Open educational resources in support of science learning: tools for inquiry and observation

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This article focuses on the potential of free tools, particularly inquiry tools for influencing participation in twenty-first-century learning in science, as well as influencing the development of communities around tools. Two examples are presented: one on the development of an open source tool for structured inquiry learning that can bridge the formal/informal spaces for inquiry learning. This is contrasted with an example of the use of free tools and community development for observation of scientific phenomena supported by open educational resources (OER) with a citizen science perspective. The article provides an assessment of how the availability of the resources has a potential for shaping the communities using OER for science learning and a discussion of the means of supporting inquiry.

Keywords: open educational resources; science; inquiry learning; participation

Introduction

Today’s technologically rich digital environment provides both challenges and opportunities for educators. For example, mobile and Web-based learning offers the opportunity to take learning outside the classroom, allowing educators to explore ways in which learning can be organized across formal and informal educational contexts, although Conole and McAndrew (2012) cautioned that “the impact of technologies has not been as transformative in education as … in other industries” (p. 2). Atterwell and Savill-Smith (2004) argued that making use of mobile technologies, which are already widely used by young people, may be one way in which educators could engage disaffected youth in learning activities. Furthermore, there has been a body of work developing the public engagement with science, reflecting an increased awareness of the importance of science in the lives of all citizens (e.g., Irwin & Michael, 2003; Miller, 2001). The focus in this article is on exploring the ways in which the use of open educational resources (OER) for science has an impact on involvement in science and hence on social inclusion. The relationship between involvement and inclusion as it plays out in this setting will be discussed later. Public engagement in science is important for a variety of reasons. The importance of active participation is growing as science plays an increasingly large role in the everyday lives of the public. The European Union has recognized that achieving this participation does not “mean turning everyone into a scientific expert,

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but enabling them to fulfill an enlightened role in making choices, which affect their environment” (European Commission, 1995, p. 28).

This article looks at how technology can be used to engage a wider proportion of the public in science. First, we consider the move toward openness in educational resources and in open science practices. Emerging practices are empowering learners and offering them new ways to be included in the learning process. Next, we consider inquiry learning as a learning mechanism both for formal and informal learning, a paradigm that particularly brings out the value of openness. Then, we consider two contrasting case studies of open tools made freely available to support science investigations with the potential of extending social inclusion.

Social exclusion is defined as “the inability of our society to keep within reach of what we expect as a society, and conversely social inclusion is needed to ensure all members have an equal opportunity to realise their full potential” (Power & Wilson, 2000, cited in Nivala & Hujala, 2002, p. 130). Seale (2009) outlined the key findings on the use of digital technologies to promote social inclusion and Selwyn, Gorard, and Williams (2001) offered a commentary on the digital divide—all of them emphasizing that more needs to be considered than mere access to resources.

OER

UNESCO (2002) defined OER as the “technology-enabled, open provision of educational resources, for consultation, use and adaptation by a community of users for non-commercial purposes” (3). OECD (2007) defined OER as “accumulated digital assets that can be adjusted” (p. 2). Weller (2011) described how “the term OER was coined in 2002 to describe the application of open source principles to the release of educational content, initiated by MIT’s Open CourseWare project” (p. 85). The William and Flora Hewlett Foundation helpfully point out the variety of materials that this can encompass and they mention “full courses, textbooks, streaming videos, exams, software, and any other materials or techniques supporting learning ... free tools and content” (Atkins, Seely Brown, & Hammond, 2007, p. 4). Kozinska, McAndrew, Jones, and Scanlon (2011) reported:

Since UNESCO’s Second Global Forum on International Quality Assurance, Accreditation and the Recognition of Qualifications in Higher Education in 2004, which focused not only on the quality of resources but also on supporting learner communities, a trend towards more socially-focused OER rather than content-centred initiatives has been observed. (p. 1)

McAndrew (2010) drew attention to the fact that “the original goals for the William and Flora Hewlett Foundation’s investment in OER (quoted in Atkins, Seely Brown and Hammond, 2007) were to ‘equalize access to knowledge and educational opportunities across the world’” (p. 10). OER are said to embody “a culture of sharing resources and practices which will help facilitate change and innovation in education” (OER Commons, 2007). Geser (2007) discussed the role of OER in lifelong learning and social inclusion. The report from the American National Science Foundation Task Force on Cyberlearning (Borgman et al., 2008) outlined the potential of the use of information and communications technology to share resources. Of course, there are a number of issues in the uptake of OER ranging from institutional and cultural barriers to uptake, to the appropriate design of the
resources. However, dos Santos (2008) emphasized the importance of the motivation toward social justice underlying many OER initiatives and the role they are assumed to play in promoting social inclusion.

