Open Data as Open Educational Resources: Towards transversal skills and global citizenship

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Abstract

Open Data is the name given to datasets which have been generated by international organisations, governments, NGOs and academic researchers, and made freely available online and openly-licensed. These datasets can be used by educators as Open Educational Resources (OER) to support different teaching and learning activities, allowing students to gain experience working with the same raw data researchers and policy-makers generate and use. In this way, educators can facilitate students to understand how information is generated, processed, analysed and interpreted.

This paper offers an initial exploration of ways in which the use of Open Data can be key in the development of transversal skills (including digital and data literacies, alongside skills for critical thinking, research, teamwork, and global citizenship), enhancing students' abilities to understand and select information sources, to work with, curate, analyse and interpret data, and to conduct and evaluate research. This paper also presents results of an exploratory survey that can guide further research into Open Data-led learning activities. Our goal is to support educators in empowering students to engage, critically and collaboratively, as 21st century global citizens.

Keywords: Open Data; Open Educational Resources; Research based learning; Critical Thinking; Global Citizenship; Higher Education

Introduction

The illusion of access promoted by computers provokes a confusion between the presentation of information and the capacity to use, sort and interpret it.
(Brabazon, 2001)

In today's information society, knowledge must be constructed by critically analysing streams of information from various sources and formats, and moreover, by understanding data and becoming capable of analysing and interpreting it. For Nowotny, Scott and Gibbons (2001), "the emergence of the knowledge society means that a much wider range of social, economic and even cultural activities now have 'research components'" (p. 225); and as Castells (2000) notes, we should "foster lifelong learning, a major asset in the knowledge-based social organization characteristic of the society" (p. 16). Beetham, McGill and Littlejohn (2011) highlight the growing importance of digital literacy, which they describe as "those capabilities which fit an individual for living, learning and working in a digital society"; and we would suggest that in addition to the digital, overlapping competencies in information and data literacy are key enablers for our students and graduates in meeting these challenges.

Indeed, higher education is already seeing a turn towards the development of transversal skills, which are defined by UNESCO (2015) as "critical and innovative thinking, inter-personal skills; intra-personal skills, and global citizenship" (p. 4); and as Rychen & Salganik (2003) note for the OECD, "certain areas of competence are needed not only in the labour market but also in private relationships, in political engagement and so on, and it is these transversal competencies that are defined as key" (p. 7). In this context, new pedagogies are reflecting these concerns, driving the adoption of problem- and research- based learning (e.g. Van Heuvelen, 1991; Dolmans, De Grave, Wolfhagen & Van Der Vleuten, 2005) and reframing of the role of the student as a producer rather than consumer of knowledge (e.g., Kotzé & Du Plessis, 2003; Neary & Winn, 2009).

Our purpose in this paper is to consider how curricula can enable students (particularly at HE level) to engage more frequently with the needs of society through critical engagement with raw data - which is now increasingly made available by international organisations, governments, NGOs and academic research institutions as 'Open Data'. As yet, the literature on Open Educational Resources (OER) has made little reference to Open Data and its potential use as a form of OER. We also present initial qualitative data obtained through an exploratory online survey with academics regarding their use of Open Data in teaching, with the purpose of offering an initial springboard for further research and more complex questions. In connecting these open dots, our aim is to initiate a discussion around good practice in the use of Open Data as a basis for research-based learning activities that can contribute to the development of students' transversal skills and field-specific competences.

Unlocking the potential of Open Data in Higher Education

Students may be less effectively educated and trained if they are unable to work with a broad cross-section of data.

(Uhlir & Schröder, 2007, p. 201).

As content has become increasingly digital, and thus potentially much more accessible, governments, international bodies, and academic organisations are advocating for the right to access information and knowledge as public goods (especially where these have come about as a result of public funding). Consequently, we have seen the rise of parallel open or 'opening' movements[1], focusing on OER; open course delivery (OpenCourseWare, MOOCs); Open Access (OA); and Open Data, which have led to a series of declarations (on OA[2,3], Open Education[4], OER[5] and Open Data[6]). While remaining somewhat discrete in their concerns, these movements are interconnected by drives for transparency, collaboration, democratisation, and citizenship.

