

Fostering Open Science to Research using a Taxonomy and an eLearning Portal

Nancy Pontika
Open University
Walton Hall
Milton Keynes, United Kingdom
nancy.pontika@open.ac.uk

Petr Knoth
Open University
Walton Hall
Milton Keynes, United Kingdom
petr.knoth@open.ac.uk

Matteo Cancellieri
Open University
Walton Hall
Milton Keynes, United Kingdom
matteo.cancellieri@open.ac.uk

Samuel Pearce
Open University
Walton Hall
Milton Keynes, United Kingdom
samuel.pearce@open.ac.uk

ABSTRACT

The term "Open Science" is recently widely used, but it is still unclear to many research stakeholders - funders, policy makers, researchers, administrators, librarians and repository managers - how Open Science can be achieved. FOSTER (Facilitate Open Science Training for European Research) is a European Commission funded project, which is developing an e-learning portal to support the training of a wide range of stakeholders in Open Science and related areas. In 2014 the FOSTER project co-funded 28 training activities in Open Science, which include more than 110 events, while in 2015 the project has supported 24 community training events in 18 countries. In this paper, we describe the FOSTER approach in structuring the Open Science domain for educational purposes, present the functionality of the FOSTER training portal and discuss its use and potential for training the key stakeholders using self-learning and blended-learning methods.

Keywords

Open Science, FOSTER, project, scientific communication, software, taxonomy, elearning, courses, research, stakeholders.

1. INTRODUCTION

In the current scholarly communications agenda the concept of Open Science (OS) ranks highly, mainly due to its widely accepted benefits for the scientific world. OS allows the reproduction of the research findings, enables transparency in the research methodology, increases the researcher's societal impact and saves money and time both for researchers and research institutions [1]. Recently, many researchers are interested in embedding OS practices in their research projects [2] [3]. There are also some who already apply them, but there is still a large knowledge gap regarding the best practices, workflows, software and techniques that can or should be used. OS is a relatively new and complex concept and its adoption will require a shift in the researchers' behaviour regarding the conduction of research and information sharing and will demand the adoption of new practices. Nonetheless, the information regarding all these new trends is either not available, or it is spread across a variety of resources making it difficult to be found. Therefore, many researchers are today not aware of all the components that comprise OS and have not been trained to practise OS.

In order to better understand the core components of OS we must provide a definition for each one of the four terms that compose it. *Open access* refers to online, peer-reviewed scholarly outputs, which are free to read, with limited or no copyright and licensing restrictions [4]. The first official recognition of open access dates back to 2002, when the Budapest Open Access Initiative [5] defined open access not only as a term, but also as a strategy that could induce an increase in the amount of free of cost, accessible and reusable research outputs. Since then, the open scholarly communications agenda has grown and currently more terms are embedded in it such as open data, open source and open reproducible research. *Open data* deals with the online publication of the research data gathered during a research project and made available for access and re-use [6]. When we talk about *open source*, we mean software that can be accessed online for free, with a source code license that allows its use, creation of derivatives and distribution [7]. *Open reproducible research* is the act of practicing OS to enable the independent reproducibility of the research results [8].

OS comprises of all these aforementioned terms and shares the same underlying principles: transparency, universal accessibility and reusability of the scientific information disseminated via online tools [9]. The fact that OS is inclusive of these four terms demonstrates a universal trend that calls for a shift in the researchers' behaviour towards open content and for the adoption of a wide range of open practices and strategies that relate to the whole research life cycle.

Among the four open movements, open source and open access are the ones that have existed longer, have gained plenty of supporters, progressed and grown. With regards to open source, currently, there are open platforms for open software, such as GitHub¹, Bitbucket² or SourceForge³. In terms of open access many open access journals and open repositories have been developed; as of 1st June 2015, the Directory of Open Access Journals⁴ listed 10,589 open access journals, while OpenDOAR⁵, the directory of open access repositories, listed 2,730 repositories.

