STEM Learning: Futures

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Following on from the account of some CALRG research related to STEM learning in the previous chapter we discuss here several examples of attempts to explore the technology and pedagogy of learning science. In one thread we look at informal learning and linking journeys between formal and informal learning and how we have built on previous work on developing inquiry learning. In the second we look at a design to support collaborative working at a distance building on our previous work on learning from simulations. The case studies in this chapter illustrate the persistent intent of supporting science learners and a shared vision of the range of support under development for this end.

Introduction

Recent direction of this research has emphasized informal learning, journeys between formal and informal learning and collaborative working. The development of the nQuire-it project initiated a series of projects in the field of Citizen Science. It resulted in the development of the nQuire-it platform and the Sense-it app supporting the design and implementation of personally meaningful

investigations outside the classroom, by citizens of all ages. Through the BBC's 'Tomorrow's World nQuire', this has developed further into a dynamic and social toolkit hosting multiple types of Citizen Science projects such as image, audio and text-based projects as well as survey-type projects with personalized feedback. In the LEARN CitSci project, our international Citizen Science collaboration with six natural history museums and universities in the US and UK is aiming to improve the design of existing Citizen Science projects led by museums and make science learning more enjoyable and accessible to young people.

Case study 1: Citizen Inquiry

The story of Citizen Inquiry is a strong example of how an innovative pedagogy reinforced and guided the development of relevant technology. Pedagogy may often be overlooked in technology-enhanced learning (TEL) and this is due to the emphasis often placed upon technological elements rather the learning engagement, processes, and outcomes. In the case of Citizen Inquiry, advancements in technology enabled testing and evaluation of this pedagogy and supported progress towards a learning vision. Citizen Inquiry is an innovative approach to inquiry learning, proposed by OU Emeritus Professor Mike Sharples. It is located at the intersection between 'Citizen Science' and 'inquiry-based learning' and refers to mass participation of the public in joining and initiating inquiry-led scientific investigations. Specifically, "*it fuses the creative knowledge building of inquiry learning with the mass collaborative participation exemplified by Citizen Science, changing the consumer relationship that most people have with research to one of active engagement*" (Sharples et al., 2013, p 36). The 'citizen inquiry' paradigm shifts the emphasis of scientific inquiry from scientists to the general public, by having non-professionals (of any age and level of experience) determine their own research agenda and devise their own science investigations underpinned by a model of scientific inquiry. Citizen inquiry aims to leverage the pedagogical potential of inquiry-based learning – a productive approach to the development of learners' knowledge of the world and the enhancement of higher-order thinking skills – through opening up massive participation in inquiry-based activities.

It becomes evident that Citizen Inquiry emerged from a reconfiguration of existing ideas and social practices, that is the increasing interest and growth of Citizen Science and its consequences for how science is conducted (Bonney et al., 2009) and Inquiry Learning as a problem-solving approach to learning that requires guidance and 'scaffolding'(Quintana et al., 2004). This is an example of 'bricolage' (Scanlon et al., 2013) where the central idea or the vision of TEL innovation resulted from examining available materials, approaches and ideas, and experimentation, rather than the configuration of a vision that is precedes the development of relevant material. A new research project may emerge from either inventing and testing a new idea, or through the process of bricolage, that is bringing together and reconfiguring what is already known.

The first step towards examining or testing the idea of Citizen Inquiry was to attract funding. In 2013, one-year funding from Nominet Trust enabled the recruitment of a software designer and an educational developer to design tools that could scaffold or facilitate learning through Citizen Inquiry. Advancements in technology such as synchronous and asynchronous communication, and the instant data upload from mobile phones to the web could enable communication and mass participation of citizens in inquiry-led learning activities, and thus instantiate the idea of Citizen Inquiry. In partnership with teachers and students from the Sheffield University Technical College (UTC), we designed in a participatory manner the nQuire-it platform and a mobile data collection application, Sense-it (available on Google play). The tools were developed through a design-based research approach, where prototypes of the tools were evaluated by young people, improved and retested (Herodotou, Aristeidou, Sharples, Scanlon, 2018, Herodotou et al., 2014). The delivery of functional versions of the tools was very timely as it coincided with the research activities of a PhD student who was examining inquiry learning in online settings. In practice, this allowed for additional research to take place that could not be supported by the project funding, in two main areas: evaluation of the usability and general functionality of the tools and capturing early evidence of learning impact. It also extended the scope of tools to adult participants through a study with amateur meteorologists and weather watchers and provided recommendations as to how to sustain participation in citizen inquiry learning communities (Aristeidou, Scanlon, Sharples, 2014).