Open Data is, by definition, accessible, interoperable, reusable and universal[7]. Also, it is characterised by "a commitment to make data available publically in non-proprietary, machine-readable formats at the lowest level of granularity possible" (Johnson, 2014, p. 264). Among other champions of opening data, Huijboom and Van de Broek (2011) argue that "publishing of government data can empower citizens to exercise their democratic rights" (p. 4). Open Data can also be considered an invaluable resource for scholarly communities. For Arzberger *et al.* (2004), "open access to, and sharing of, data reinforces open scientific inquiry, encourages diversity of analysis and opinion, promotes new research, makes possible the testing of new or alternative hypotheses and methods of analysis" (p. 139). For Molloy (2011), "better science - in terms of transparency, reproducibility, increased efficiency, and ultimately a greater benefit to society - depends on open data" (p. 4). However, we would concur with the advisory issued by Zuiderwijk *et al.* (2012) when they state that "the process in which data are published, found, used, linked, reused and discussed, which is here referred to as the open data process, seems to encounter many socio-technical impediments" (p. 156).

The argument that scientists and researchers can benefit from the openness of data is compelling, but as Worthy (2015) notes, "the public were supposed to be the beneficiaries of the new data. Exactly who the 'public' users are remains a bit of a mystery". For Gurstein (2011),

> This drive towards increased public transparency and allowing for enhanced data–enriched citizen/public engagement in policy and other analysis and assessment is certainly a very positive outcome of public computing and online tools for data management and manipulation. However, as with the earlier discussion concerning the "digital divide" there would, in this context, appear to be some confusion between movements to enhance citizen "access" to data and the related issues concerning enhancing citizen "use" of this data as part, for example, of interventions concerning public policies and programs.

And for Davies (2010), "there will be greater need in future for capacity both in state and society to be able to debate the meaning of data, and to find responsible ways of using open data in democratic debate" (p. 5). While the availability of open data in civil society and its adoption within the business sector is growing, it appears that educational use is not yet widespread. In our view, public engagement with these datasets is only likely to grow if educators take up a key role in fostering an understanding of them as sites of enquiry and supporting the development of relevant skillsets.

As we see it, the educational value of Open Data is as a key component in research- and scenario-based learning activities, where its deployment can enhance information and digital literacies and support the development of critical, analytical, collaborative and citizenship skills. Therefore, the use of Open Data as OER can enable mechanisms for collaboration, discussion and engagement with local communities towards the development of global citizens.

Research-based learning can be understood as teaching and learning activities guided by the scientific method of enquiry, which therefore involve posing research questions, testing these questions using quantitative and qualitative techniques, and presenting findings within a framework of research integrity, thus supporting students' reflective practice (Gilardi, & Lozza, 2009; Ambrose, Bridges, Di Pietro, Lovett & Norman, 2010; Wagner, 2014). In the context of a research-based approach, educators can use scenarios or problems relating to local and global problems, with the aim of developing a skilled data-savvy workforce, active and critical learners, and conscious citizens (Bindé & Matsuura, 2005; Borne *et al.,* 2009; Littlejohn, Beetham & McGill, 2012; Eve, 2013).

Drilling down further into educational research literature regarding the skills, abilities and attributes that students should develop in higher education, we have identified a set of core, discipline-agnostic competencies that we believe students can acquire in the context of research-based learning activities based on open datasets.

- **Critical thinking:** For Weinberger & Fischer (2006), "learners are supposed to engage in an argumentative discourse with the goal to acquire knowledge" (p. 4); therefore, it is necessary to embed creative and innovative approaches in face-to-face, blended and distance teaching and learning (Silberman, 1973; Papert, 1987).
- **Data curation skills:** For Mazon *et al.* (2014), when setting the aims and objectives of a research-based instance, it is necessary to provide students with data curation techniques including data organisation models, data repositories, and data analysis software that can help them to achieve the expected results facilitating learning through the use of open data. In addition, Baker & Duerr (2015) recommend careful selection of data collections, development of a data curation plan, keeping data collection activity logs and providing training in summarising the results.
- **Research skills:** Open Data can facilitate the education of new researchers; for example, openly available datasets can be used to create games, activities and resources in order to promote learning in science education (Uhlir & Schröder, 2007; Bradley, Lancashire, Lang &

Williams, 2009). Students should be provided with learning experiences in which they collaborate, analyse information and data, and communicate results effectively and by relating these tasks to specific scientific or social problems (Zamorski, 2002; Barrie, 2004; Fischer, Rohde & Wulf, 2007; Smith, 2008).

- **Statistical literacies:** Schield (2004) considers that "students must be information literate: they must be able to think critically about concepts, claims and arguments: to read, interpret and evaluate information". Statistical literacy is an essential component of information literacy; according to Wallman (1993), the "our citizens, who encounter statistics at every turn in their daily lives often are unequipped with the statistical literacy required to evaluate the information" (p. 5). Therefore, for Watson & Callingham (2003), "statistical literacy is not only important to our society as a whole; it is also relevant to the individual members of society" (p. 4).

