possible areas of university study and research might have been broadened. There was also a suggestion that these kinds of activity would be useful for engaging 'bright' but less motivated children and for attracting children to the study of science at university. Teachers were enthusiastic but identified potential difficulties they would have introducing such activities in the classroom; such as handling the technology, finding researchers willing to participate, research data relevant to the curriculum, etc. They pointed out that although registers of 'science communicators' willing to give talks existed they knew of no such equivalent for experts willing to participate in online chat and/or video and audio-conferencing. They felt the amount of effort and time required to reproduce activities like those in these sessions and ensure their relevance to the curriculum would be impractical for most teachers to undertake.

The Young Scientists' View

A total of 43 young scientists (14-16 year olds) from two schools attended the sessions, between 6 and 12 at each session. They provided opinions in discussion at the end of each session and some also provided written feedback. Teachers felt that the students had been engaged by the activities and learners were generally very positive at the end of the sessions. Those learners that completed feedback forms all indicated they had enjoyed the sessions. Negative comments were entirely confined to disliking having to wear high visibility safety jackets for the outdoor activity, not having enough time to complete some activities and complaints about occasional technology breakdowns. Learners were also asked to comment on what they had most enjoyed about the sessions. They typically mentioned talking to research scientists using chat, using technology and going out to gather their own data. Selected examples are given below.

What did you enjoy most about today's session?

"The CO survey and conferencing", "Going out in the field", "Conferencing, I liked using the technology and measuring CO levels", "Talking to (one of the experts), she was interesting", "Using technology in conjunction with science", "Talking to scientists over England".

What is e-Science?

We asked learners to describe what they thought e-Science might be directly following the sessions. As would be expected answers were biased towards the kinds of activity involved in the sessions. Learners generally focussed on the potential benefits of global access to and sharing of data and remote communication with scientists and did not mention for example, access to super computers or distributed processing. Selected answers follow:

"e-Science is the use of computers/sensors to get measurements that would be impossible (or at least very difficult) for humans to collect. It might also allow people to contact each other across the globe", "e-Science is using ICT and technology to support science research. It helps scientists find out more information which they might not have been able to find", "e-Science is carried out by distributed global collaborations enabled by the Internet", "I think that e-Science is science with the aid of powerful computers and mobile technology to access many science related things – electronic science", "I think e-Science is finding new easy ways to collect and record data quickly and easily using the latest technology, such as sensors and 3D maps".

How could e-Science be used in schools?

We also asked how technology might be used at school to improve science classes. Learners typically indicated communication with others at a distance (experts and sometimes other schools) and access to research data as being things they would like to introduce into school science sessions. Selected examples of their suggestions are given below:

"Students could have instant access to professional opinion online anytime", "I think that e-Science could be used as a way for schools to communicate with each other on the internet and as a way to share information", "We could talk to scientists that are researching the same topics we are doing in school", "I think we could use this technology to do research in school", "In schools we could find out more of our own data in our local environment. Also, we could research more information from remote sensors", "… research in school would be more interesting and would also allow more complex scientific experiments", "I think that it could be used in schools as an extra way of learning about what scientists do and how they go about finding it out", "I think e-Science could be used in schools through e-lessons such as virtual experiments where results could be taken and shared to other people around the globe", "e-Science could be used in schools to do long experiments where you need to record information over a weekend or long periods", "Information could be sent through electronic communication from places far away for the students to use and understand".

Summary

It seems that many of the learners at these sessions were able to generalise from their experience of e-Science like activities relating specifically to the two Equator projects and see opportunities for using similar activities and technology to support scientific research and learning more generally. Also, both the participating teachers and learners were clearly enthusiastic about the sessions we conducted and would like to bring similar activities into the classroom. They believe communication with remote science experts, access to remote sensors and data and tools for collecting and sharing local data with remote others would enrich the school science learning experience. However, teachers were clearly concerned about the practicalities of setting up and conducting similar activities in schools.

Discussion

These issues led us to consider the possibility of developing a service or family of services that would make experiences like these easy to reproduce, tailor-able and potentially 'normal' parts of the science classroom. We, like Allison (Allison, 2003), believe real-world input should be easy to incorporate into learning. We also believe that this kind of activity might be capable of reducing the perceived distance between school and university and raise school-aged learners' awareness of university research science. One of our hopes is that by enabling communication between school children and researchers and providing them with access to real research and insight into university science more learners might be motivated towards studying science.

Easing the Burden of Preparation

To be useful to teachers the services we are proposing would need not only to support remote collaboration, data sharing and visualisation but also to perform much that, for our sessions, was done through human conversation; e.g. finding, contacting, checking availability of experts for chat sessions, etc. We feel it is useful to describe what we want to build for teachers as services, as distinguished from products, for many of the reasons that Cerri (Cerri, 2003) identifies; what is required is dynamic, the service users goals need to be negotiated on the fly through conversation with the service and will vary from session to session, and certainly the services we propose need to build a relationship of trust. For clarification, an example of the kind of service we propose might in human terms be described as a 'good networker'. Such a service would have responsibility for finding and negotiating successful contact between on the one-hand educators and their associated learners and on the other researchers and associated research projects. In order to establish successful collaborations such a service would need knowledge of both parties interests, availability, the communication technology available at both ends (webcam, audio, video conference, text only). The service might also need to make introductions, clarify expectations, negotiate mutually convenient contact times, remind about engagements, suggest alternative contacts, etc. Such a service would need to be adaptive to the needs of participants, the learning context and the available resources. And might be expected, over time to learn about its users and tailor the options it offers more appropriately. Like the Broadband User Model proposed by Luckin and du Boulay (Luckin & du Boulay, 2001) this service would need to coordinate not only digital but also the physical and human resources appropriate to the learners' current circumstances.