Despite the overall success of the project in developing and evaluating tools to support the process of Citizen Inquiry and a collection of papers published (Herodotou et al., 2017), a period of uncertainty followed the project completion. Additional sources of funding were needed to sustain and monitor the tools, provide support to current and prospective users, develop and enhance the functionality of the tools and disseminate project outputs, and enable uptake of the innovation. During this critical period of no additional financial resources, the OU agreed to provide minimum technical support for maintaining the tools. Also, the research team made systematic attempts to attract additional funding. These efforts were directed both to external funders and the university; in the case of the latter, the intention was to integrate the tools and the new learning approach to the design of new or existing courses. What motivated these efforts was the fact that all involved researchers shared the same vision around the potential of Citizen Inquiry to make learning engaging and interactive while they were also willing to dedicate time to identify new sources of funding. In practice, we scheduled monthly or fortnightly meetings where we discussed our progress towards attracting funding and set actions to be completed before the next meeting. In this way, our efforts were systematic and persistent over time.

Persistent intent (Scanlon et al., 2013) plays a significant role in pursuing and mainstreaming innovation in TEL. The sharing of a clear and common vision

amongst a research team can also help steer and plan future activities aiming at extending the project lifecycle. In the case of Citizen Inquiry, persistent intent resulted in a partnership with the BBC's 'Tomorrow's World' science programming (http://www.bbc.co.uk/tomorrowsworld), the aim of which was to extend existing tools and support large-scale public investigations in both the natural and social sciences (e.g., psychology). For example, tools should enable citizens to create and run online studies to explore attitudes and personality. This project, running for a year, involved certain technical developments including new ways to enter responses, secure handling of personal data, and ways for participants to overview results. Overall, this funding enabled the re-implementation of tools to run large studies linked to BBC TV or radio programmes. By the end of the project funding, a new version of the now called nQuire platform had been developed (nQuire.org.uk) (see Figure 9.1).

The platform was launched in 2018 with an investigation proposed by the BBC about the incoming General Data Protection Regulation: 'GDPR – My
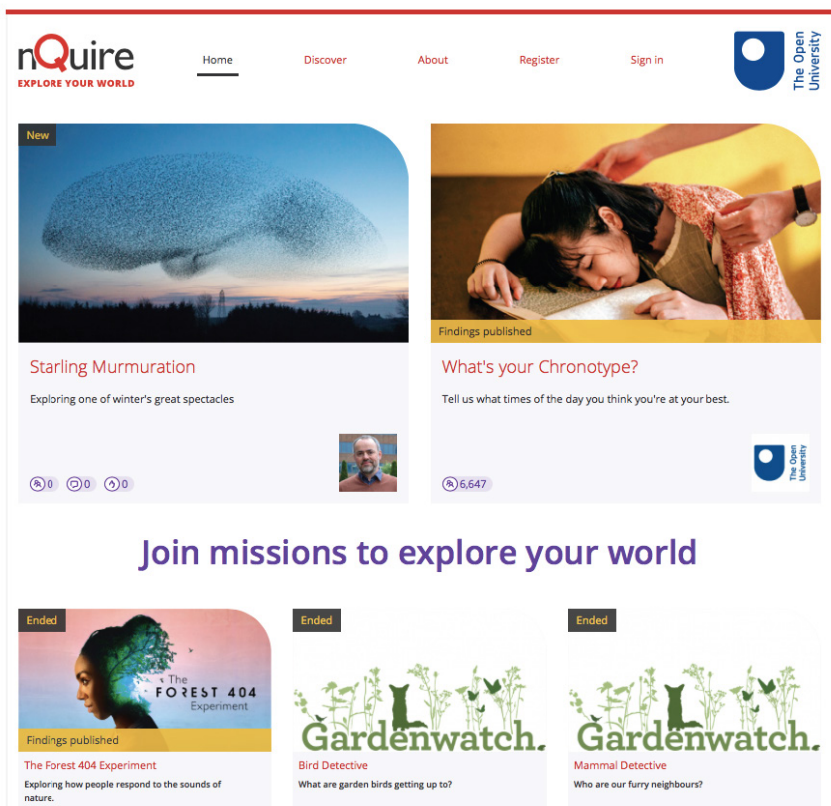

Figure 9.1: The nQuire platform supporting citizen inquiry.