- **Teamwork skills:** In research-, scenario-, and problem-based activities, students collaborate, sometimes within multidisciplinary research teams, solving complex problems; for Duch, Groh and Allen (2001) this collaboration develops skills in explaining results to others by learning to write reports and papers and to model graphics to visualise the data in order to make it comprehensible for readers.

- **Global citizenship:** Higher education not only educates future professionals; it educates citizens who should be able to think critically, evaluating information in order to be aware of local and global problems (Evans & Nation, 1993; Soder, Goodlad & McMannon, 2001). According to Willems & Bossu (2012), "While the new technologies are a source of social change, they can only become a promise of development for all through the alliance of freedom of expression, knowledge, democratic principles and the concept of justice" (p. 185). However, for Johnson (2014), "open data cannot be expected to universally promote justice. It can just as easily marginalize groups that are not part of the data: people whose lack of privilege excludes them from the kinds of interactions that produce data and makes their viewpoints invisible to those who collect data" (p. 267). We would also agree with Gurstein (2011) that for "open data to have a meaningful and supportive impact on the poor and marginalized, direct intervention is required to ensure that elements currently absent in the local technology and social ecosystem are in fact, made available".

Open Data-led activities in Research-based curricula

Open data and a change of mindset is the next step in the internet revolution
(Berners-Lee, 2011)

For students to engage with contemporary social problems, it is key to embed Open Data principles in research-based teaching and learning contexts provides students with the experience of working with the same raw materials scientists and policy-makers use (Atenas, Havemann & Priego, 2015), applying different methodologies in real scenarios and presenting the results in research papers that can be assessed, therefore connecting learning with real world problems (Kasl, Marsick & Dechant, 1997; Barron *et al.*, 1998; Hmelo-Silver, 2004; Davies, 2010; Piorun *et al.* 2012).

In the previous section we outlined the core benefits students might develop by engaging with Open Data. We conducted an exploratory survey disseminated via a blog post and social media between March and May 2015 in which we asked academics to describe how they used or embedded open data in their teaching and learning practices, and which portals they most frequently used. This survey was intended to provide us with some indications of the range of data sources in use and of disciplines in which academics already see educational value in such datasets. We had 26

responses from North America, Latin America and Europe, and from academics teaching many different subject areas. The intention was to provide initial building blocks for further correlation between the core competencies we have outlined and the educational objectives of the learning activities in which Open Data has been used.

Out of these 26 responses, 11 reflected clear uses of Open Data, describing activities within the contexts of academic development, PhD training, library and information science, classical studies, communications, engineering, archaeology, digital humanities, biomedical sciences and social sciences. The remaining 15 answers referred to the use of other types of open content, and types of data which are not open. While those have therefore been excluded from our reporting below, we believe it is noteworthy that less than half of our respondents appear to have clearly understood what we meant by the phrase 'Open Data', indicating that there is some way to go in raising the awareness of academics of this topic. The table below summarises the 11 responses, which pertain specifically to the use of Open Data in teaching (see table 1).

Table 1: Summary of survey responses organised by country of affiliation of respondent

Region	Examples of how you used open data in your teaching	Which portals have you used to retrieve open datasets?	URL
Latin America	To train early career researchers in data curation techniques and research data management	European Union Open Data Portal	https://open-data.europa.eu/en/data/
Europe	We have used data from Twitter, the Old Bailey Online and Altmetric to do text analysis and create new datasets	Altmetric	http://www.altmetric.com/
		UK Open Gov Data	http://data.gov.uk
		Figshare	http://figshare.com/
Europe	In Data Expeditions related with data journalism	Hub of Russia	http://hubofdata.ru/
		Russia Open Gov Data	http://opengovdata.ru
Europe	Ancient Greek and Latin texts (analysis, visualisation), GIS for the ancient world	Perseus Digital Library	http://www.perseus.tufts.edu/
		Linked ancient world data, Pelagios	http://pelagios-project.blogspot.com/
		Pleiades Data	http://pleiades.stoa.org/
Europe	In my course I used data from the archaeology data service to teach GIS	Archeology Data Service UK	http://archaeologydataservice.ac.uk
North America	We are building data driven curriculum modules based off of data sets housed in Dryad Digital Repository. The modules represent a collaborative effort between the researcher and pedagogical expert.	Dryad Digital Repository	http://datadryad.org