Kozinska et al. (2010) described the hopes that various bodies have expressed about the potential impact of OER on social inclusion in higher education:

CERI predict that “challenges will arise linked to the possible social exclusion of groups not involved in higher education” (OECD, 2008:14) and discuss issues relating to students with disabilities observing a significant increase in their participation in higher education recently and suggesting that “greater responsiveness to diversity, which the approach to diversity exemplifies, should become more widespread in the interests of all students” (OECD, 2008:17). It is worth contemplating how various OER initiatives might contribute to making higher education more accessible and inclusive. OECD recognises “globalisation, an aging society, growing competition between higher educational institutions both nationally and internationally, and rapid technological development” (OECD, 2007:1) as some of the issues higher education will have to deal with, identifying OER as a potential solution in helping “expand access to learning for everyone, but most of all for non-traditional groups of students, and thus widen participation in higher education (...) [promote] lifelong learning (...) and bridge the gap between non-formal, informal and formal learning” (OECD, 2007:1). (p. 6)

There is a need to explore how to make use of OER in conjunction with the research findings emerging on technology-enhanced learning. The settings in which OER are used range from relatively traditional classroom settings to emergent distributed virtual learning groups. We need to explore further how formal learners interact in a new world where they can pick up open content and how their course providers will reversion and structure that content for them. Equally we need to know how informal learners will interact in a new world where they can pick up open content and choose tools, and how they can then choose their own groups and support structures making use of Web 2.0 and other tools.

Ehlers (2011) emphasized that it is too simple an interpretation of the impact of OER on social inclusion to only consider the impact of “extending access to resources” (p. 1), rather than the adoption of open educational practices. From the perspective of the UK Open University OpenLearn project (http://openlearn.open.ac.uk/), extending access to resources has demonstrated that openness not only increases involvement with learning but also changes the nature of that involvement. Godwin and McAndrew (2008) described the motivations of students who have used these resources, noticing a difference between “social learners” and “volunteer students” in the use of OER (p. 3717). They also point out that the different means of contacting others on OpenLearn allowed more people to find those with similar interests and form connections, the “social learners.” The US Department of Labor is targeting the use of OER to expand its education offering at college level via the Trade Adjustment Assistance Community College and Career Training program (Park, 2012) and Noveck (2011, cited in Vollmer, 2011, 5) commented on this initiative leading to the “widest possible distribution of this important job-training software.”

One area of interest is how communities of practice (Wenger, 1998) develop for OER and how such communities function. Ghosh, Glott, Krieger, and Robles (2002) reported on open source communities, which function as self-organizing, knowledge-sharing communities, and other communities that are hybrid and feature
educational technologists forming informal learning communities around OER (e.g., Burbules, 2006). Vogiazou, Eisenstadt, Dzbor, and Komzak (2004) discussed what support in location-based activities could help to build community. Dron and Anderson (2007) provided an elaboration of types of community relevant to this (see Conclusions section).

One particular focus of interest in OER is science learning related to developments in science practices. The Open Science Movement promotes more transparent, collaborative, and inclusive science. As part of this, scientists share their data and aim to publish in open access journals (Chalmers, 2009). One aspect of this openness is in the area of the provision of online tools. The next section discusses open science practices and later sections the provision of tools to support inquiry learning. The availability of tools is important in terms of social inclusion as they provide an opening up of experiences as well as content (see, e.g., Piedra, Chicaiza, Lopez, Tovar, & Martinez, 2009).

Open science practices

There is also an agenda for public understanding of important areas of activity such as citizenship, often, though not exclusively, applied to understanding science. Originally, public understanding of science was the term coined to describe this new movement, but from the outset, the term was felt to be problematic. Concern that it implied a hierarchical relationship with scientists laying down the law to an uninformed public was part of the problem, as well as difficulties in deciding who might constitute the public. The term understanding was also found wanting, with some suggestion that what was needed was an increase in the public’s awareness of contemporary science and the development of a population of informed citizens engaged in science to allow their active participation in discussions. Whatever name is given to this activity it requires members of the public to engage in science-related activities of their own choosing, often in informal settings (Scanlon, 2012).