Towards some eServices for Educators

Our route towards defining these e-Services for educators is similar to the Service Elicitation and Evaluation/Exploitation Scenarios (SEES) service development life cycle (Cerri, 2003). This identifies 5 phases, (1) Service Motivation for Service User Scenarios (SUS), (2) Service Definition through SUS, (3) Service Use by SUS, (4) Service evaluation by SUS, (5) Service abstraction by SUS and Service Developer Scenarios (SDS). The SEES life-cycle usefully distinguishes between services described at the very high level (e.g. contact management) that is intelligible to service users and useful in the development of Service User Scenarios (SUS) and services described at the much lower technical level (e.g. authentication for peer-to-peer access) that is useful to service developers in Service Developer Scenarios (SDS). The higher level services proposed might appropriately be built on lower level Open Grid Services Architecture (Foster et al, 2002). But we are not yet concerned with implementation. Our 'e-Science' sessions, facilitated by experts and using the web for data access and MSN Messenger™ for communication, have allowed us to demonstrate the possibilities to teachers and learners and have provided us with common ground to enable further conversation. These sessions have established a well-founded motivation for development of the services we propose, corresponding to phase 1 of the SEES life cycle. We are now moving into phase 2, service definition, in which we intend to widen our conversations with teachers and learners and collaboratively develop Service User Scenarios. As a first step we propose three related services for which we wish to begin to develop definitions and scenarios. These might be called:

- The Science Expert Contact and Communication Service
- The Research Data Access Service
- The Data Sharing and Representation Service

An Example - The Science Expert Contact and Communication Service
At first it may seem that this Contact and Communication Service could be adequately provided using existing services such as MSN Messenger™. Why can't teachers just use MSN Messenger™ at school, get in touch with a relevant expert and get the class to chat to her? This position fails to acknowledge the human side of setting up and running activities involving chat with experts. Several issues rapidly become apparent when you discuss this with a teacher.

- Messenger probably isn't allowed on the school network because of worries about misuse, security, etc.
- How do you find an expert in a relevant field in the first place?
- How do you make contact?
- How do you establish availability (when and for how long)?
- How do you establish shared expectations of the chat between teachers, learners and experts?
- What about if you wanted to find someone on the spur of the moment to answer something that comes up in class?
- How do you know the person you are chatting with is who she claims to be?
- How would you find the time to set all this up?

The service we propose would need to handle not just the lower level technical issues, such as establishing secure, authenticated, peer-to-peer communication but also high-level issues such as those mentioned above. Similar issues become apparent when we begin to explore the other services we propose.

- How do you find data and sensors relevant to the curriculum, or the class' interests?
- How can you be sure of the validity of that data?
- How can you contact the providers?
- How can you make your own data accessible to others?
- How can you see what others do with your data?

Future Work
Clearly, part of the work that needs to be done is technical and involves designing, developing and evaluating services that can answer the questions posed above. However, we also need to get into the schools context, as opposed to a university context, in order to really draw out and clarify the issues that arise specifically as a result of being in school. We suggest setting up more sessions but this time in school, with teachers running the sessions and involving the full spectrum of learners. Interleaved with these sessions we would involve teachers and learners in collaborative development of detailed service user scenarios. In order to support our belief that the e-Science like activities in our sessions can bridge the gap between school science and university research – broadening awareness, changing attitudes and possibly motivating learners towards scientific research we would need to obtain data on the participants' attitudes to science, awareness of science research and future study intentions, prior to and at various stages after the sessions.

Conclusion
In this paper we have described the e-Science sessions we ran at the University of Sussex with school-aged scientists. The sessions explored two e-Science projects, remote sensing on an Antarctic lake and urban pollution monitoring and involved live communication with remote scientists, use of mobile sensing equipment to gather and submit local pollution data for visualisation and analysis and investigation of the Antarctic device

and data. Our aim was to provide teachers and young scientists with an 'e-Science like' experience, see how they responded and find out how they would like to see similar technology employed. Both teachers and learners were enthusiastic about the experience and about the possibility of bringing real research, researchers and data into the classroom and about participating in research through technology. We believe one benefit of such activities is the opportunity provided to bridge the gap between school science and university research – broadening awareness, changing attitudes and possibly motivating learners towards scientific research. However, setting up and running this kind of activity would at present place an unreasonable burden on teachers. We suggest that e-Services for educators could be developed which would take on much of this burden; finding and contacting researchers, accessing data and providing tools appropriate to teachers' and learners' requirements. In order to move towards defining such e-Services we propose running similar 'e-Science' sessions in schools and in tandem collaboratively developing service user scenarios with the teachers and learners involved.

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