Region	Examples of how you used open data in your teaching	Which portals have you used to retrieve open datasets?	URL
Europe	In a postgraduate programming module, I devised courseworks around open data as a raw material. Firstly, students were asked to produce an e-reader that could be used with books from http://www.gutenberg.org/, secondly, they were tasked with creating a live parking monitor application, based on data available through.	Open Data Nottingham	http://www. opendatanottingham.org. uk
Europe	Reusing open data through project-based learning within the degree in Computer Engineering group activity	US Open Gov Data	http://data.gov
		UK Open Gov Data	http://data.gov.uk
Europe	Database design in a computer science HE course using mainly government census data	US Open Gov Data	http://data.gov
Europe	I have taught classes and workshops on Linked Open Data and Semantic Web technologies in digital humanities. I covered topics such as RDF and SPARQL.	British Museum Open Data Collection	http://collection. britishmuseum.org
		Dbpedia	DBpedia http://dbpedia. org/sparql
		Kerameikos org Open Data	http://kerameikos.org/ sparql
Latin America	Case study analysis activity using a set of statistical methods and data visualisation tools	World Bank Open Data	http://data.worldbank.org
		Interamerican Development Bank Open Data	http://data.iadb.org
Europe	Using open EEG data to let students experiment with brain open data and connectivity analyses	Medical Education Linked Arena	http://www.meducator3. net/melinaplus/
		Laboratory of Medical Physics - Medical School of Aristotle University of Thessaloniki	http://medphys.med.auth. gr/

Going forward with Open Data as OER

All citizens should have equal opportunities and multiple channels to access information, be consulted and participate. Every reasonable effort should be made to engage with as wide a variety of people as possible
(OECD, 2009, p. 17)*.*

Arguments in favour of opening data have been advanced somewhat in isolation from parallel open education debates, which have tended to focus much attention on the matter of Open Educational

Resources (OER). OER have been defined variously but for UNESCO, they are "any type of educational materials that are in the public domain or introduced with an open license".[8] It is our contention that open datasets can therefore certainly be understood as a form of 'educational materials', whether or not originally created as such, and therefore as OER; and indeed, not only can, but should be used in this way.

Already educators are at liberty to take advantage of Open Data by facilitating and encouraging students to select and use open datasets from different countries, thus to experiment with data at a global level; portals that provide access to such transnational datasets include Open Data Index place overview[9] and the Data Repository directory.[10] However, for us it is also vital to start providing students with access to datasets being produced within the academy, using the same research methodologies that students are learning to master. This can be facilitated via policies that will support scholars in making these datasets openly available at the institutional level, enabling spaces for multidisciplinary approaches to research projects inside each university.

The embedding of research principles in higher education curricula can support the development of critical thinking and rigour in academic practice, helping them to become data literate at different levels developing skills that can enhance their employability (Healey, 2005; Tanner, 2006). Table 2 showcases examples of different levels of expertise and proficiency in open data related research based activities.

Table 2: Research and data handling skills differentiated by level

Skills/Level	Basic	Intermediate	Proficient	Advanced
Critical thinking	Students understand basic concepts of critical thinking	Students can use data to verify information from the media	Students can analyse phenomena from their region using data and write reports critically analysing solutions	Students are able to develop and present complex evidence-based arguments in key academic formats
Data analysis skills	Students can analyse data using quantitative and qualitative methods	Students gain experience in using popular software for data analysis such as SPSS or NVivo	Students use proficiently software for data analysis which are relevant for their own disciplines	Students can present complex reports based upon data analysis in the form of research papers or posters
Data curation skills	Students can organise datasets in simple folders	Students can identify different sources of datasets and organise them in databases	Students can use electronic tools for data curation and share it with others	Students can develop databases and automate the process to organise and merge datasets, and embed metadata into the files to facilitate access to the resources
Data information management skills	Students can identify datasets from different sources	Students can select datasets from different portals in different formats	Students can extract, filter and compare data from different data sources creating a single dataset	Students can filter and format data in different formats analyse it creating complex datasets