Both examples referred to in this article discuss the impact on science of the particular technology application described. The practices of scientists are changing with respect to openness. Christine Borgman, a professor of information sciences engaged in research on the creation, use, and management of scientific data associated with the Center for Embedded Network Sensing in Los Angeles, California, writes about her empirical research work as follows:

As scholarship in all fields becomes more data-intensive and collaborative, the ability to share, compare, and reuse data becomes ever more essential. Data increasingly are seen as research products in themselves, and as valuable forms of scientific capital. Technologies such as embedded sensor networks are contributing to the “data deluge.” Our research addresses data characteristics, data sharing, data policy, and data architecture. The goals are to apply knowledge of scientific data practices to the design of data collection and management tools, and to the design and policy of information services for research and education. (http://polaris.gseis.ucla.edu/cborgman/)

In the report from the American National Science Foundation Task Force on Cyberlearning, Borgman et al. (2008) gave an example of the unexpected consequences of the way that data sharing and working with others can be particularly
productive and can even lead to the development of new scientific knowledge. They wrote:

In July 2007, a group of astronomers created a mashup of galaxy images from the Sloan Digital Sky Survey (the Cosmic Genome Project), the world’s largest digital map of the universe. The public was asked to perform a simple visual classification of about a million galaxies. The response was overwhelming: more than 100,000 people participated and created 40 million classifications. The results were on par with a similar, but much smaller scale, effort made by professional astronomers. The level of enthusiasm resulted in thousands of blogs by video gaming communities, and the participants were thrilled by being able to help in doing real, meaningful science. (Borgman et al., 2008, p. 28)

Of course, much reporting of these initiatives focuses on successful examples. This one builds on a well-established area and community of interest (amateur astronomy) and informal learning, which was taken to another level by the introduction of technology. The term citizen science (e.g., Bonney et al., 2009) has been used widely to describe such projects where partnerships between scientists and non-scientists are formed to conduct investigations of some type. For example, the EPSRC/DTI Participate project (http://participateschools.co.uk/) explores how pervasive computing can support mass participation in environmental monitoring and science learning. Preece and Schneiderman (2009) described a useful framework that can be applied to levels of participation in informal technology-mediated collaborative working like the example cited above. Forstner et al. (2011) discussed the importance of open access tools across a wide range of areas of the science process but there has been little work as yet on the diversity of the people becoming involved. Lane in a number of studies (2008a, 2008b, 2011) documented examples of impact on social excluded groups of OER produced by the UK Open University and other providers. He concluded that OER “greatly increase the opportunities for people to engage with informal and non-credit bearing or non-formal (peer group or employer organised and non-credit bearing) higher education study” and in doing so “better bridges into formal study for those groups currently excluded are built” (Lane, 2011, p. 6).

By engaging citizens in community action, the relevance of science to their lives can be demonstrated. There are also tools with wide uptake being adopted by different communities (Web 2.0). Freely available information (Google, Wikipedia) is starting to be supplemented with freely available material that has been designed to assist learning (e.g., OpenLearn [http://openlearn.open.ac.uk], MIT OpenCourseWare [http://ocw.mit.edu]), particularly through syndication of content. There are new opportunities to exploit the power of users to work together with tools coming from the eScience community. It seems that the real challenge for researching open content may be in the move from the production of open content repositories to the development of open sense-making communities (see, e.g., Buckingham Shum & Okada, 2007).

The recent moves into the production of massive open online courses (MOOCs) as a means of increasing access is interesting in this regard. There is undoubtedly global reach in the uptake of the Stanford MOOCs; for example, 160,000 students from 190 countries on a course on artificial intelligence translated into 44 languages (Lewin, 2012). However, the model of learning is different in other MOOCs such as the Georgia Institute of Technology’s Change 11 course, which is “a free floating
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course, Nature Neighborhood, for which the Web site formed an integral part. More
detail on each example is provided below.

**Example: representing and supporting inquiry learning**

The first case study describes the development of the nQuire toolkit. It was pro-
duced as part of the Personal Inquiry project, which ran from 2008 to 2011, funded
by the ESRC/EPSRC Technology Enhanced Learning program. This project, a col-
aboration between the University of Nottingham and the UK Open University,
investigated evidence-based inquiry learning across formal and informal settings
with young people aged 12–15. The toolkit was developed taking on board the
views of participants and an advisory group of stakeholders consisting of commu-
nity groups and industrial sponsors. Users and course developers can run demon-
stration inquiries through a Web-based interface or download the software to extend
existing inquiries or author new ones.

nQuire is a Web-based activity guide that supports students’ progress through
their scientific inquiries. During the project, inquiries were undertaken on the topics
of healthy eating, urban heat islands, microclimates, the link between exercise and
heart rate, food packaging, and noise pollution. nQuire runs scripts that guide the
learners through a process of gathering and assessing evidence and conducting
experiments, and the downloadable version is customizable for a range of inquiries,
with some sample inquiries available as exemplars. Interviews with participants in
the trials provided evidence of increased understanding of the inquiry learning pro-
cess by both children and teachers and of an impact on learning outcomes and
enjoyment (Anastopoulou et al., 2011).

nQuire (see Mulholland et al., 2011, for detail; Figure 1 for the Web site) has
been used to author, orchestrate, and monitor successful learning activities. Most
importantly, it can be used to represent the inquiry process, allow learners to visual-
ize results, and support a sequence of activities.