¹ <https://github.com/>

² <https://bitbucket.org/>

³ <http://sourceforge.net/>

⁴ <http://doaj.org/>

⁵ <http://www.opendoar.org/>

Even though there has been a lot of progress, the release of open data still remains challenging. Currently, there are leading actions that promote open data, such as the Global Open Data Initiative⁶, tools that register research data repositories and assist users locating them, such as re3data⁷ and databib⁸ respectively, while the Open Access Directory⁹, a wiki on factual lists on open access, provides a list of data repositories per discipline¹⁰. Nonetheless, distributing research data openly is still not a common behaviour and practices differ; for example, even though there is a high uptake in openly sharing data in astronomy and genomics, the sharing methods vary among researchers even in the same subject fields [10]. In addition, due to the fact that research data can appear and be defined in a wide variety of shapes and arrangements, their meaning could be misleading when they are disassociated from their original context [11]. Borgam [12] supports that even though there is a high demand for scientists to adopt actions and best practices for sharing data, there is still a lack of clarity with regards to the ways of sharing research data with the various research stakeholders and under which circumstances the data must be analysed and interpreted.

The fourth component of OS, open reproducible research, is lacking the necessary attention from the research community. The term “reproducible research” appears widely in the sciences, primarily in the computer science and more specifically in the computer engineering subject field [13]. But the prominent question is “*how do we make use of computer engineering to support reproducible research in all scientific disciplines?*” If we wanted to take this question even further and broaden it with respect to the other scientific fields, we should ask *how does one can make available the steps taken in a specific experiment, present the supporting tools, such as the materials, code, instruments, etc. and the concluding data after conducting an experiment?* Kraker et al. [14] describe the component that serves as a bridge between the pre-processed data and the concluding output as *open methodology*. With the open methodology the authors attempt to create a link between the research results presented in the scientific research paper and all the processes that were followed and applied in order to produce these results, which are very rarely mentioned in the scientific paper.

Since we are lacking the knowledge on how to apply open reproducible research and due to the difficulties we face with formulating common grounds and best practices in openly sharing research data, the next emerging question is: *how can the application of OS be made possible? How can researchers apply OS?*

2. OPEN SCIENCE EMBEDDED IN E-LEARNING

Nowadays, technology is advancing at a fast speed offering new opportunities for educators and online knowledge sharing. The advancement of the Information and Communication Technologies offered new ways of partnerships and participation

[15] and brought new methods in the adoption of educational and learning methods [16]. The establishment of the movement around Open Educational Resources (OERs) has introduced new practices in acquiring knowledge and accelerating the learning process [17], with the primary goal of the OERs being the creation of “a culture of sharing resources and practices which will help facilitate change and innovation in education” [18]. Most recently there is also the appearance of the Massive Open Online Courses (MOOCs), which are e-learning virtual classes to which everyone can participate free of cost. MOOCs often use a wide combination of the available technological educational methodologies; they broadcast lectures on the course topic, direct learners to useful webpages, provide research papers for download, have discussion groups and videoconferencing, and offer online quizzes and tests [19].

In a world where technology has advanced greatly and a large number of learners of all ages are pursuing a high standard of education, the growth of electronic learning (e-learning) is nothing else but prominent. The purpose of e-learning is to take advantage of the existing communication and teaching technologies in order to increase the value of the learning process and promote lifelong learning and continuous education. The significance of e-learning in education is that learners can experience learning both as individuals, but also as part of a group in a flexible environment and make use of the wide variety of the communication and learning tools and virtual classrooms [20].

FOSTER proposes that a meaningful way to teach OS is through an online environment, which has already proved it can reach a wide number of learners. Up until now, whenever OS is embedded in an institution's curricula it is taught only in face-to-face classes within the institution's premises. In such an environment, information dissemination is not possible, since it reaches only those participants who participate in it. Most of the times, these classes are in a form of a workshop and often, are not highly attended. In network science, where courses and scientific material is available online for free, with a plethora of information carrying open licenses, we need to take advantage of this new technological paradigm and extend the use of the online