Skills/Level	Basic	Intermediate	Proficient	Advanced
Data Mining skills	Students can locate CSV files on the internet	Students can extract datasets from PDFs	Students can extract datasets from different sources	Students can use complex methods for developing datasets
Data visualisation skills	Students can create graphics and charts	Students can use online software to develop simple infographics	Students can use graphic design software to develop infographics	Students can use data visualisation techniques to present their findings using complex statistical modelling
Research skills	Students understand the scientific method and are familiar with the concepts of quantitative and qualitative methods	Students can structure their research and apply different techniques to obtain results	Students can replicate experiments and studies following research methods explained in the literature	Students can compare data and information from different data sources and research papers and replicate experiments and studies to produce new research findings
Statistical skills	Students can perform basic statistical operation including averages, media and median	Students can perform statistical operations using clusters, standard deviations, significance, chi square, correlation or regression analysis	Students can use data modelling techniques for different statistical methods such as forecasting to predict future events	Students can write queries in order to perform complex statistical analysis functions and create models and complex graphs and visualisations

In addition to the development of these practical research and data handling skills, we consider that Open Data poses a real opportunity for students to engage as active, curious and informed citizens, with local and global issues. In order to develop such citizenship skills we suggest (in table 3) a series of activities at different levels that can be considered as guidelines to promote civic engagement.

Table 3: Activities for civic engagement differentiated by level

Activity/Level	Initial	Intermediate	Advanced
All levels	Invite subject and data experts to discuss face to face or online with your students about local and global issues	Engage students with political and legal deliberations and discussions at local and global level asking to them analyse the data related to it	Establish a model for students to understand the process and engage them in policy making by reviewing and analysing data and official reports
Undergraduate	Engage students in evaluating facts and contrasting information by analysing data presented in news media	Encourage students to use digital tools to engage and monitor political activities and to assess reports and news by analysing their data	Support students in assessing data from their government to identify problems and compare local with global information

Activity/Level	Initial	Intermediate	Advanced
Postgraduate	Support students in identifying organisations that are campaigning in citizenship issues and enable instances for students to engage in civic monitoring activities and evaluate data driven arguments	Promote student collaboration with civil society organisations, in order to gain experience working with their data, supporting their activities, and enhancing their openness through data and publications	Support students in writing dissertations based on analysis of open data which engages with a real local or global problem; encourage them to publish findings in an open format

It is not our intention to oversimplify the extent to which key concepts, data, and research methods vary across the disciplines, and the extent to which activities must be designed carefully for different skill and experience levels. But we would assert that students at any level can begin to engage critically with data. It is necessary to make a preliminary diagnosis when planning a research-based activity, in order to understand the following: if students have developed communication and collaborative skills, if they have worked in teams before, if they understand research data management, including having training in software they will use, and if they are capable to apply different research methods to be able to collectively describe the results in a format that can be assessed by their peers and lecturers (Van Heuvelen, 1991; Doucette & Fyfe, 2013).

In addition, we recommend that academics intending to implement research-based activities using open data should:

- Identify and describe the learning outcomes for the intended activities;
- Identify the portals which will source the data;
- Clearly identify and describe the challenges students might face;
- Provide training materials for the software students will need to analyse the data;
- Support students in communicating their findings to local or wider communities.

There is much research still to be done to join the dots between Open Data, Open Educational Resources and the development of transversal skills and discipline-specific competences. There is a world of potential to be explored, particularly in relation to the development and adoption of methods of assessment that identify how the use of Open Data can feed into specific competences. Moreover, there is still a paucity of research regarding any linkages between communities of practice in Open Data and research and education.

If we understand learning as a transformation of knowledge, mere field-specific "competences" may not be enough; it is necessary to "cross boundaries" (Wenger, 1998, p. 140) in order to be exposed to different modes of behaviour, processes and outcomes. So far, it seems that engagement with Open Data has been driven by experience, rather than competence, but competences have been developed through the exposure (experience with) open datasets. In order to formalise more objective mechanisms of assessment, it is necessary to engage critically with, and foster further interconnections between, those engaged in Open Data and those engaged in education.

Notes

[1]   The Open Definition "sets out principles that define "openness" in relation to data and content. It makes precise the meaning of "open" in the terms "open data" and "open content" and thereby ensures quality and encourages compatibility between different pools of open material" http://opendefinition.org

[2]   Open Society Institute. (2001). *Budapest Open Access Initiative*. Budapest. Retrieved from http://www.budapestopenaccessinitiative.org/read

3   Max Planck Gesellschaft. (2003). *Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities*. Berlin. Retrieved from http://openaccess.mpg.de/286432/Berlin-Declaration

4   Open Society Institute. (2007). *The Cape Town Open Education Declaration*. Cape Town: Open Society Institute - Shuttleworth Foundation. Retrieved from http://www.capetowndeclaration.org