The activities supported can be related to logical phases of the inquiry process,
held within temporal stages (see Figure 2). Activities can be related to searching for

![nQuire Web site](http://www.nQuire.org.uk)

**Figure 1.** The nQuire Web site (http://www.nQuire.org.uk).
existing knowledge from the literature as well as working on experiments inside or fieldwork outside. The environment also supports an understanding of how data collected through personal inquiry can be validated, shared, and presented.

During the Personal Inquiry project, the toolkit was successfully appropriated by teachers and students in contexts including classroom lessons, formal and informal field trips, informal investigation in an after-school club, and home-based inquiries. Once the project was underway, there was a process of co-design of activities by children, teachers, and researchers. The activities at first were produced for formal investigations and developed separately in two school locations. We designed into the project plan the swopping of the templates of the initial studies (a location-based activity and a diary-based activity) between schools. In addition, as the project developed, the activities situated in the less formal settings of a nature reserve and an after-school club were developed and turned out to be particularly successful (Scanlon et al., 2010; Sharples et al., 2012). These in particular resulted in high levels of engagement.

Working with the toolkit presents learners with a persistent and dynamic representation of the inquiry learning process (see Figure 3), which allows them to come to a better understanding of how activities such as deciding an inquiry question, planning an inquiry, collecting evidence, analyzing data, and sharing results form part of the process of scientific investigation. They develop ideas about the way the stages of inquiry are linked, for example, that altering the focus of an inquiry question may make data they have already collected irrelevant, or that sharing data puts constraints on the form in which it is collected. Most importantly, they are supported in coming to the realization that conclusions reached need to be directly related to the original inquiry questions. In this way, the toolkit can help users to act like scientists by the provision of tools to conduct scientific investigations that they find important.

The software can run on a Windows, Macintosh, or Linux computer, and on mobile devices, or can be downloaded to a USB data-stick, which allows it to be run from the stick without the need to install software on the computer. The toolkit is fully accessible to the academic community worldwide, so that it can be used to
Figure 3. The nQuire interface is both persistent and dynamic: "Hypothesis" and "Key Questions" decided earlier on are drawn through to be re-presented to the learners for them to reflect on when considering how to frame their data analysis.

design, author, and share scripted personal inquiries for use in formal or informal settings. The project is creating an online community with facilities for uploading new inquiries, including teaching materials, and initiating a newsfeed and discussion area for each new inquiry.

A key feature of the contribution that the nQuire toolkit may make to social inclusion is facilitating the participation in science by excluded groups, which can be scaffolded by the tool. For example, the development of the toolkit involves its incorporation into the Wolfson Open Virtual Science Laboratory under development at the UK Open University. Another feature that supports inclusion is the persistence of the inquiries once developed, which then can be shared. The nQuire Web site is a place where the tool can be downloaded, and example activities and designs shared by a growing community of teachers. It can be difficult to persuade young people to consider science as an option for further education or as a career, particularly those from socially disadvantaged backgrounds. However, science shapes the world in which we live and it is important that people from all backgrounds develop the skills necessary to understand their society. The personal inquiry learning process can help with this.

Example: community development for the observation of scientific phenomena

This example iSpot (McAndrew, Scanlon, & Clow, 2010) comes from Open Air Laboratories, which aims to create and inspire a new generation of nature lovers by getting people to explore, study, enjoy, and protect their local environment. The iSpot Web site (Figure 4) developed as part of this initiative allows users to upload observations on wildlife. Sharing observations in this way allows them to get help with identification. However, users can upload their own observations and also
Figure 4. The iSpot Web site (http://www.ispot.org.uk).

comment on other people's observations. Users range from novices to experts and are of all ages, so there is a variety of expertise on offer. This could be seen as an example of crowd-sourcing, and indeed in one case a young user identified a species of moth that had not been previously seen in the UK. A brief description is
that the project is “helping a diverse group of people to learn about nature in an engaging way via social networking” (Open University, 2010).