Life, My Data, MyTomorrow'. Advertised on the BBC Tomorrow's World website and systematically shared in social media, the expectation was that a significant number of users would visit the platform and complete the mission, thus raising the profile of the platform as a tool for joining or initiating investigations. A significant aspect of every piece of research is to achieve impact, in the case of Citizen Inquiry this means populating the platform with investigations set by both citizens and scientists, supporting Citizens' Inquiry learning through joining or setting up investigations, and integrating the tools in teaching practices. This first mission did not meet expectations, as only a few people participated. A reflective activity within the team identified that the process of accessing the platform, in particular the requirement to register before joining an investigation, most likely explained the low response rate. Given the remaining funding available, respective changes were made to the platform.

The end of the project with the BBC resulted in a second critical point of uncertainty. Although this partnership had significant outputs, the challenge of achieving impact by having a large number of citizens systematically engaged with the tools had not yet been met. In line with 'persistent intent', the research team shared responsibilities and directed dedicated effort towards two directions: (a) identifying external organisations such as the BBC and schools that would be interested in using the platform and setting up investigations, and (b) identifying courses at the OU that could integrate the platform into their design to support teaching and learning. In this respect, networking was shown to be a critical factor influencing the future of the innovation. Through existing contacts and ongoing communication, the research team identified relevant stakeholders to whom they presented the vision and the tools. This was a fruitful activity as it resulted in a number of outcomes. First, the Chronotype mission was launched and shared with undergraduate students across the university, generating 4,700 responses. Second, leveraging internal funds, a researcher was recruited to identify ways of integrating the platform within Open University courses. Third, the platform was integrated into the design of a new course about technology-enhanced learning, that was managed by colleagues in the same department. This is the first application of the approach and the tools to formal education. Fourth, the partnership with the BBC resulted in the design of additional investigations such as Gardenwatch (See Figure 9.2)- a partnership between the BBC and the British Trust for Ornithology (BTO) surveying gardens across the UK – that engaged thousands of people with the platform and the process of Citizen Inquiry. Finally, relevant applications are under preparation or have been submitted, aiming to attract further funding.

In parallel, the dissemination activities of the research team over time, including presenting at local and international conferences and other universities, attracted the interest of schools. For example, a primary school in China reported high levels of student engagement when students (11–12 years old) were using the platform and the Sense-it application. Students recorded sounds and lights in a shopping mall and conducted interviews with people who live

Figure 9.2: The Gardenwatch mission supported by the BBC and BTO.

around the mall to identify whether living next to the mall affects daily life. In the classroom, students discussed data and wrote a proposal for improving the environment around the shopping mall.

Another example of how supporting distance learning students with their understanding of Science has led to the development of new technologies especially within the realms of Computer Supported Collaborative Learning is our work on shared simulations. Building on the work on learning from simulations in the conceptual change in science projects (see Chapter 8, and shared simulations (see e.g. the SharedArk project, Scanlon et al. 1993) our challenge has been to support learners at a distance working together on complex tasks.

Case study 2: real time working together on simulations

This second case study provides an interesting narrative around the need to reduce the isolation of students working remotely with a positive experience of lerning science together through working in pairs in real time on a computer simulation. This research came to fruition in 2006 by linking together, two software developments, which were built at the OU, known as BuddyFinder and SIMLINK. BuddySpace was the original application that was of interest for this particular Science learning innovation and it was developed as an Instant Messaging environment for community building see Vogiazoglou et al (2005). BuddySpace provided enhanced capabilities for users to manage and visualise the presence of colleagues and friends in collaborative working, gaming, messaging, and other contexts. Of particular interest to our Science project was

the role of graphical metaphors for presence, including maps,the BuddySpace team were also studying at this time the semantics of presence, in order to move beyond simple flags such as 'online' and 'busy' to include rich contextual and spatio-temporal information more appropriate to the user's focus of activity.

Buddy Finder was then developed, by the Knowledge Media Institute, to enable users to perform two different functions. First of all it allowed each user to input keywords describing their individual interests and/or skills. Secondly it allowed a user to search the user-defined keyword space to find another user or users that match a specified keyword. The idea being that students would describe themselves, for example, as knowledgeable about or interested in climate change so that other students wishing to discuss this topic would be able to contact them via BuddySpace. Figure 9.3 shows the original BuddySpace messaging Interface while Figure 9.4 illustrates the BuddyFinder interface where students could see from the hotspots on the map, which students were actively online and also search to see if any were interested in working with them on the Global Warming topic see Figure 9.5 below