5   UNESCO. (2012). 2012 Paris OER Declaration. In *2012 World Open Educational Resources (OER) Congress, Paris, June 2012*. Paris: United Nations Educational, Scientific and Cultural Organization. Retrieved from http://www.unesco.org/new/index.php?id=64395

6   Open Knowledge Foundation (2013). *A Citizens' Call to Action on Open Data*. Retrieved from http://globalopendatainitiative.org/declaration/#sthash.DCRKoco6.dpuf

7   Open Data Definition http://opendatahandbook.org/guide/en/what-is-open-data/

8   UNESCO What are Open Educational Resources (OERs)? http://www.unesco.org/new/en/communication-and-information/access-to-knowledge/open-educational-resources/what-are-open-educational-resources-oers/

9   Open Data Index: Place overview http://index.okfn.org/place/

10   Data Repositories http://oad.simmons.edu/oadwiki/Data_repositories

References

Ambrose, S. A., Bridges, M. W., DiPietro, M., Lovett, M. C., & Norman, M. K. (2010). *How Learning Works: Seven Research-Based Principles for Smart Teaching*. John Wiley & Sons.

Arzberger, P., Schroeder, P., Beaulieu, a, Bowker, G., Casey, K., Laaksonen, L., . . . Wouters, P. (2004). Promoting Access to Public Research Data for Scientific, Economic, and Social Development. *Data Science Journal*, *3* (November), 135–152. http://dx.doi.org/10.2481/dsj.3.135

Atenas, J., Havemann, L., & Priego, E. (2015, March 9). *The 21st Century's Raw Material: Using Open Data as Open Educational Resource*s. Open Education Working Group. Open Knowledge Foundation. Retrieved from http://education.okfn.org/the-21st-centurys-raw-material-using-open-data-as-open-educational-resources/

Baker, K. S., & Duerr, R. E. (2015). Authentic Learning in the Research Data Curation Classroom. In *iConference 2015 Proceedings* (p. 4). Retrieved from https://www.ideals.illinois.edu/bitstream/handle/2142/73703/361_ready.pdf?sequence=2

Barrie, S. C. (2004). A research-based approach to generic graduate attributes policy. *Higher Education Research & Development*, *23*(3), 261–275. http://dx.doi.org/10.1080/0729436042000235391

Barron, B., Schwartz, D., Vye, N., Moore, A., Petrosino, A., Zech, L., & Bransford, J. (1998). Doing With Understanding: Lessons From Research on Problem and Project-Based Learning. *Journal of the Learning Sciences*, *7*(3), 271–311. http://dx.doi.org/10.1207/s15327809jls0703&4_2

Beetham, H., McGill, L., & Littlejohn, A. (2011). *Thriving in the 21st century: Learning Literacies for the Digital Age*. Retrieved from http://www.jisc.ac.uk/publications/documents/elearningllidareport.aspx

Bindé, J., & Matsuura, K. (2005). *Towards knowledge societies*. Paris: UNESCO. Retrieved from http://unesdoc.unesco.org/images/0014/001418/141843e.pdf

Borne, K. D., Jacoby, S., Carney, K., Connolly, a., Eastman, T., Raddick, M. J., . . . Wallin, J. (2009). The Revolution in Astronomy Education: Data Science for the Masses, (March), 12. Retrieved from http://arxiv.org/abs/0909.3895

Brabazon, T. (2001, June 4). Internet teaching and the administration of knowledge. *First Monday, 6*(6). Retrieved from http://www.ojphi.org/ojs/index.php/fm/article/view/867/776

Bradley, J. C., Lancashire, R. J., Lang, A. S., & Williams, A. J. (2009). The spectral game: Leveraging open data and crowdsourcing for education. *Journal of Cheminformatics*, *1*(1), 1–10. http://dx.doi.org/10.1186/1758-2946-1-9

Castells, M. (2000). *The Network Society*. University of Massachusetts Amherst.