Many people in the UK enjoy watching television nature programs. Motivating them to learn more about nature is one of the aims of the project. iSpot provides support for identification through its social network, and online resources to support learning including an online identification guide. It also incorporates freely available material ranging from basic introductory field guides, through species information on Wikipedia and the Encyclopedia of Life (http://www.eol.org), to final-year undergraduate-level OER. The essence of iSpot therefore is to help motivate learners to engage with the resources and other learners. The site also includes a reputation management system to help recognize those users who demonstrate expertise on the site. Clow and Makriyannis (2011) argued there is considerable potential to apply such a reputation system in other participatory learning contexts.

iSpot has over 16,000 registered users who have added more than 140,000 images in 85,000 observations that they have used to identify more than 5500 species (D. Clow, personal communication, January 5, 2012). Real science can be done by amateurs with this support. (See Silvertown [2009, 2010] for a range of reports on this, and Silvertown et al. [2011] for descriptions of similar activity on the Evolution MegaLab, a citizen science project that engaged thousands of volunteers in 15 countries throughout Europe.) Such participation can be seen as a form of inclusion. The iSpot model of scaffolding could be regarded as a route toward social inclusion, balancing the inputs from visitors with those from experts.

One interesting feature of participation is how such contributions can be motivated. Rotman et al. (2012) commented on the structuring of the activity necessary to ensure proper engagement in citizen science projects. Although some writing has been done in relation to the motivations of scientists on engaging in such projects (e.g., Silvertown, 2009) more work needs to understand the motivation of members of the public engaging in such initiatives (see Curtis, 2011).

Conclusions

As illustrated above, there are new approaches to the provision of resources and tools through the OER movement that show potential for further developing social inclusion. Some commentators note the changes to what it means to be an e-learner offered by OER but others have noted that there are also risks, which could lead to opening up a divide between those involved and those who cannot get across the barrier to become a new type of learner (see, e.g., Reich, 2011). There is a further risk that the match between what the world sees as the markers for knowledge (accreditation and assessment) and these much more informal and transient actions will be lost.

This article has outlined the potential of tools developed to support the inquiry learning process and to support the inquirers across contexts. Tools such as nQuire and iSpot in particular have suitable characteristics—sharable data and designs, and ways to support participation, increase motivation, and provide scaffolding to help learners. nQuire was developed in open source and made freely available. iSpot has focused on the development of communities to support participation. The affordances (Conole & Dyke, 2004) of each tool for supporting the inquiry process have been briefly described here. The developing interest in citizen science has led to thousands of people becoming involved in gathering and sharing scientific knowl-
edge, and much of this activity is made possible by the use of technology to mediate the interactions. As described here, both approaches provide a way of supporting the engagement of the public with science. The approach taken in the nQuire toolkit is to embed within the toolkit the necessary scaffolding and support for inexperienced novice scientists, while in iSpot the design features of interest aiming to support novice scientists are community support and an innovative approach to reputation management.

The potential of these two approaches seems strong. nQuire provides scaffolding of learning activities by the way that a model of inquiry learning is embedded in the tool. Dron and Anderson (2007) wrote about the complex mix of dynamics that occur in online communities, presenting a spectrum of groups, networks, and collectives. nQuire is an example of a tool that in its development supported a closed community of inquirers, for example, a class of schoolchildren engaging on a project together. Dron and Anderson would describe this closed community as a group: “Groups are cohesive and often have formal lines of authority and roles, such as teacher ..., enrolled student etc. Groups consist of individuals who see themselves as part of that group.... Groups are often structured around particular tasks or activities” (2007, p. 2460). According to them, “Collectives are aggregations, sets formed of the actions of individuals who primarily see themselves as neither a part of a group nor connected through a network” (p. 2462). They described the properties of networks as follows:

Individuals join Networks to associate with others of like interest or vocation, or who know more, or who would like to learn similar things. Networks enable us to identify and, most importantly, to contribute with the people we might want to know, the subjects that fit together, the "buzz" that is current in a subject area. (p. 2461)

They identified a property of a network to be the formation of emergent groupings as the network subdivides. In these terms, iSpot is an example of a looser network, operating even as a collective. These classifications could prove to be a key feature in understanding how open tools may require certain structuring in communities to support the collaborative activity required to make best use of the resource.

Both examples of support for the development of public engagement in science inquiries described in this article suggest that OER tools may provide an opportunity to promote social inclusion in terms of understanding and participation in science debates.

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