SIMLINK was the second programme which was built to allow students to work together at a distance with the Global Warming simulation see Figure 9.5. The variables that could be changed in this simulation were those of; cloud cover, amount of ice and snow, albeado, aerosol content, water content, carbon dioxide content and the solar constant. See Figure 9.5 below. Students were linked together remotely using SIMLINK which was in essence a Java based downloadable plugin which formed part of the BuddySpace family of communication tools. It allowed users at a distance to work on a joint simulation together. The users could view the same screen. This meant that when one student made a change to the simulation the other saw this change. In effect the pair working together were viewing identical representations on their monitors, as they would
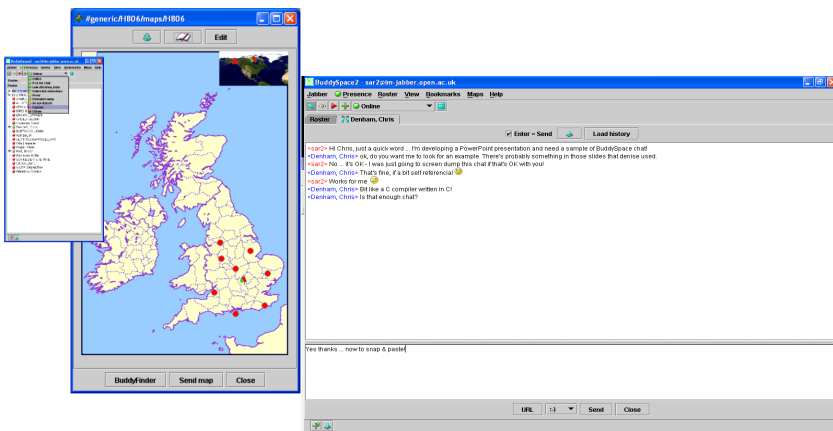

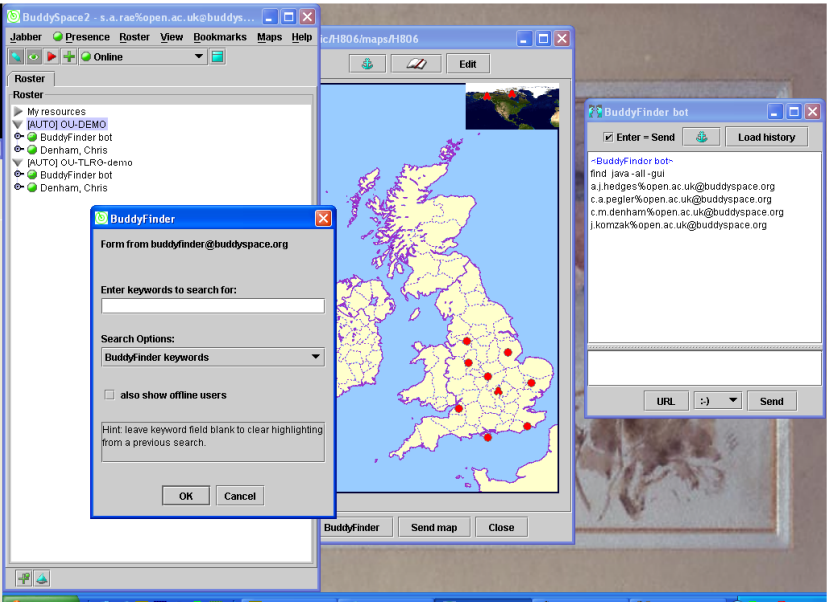**Figure 9.3:** BuddySpace messaging Interface.
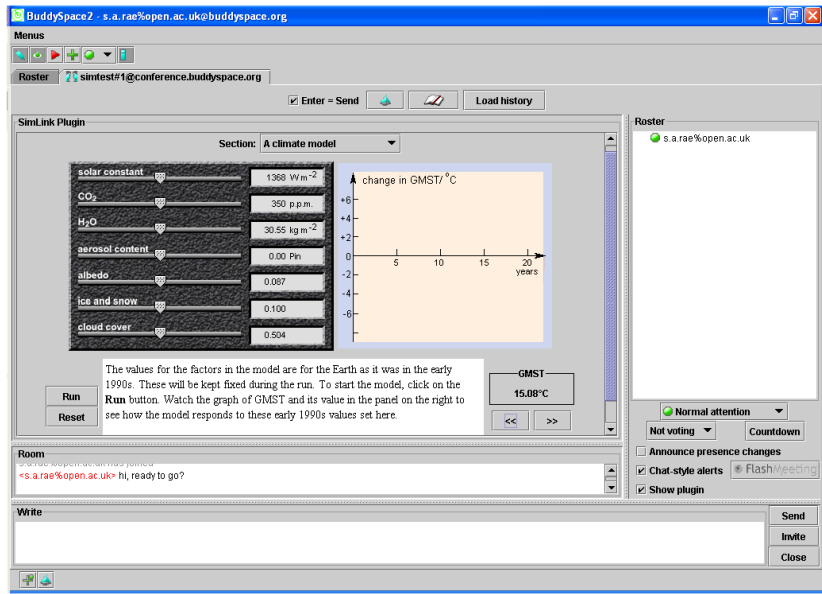
Figure 9.4: BuddyFinder interface.