Davies, T. (2010). Open data, democracy and public sector. *Interface*, 1–47. Retrieved from http://practicalparticipation.co.uk/odi/report/wp-content/uploads/2010/08/How-is-open-government-data-being-used-in-practice.pdf

Dolmans, D. H. J. M., De Grave, W., Wolfhagen, I. H. a P., & Van Der Vleuten, C. P. M. (2005). Problem-based learning: Future challenges for educational practice and research. *Medical Education*, *39*(7), 732–741. http://dx.doi.org/10.1111/j.1365-2929.2005.02205.x

Doucette, L., & Fyfe, B. (2013). Drowning in Research Data: Addressing Data Management Literacy of Graduate Students. *Imagine, Innovate, Inspire: The Proceedings of the ACRL 2013 Conference*, 165–171. Retrieved from http://0-www.ala.org.librarycatalogs.nnu.edu/acrl/sites/ala.org.acrl/files/content/conferences/confsandpreconfs/2013/papers/DoucetteFyfe_Drowning.pdf

Duch, B. J., Groh, S. E., & Allen, D. E. (2001). *The Power of Problem-based Learning: A Practical "how To" for Teaching Undergraduate Courses in Any Discipline*. Stylus Publishing, LLC.

Evans, T., & Nation, D. (1993). *Reforming Open and Distance Education: Critical Reflections from Practice*. Psychology Press.

Eve, M. (2013). *Before the law: open access, quality control and the future of peer review*. London. Retrieved from http://eprints.lincoln.ac.uk/10019

Fischer, G., Rohde, M., & Wulf, V. (2007). Community-based learning: The core competency of residential, research-based universities. International Journal on Computer-Supported Collaborative Learning. *International Journal of Computer-Supported Collaborative Learning*, *2*(1), 9–40. Retrieved from http://l3d.cs.colorado.edu/~gerhard/papers/final-iJCSCL07-rhode-wulf.pdf

Gilardi, S., & Lozza, E. (2009). Inquiry-Based Learning and Undergraduates' Professional Identity Development: Assessment of a Field Research-Based Course. *Innovative Higher Education*, *34*(4), 245–256. http://dx.doi.org/10.1007/s10755-009-9109-0

Gurstein, M. B. (2011). Open data: Empowering the empowered or effective data use for everyone? *First Monday*, *16*(2). http://dx.doi.org/10.5210/fm.v16i2.3316

Healey, M. (2005). Linking research and teaching exploring disciplinary spaces and the role of inquiry-based learning. *Reshaping the University: new relationships between research, scholarship and teaching,* 67–78. Retrieved from http://www.delta.wisc.edu/events/bbb balance healey.pdf

Hmelo-Silver, C. (2004). Problem-Based Learning: What and How Do Students Learn? *Educational Psychology Review*, *16*(3), 235–267. Retrieved from http://www.seattleimplementation.org/wp-content/uploads/2011/12/Hmelo-Silver-problem-based-learning-2004.pdf

Huijboom, N. & Van de Broek, T. (2011). Open data: an international comparison of strategies. European Journal of ePractice, 12, 4–16. Retrevied from http://www.epracticejournal.eu/

Johnson, J. A. (2014). From Open Data to Information Justice. *Ethics and Information Technology,* *16*(4), 263–274. http://dx.doi.org/10.1007/s10676-014-9351-8

Kasl, E., Marsick, V., & Dechant, K. (1997). Teams as Learners: A Research-Based Model of Team Learning. *The Journal of Applied Behavioral Science*, *33*(2), 227–246. http://dx.doi.org/10.1177/0021886397332010

Kotzé, T. G., & Plessis, P. J. Du. (2003). Students as "co-producers" of education: a proposed model of student socialisation and participation at tertiary institutions. *Quality Assurance in Education*, *11*(4), 186–201. http://dx.doi.org/10.1108/09684880310501377

Littlejohn, A., Beetham, H., & McGill, L. (2012). Learning at the digital frontier: a review of digital literacies in theory and practice. *Journal of Computer Assisted Learning*, *28*(6), 547–556. http://dx.doi.org/10.1111/j.1365-2729.2011.00474.x

Mazón, J.-N., Lloret, E., Gómez, E., Aguilar, A., Mingot, I., Pérez, E., & Quereda, L. (2014). Reusing open data for learning database design. In *Computers in Education (SIIE), 2014 International Symposium* (pp. 59–64). http://dx.doi.org/10.1109/SIIE.2014.7017705

Molloy, J. C. (2011). The open knowledge foundation: Open data means better science. *PLoS Biology*, *9*(12), 1–4. http://dx.doi.org/10.1371/journal.pbio.1001195

Neary, M., & Winn, J. (2009). The student as producer: reinventing the student experience in higher education. In *The future of higher education: policy, pedagogy and the student experience* (pp. 192–210). Retrieved from http://eprints.lincoln.ac.uk/1675/

Nowotny, H., Scott, P., & Gibbons, M. T. (2001). *Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty*. Wiley.

OECD. (2009). Focus on Citizens. (J. Bourgon, Ed.) *OECD Studies on Public Engagement*. OECD Publishing. http://dx.doi.org/10.1787/9789264048874-en

Papert, S. (1987). Computer Criticism vs. Technocentric Thinking. *Educational Research*, *16*(1), 22–30. Retrieved from http://learning.media.mit.edu/courses/mas713/readings/Papert,%20 technocentric%20thinking.pdf

Piorun, M., Kafel, D., Leger-Hornby, T., Najafi, S., Martin, E., Colombo, P., & LaPelle, N. (2012). Teaching Research Data Management: An Undergraduate/Graduate Curriculum. *Journal of eScience Librarianship*, *1*(1), 46–50. http://dx.doi.org/10.7191/jeslib.2012.1003

Rychen, D. S., & Salganik, L. H. (2003). Key competencies for a successful life and a well-functioning society. *OECD Definition and Selection of Competencies Final Report*, 1–20. Retrieved from http://www.oecd.org/pisa/35070367.pdf

Schield, M. (2004). Information literacy, statistical literacy and data literacy. *IASSIST Quarterly, 28*, 6–11.

Silberman, C. (1973). *The open classroom reader*. New York: Random House.

Smith, K. (2008). Embedding enterprise education into the curriculum at a research-led university. *Education + Training*, *50*(8/9), 713–724. http://dx.doi.org/10.1108/00400910810917082

Soder, R., Goodlad, J. I., & McMannon, T. J. (2001). *Developing democratic character in the young*. San Francisco: Jossey-Bass Inc.

Tanner, C. A. (2006). Thinking like a nurse: a research-based model of clinical judgment in nursing. *The Journal of Nursing Education*, *45*(6), 204–211. Retrieved from https://www.researchgate. net/profile/Christine_Tanner3/publication/7003793_Thinking_like_a_nurse_a_research-based_ model_of_clinical_judgment_in_nursing/links/0c9605294f14427681000000.pdf

Uhlir, P. F., & Schröder, P. (2007). Open Data for Global Science. *Data Science Journal*, *6*, OD36–OD53. http://dx.doi.org/10.2481/dsj.6.OD36

UNESCO. (2015). *Transversal competencies in education Policy and Practice*. (S. Strandberg, Ed.). Paris: UNESCO. Retrieved from http://unesdoc.unesco.org/images/0023/002319/231907E.pdf

Van Heuvelen, A. (1991). Learning to Think Like a Physicist. *American Journal of Physics, 59*, 891. http://dx.doi.org/10.1119/1.16667

Wagner, G. E. (2014). Research-Based Learning. In C. L. Quave (Ed.), *Innovative Strategies for Teaching in the Plant Sciences* (pp. 61–82). New York, NY: Springer New York. http://dx.doi. org/10.1007/978-1-4939-0422-8

Wallman, K. K. (1993). Enhancing Statistical Literacy: Enriching Our Society. *Journal of the American Statistical Association*, *88*(421), 1–8. http://dx.doi.org/10.2307/2290686

Watson, J., & Callingham, R. (2003). Statistical literacy: A complex hierarchical construct. *Statistics Education Research Journal*, *2*(July 2015), 3–46. Retrieved from http://www.stat.auckland.ac. nz/~iase/serj/SERJ2(2)_Watson_Callingham.pdf

Weinberger, A., & Fischer, F. (2006). A framework to analyze argumentative knowledge construction in computer-supported collaborative learning. *Computers and Education*, *46*(1), 71–95. http://dx.doi.org/10.1016/j.compedu.2005.04.003

Wenger, E. (1998). *Communities of practice: learning, meaning and identity*. Press Syndicate of the University of Cambridge, Cambridge.

Willems, J., & Bossu, C. (2012). Equity considerations for open educational resources in the glocalization of education. *Distance Education, 33*(2), 185–199. http://dx.doi.org/10.1080/01587919.2012.692051

Worthy, B. (2015). Who is using all this government open data? *Open Data Institute News*, 23 July 2015. Retrieved from http://theodi.org/blog/who-is-using-open-data

Zamorski, B. (2002). Research-led Teaching and Learning in Higher Education: A case. *Teaching in Higher Education*, *7*(4), 411–427. http://dx.doi.org/10.1080/135625102760553919

Zuiderwijk, A., Janssen, M., Choenni, S., Meijer, R., Alibaks, R. S., & Sheikh_Alibaks, R. (2012). Socio-technical impediments of open data. *Electronic Journal of eGovernment*, *10*(2), 156–172. Retrieved from www.ejeg.com