Figure 9.5: SIMLINK with Global Warming.

as if they were working side by side. This was achieved by sending mouse click changes only from one partners application to the other. This avoided bandwith problems and time delays that 'raw' screen sharing would have entailed.

Fourteen volunteers were able to work together in separate rooms using the BuddySpace and SIMLIMK software to solve problems about Global warming together in a session which lasted up to 45 minutes. They quickly became engaged in the topic and cognitive change scores i.e. the difference between pre and post scores showed an increase. This trial illustrated how the system could be used for formative assessment purposes see (Whitelock 2008). The discourse revealed participants were encouraging each other to keep to the task and were happy to explore an unfamilaiar terrain together. The participants agreed that this combination of communication tools to present complex problem solving tasks would be a beneficial asset to OU students. The potential of BuddySpace was then recommended by the Open Content Initiative, to become integrated into Moodle.

The main pedagogical driver for this research was to provide a screen sharing application that would assist with the development of complex problem solving formative assessments for students studying remotely. In this way a 'Predict, Look and Explain' modus operandi for collaborative work around a simulation that has well documented pedagogical benefits could be provided for students studying alone and remotely. One of the major findings of this project is the creativity of staff, both academic and technical, to create formative e-assessments. The development process is time consuming and costly and fewer students benefit from these electronic formative assessments when they are an optional extra in the course. It was recommended that electronic formative assessment become a compulsory element of the course teams teaching learning materials. Learners have been shown to welcome the instant feedback afforded by electronic assessment, which can also be used by tutors to diagnose student misconceptions of a given topic. Designing formative assessments around known misconceptions was a recommended outcome from this work.

Conclusions

The story of Citizen Inquiry combined insights from the Personal Inquiry (PI) project (described further in Chapter 8) and Citizen Science to develop a set of enabling Citizen Science technologies. It suggests new ways of capitalizing on the strength of Citizen Science for the benefits of each citizen and their communities. It is an interactive way of engaging learners with science and a way of making use of the pedagogical benefits of inquiry-based learning at a large scale. Overall, this journey aimed to bring science closer to the everyday life of learners and help them understand and appreciate its value by developing bridges between formal and informal education. It showcases how a successful

secondary education project on structuring scientific investigations with the support of technology can be expanded to foster participation in research activities in informal settings, with the support of technology and through communication with others. Similarly, our recent collaboration with three natural history museums and two other universities (funded by the National Science Foundation (NSF), Wellcome Trust and Economic Social Research Council (ESRC)) aims to understand what young people currently learn from their participation in Citizen Science programs led by museums, and to redesign these to effectively scaffold informal learning experiences (LEARN Citizen Science, 2017). These activities emphasise the importance of promoting a continuation of learning across settings, supporting self-regulated learning with the help of technology and social interactions, and promoting lifelong learning inspiration.

Our work on collaboration at a distance supported by technology described here, but also in other accounts of our experiments on collaborative problem solving at a distance using shared simulations (see e.g. Scanlon et al. 2005) also demonstrated the commitment to the judicious use of technology to overcome the challenges of learning science at a distance. These two themes are facing the contemporary challenge of assessing learning appropriately and effectively.

Our research engagement with science projects and activities over the years has been shown to be challenging and has required flexibility to accommodate difficulties, a strong shared vision and persistent intent. Our major challenge has been the lack of funding available that threatened the implementation of our vision of "engaging learners enthusiastically with science". Persistent intent and ongoing communication amongst the research team contributed significantly in identifying solutions and pursuing, slowly but steadily our vision. Reflecting on the last 40 years, we could argue that we did manage to engage learners with science through innovative pedagogies such as Citizen Inquiry, learning from simulations and a range of web-based and mobile technologies. What now requires further work is to ensure that learners engage "enthusiastically" with science; that they are satisfied with their participation in science activities and see learning as fun and enjoyable. Going forward, we need to address the challenges of evidencing learning in informal settings, or connecting learning across settings, and ensuring that this learning is enjoyable and engaging. In pursuit of this we should aim to create learning environments that allow for playful exploration and experimentation, promote making and recovery from mistakes, and expand over and above formal education, to professional and lifelong learning (Ferguson et al., 2019).

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