⁶ <http://globalopendatainitiative.org/>

⁷ <http://www.re3data.org/>

⁸ <http://databib.org/about.php>

⁹ <http://oad.simmons.edu/>

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

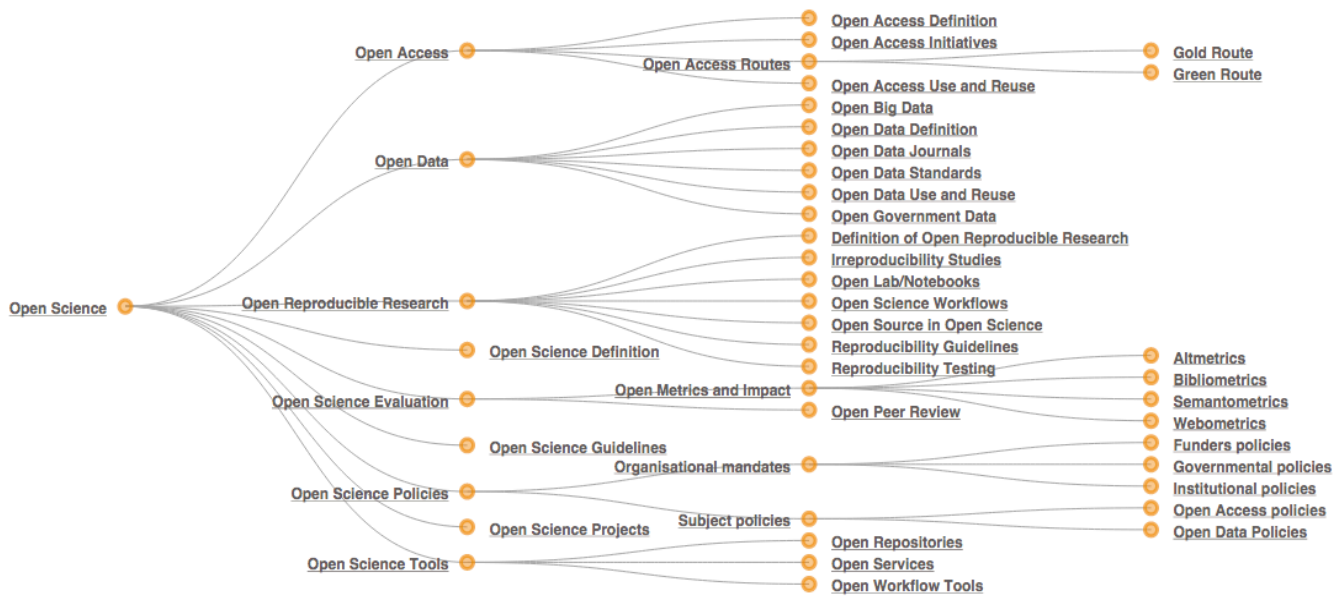


Figure 1. Open Science Taxonomy

information and collaboration into OS to promote its teaching via this method as a new skill.

OS requires multi-skilled learners, who must be able to have a good understanding of the requirements needed to conduct science, and recognise how science is evolving. Another important aspect is also the ability to recognise that there is a shift in the philosophy of sharing scientific experiences [21]. Since OS can bring financial benefits to the institutions it is important that researchers are trained to understand the technicalities for practicing OS in order that both them and their institutions take advantage of its benefits and not waste valuable money.

3. FOSTERING OPEN SCIENCE TO RESEARCH

The European Commission (EC) funding framework, Horizon2020, requires that all research results funded by the European Union (EU) should be provided open access and, with respect to research data that accompany these results. In the Horizon 2020 (H2020), the EC has established an Open Research Data Pilot [22]. However, research conducted with respect to open access implementation showed that there are still several components that need to be addressed to support the compliance of funders' open access policies and improve the availability of information that could bridge knowledge gaps [23]. The FOSTER project attempts to provide a solution to this issue by the portal users to address each problem separately and collaborate with key research stakeholders.

The primary goal of the FOSTER project is to empower the institutional training capacity and increase the compliance percentage of funders' open access policies by combining the research principles and processes with a focus primarily in early career researchers. The project's objectives are to:

- discover the existing resources in OS that could be reused and the creation new resources if there is demand for it

- construct a portal that can be used as an e-learning platform, where all the resources would be hosted, and
- deliver training to all types of research stakeholders.

In this paper we focus on the second objective; we explore how FOSTER defines the OS domain by building a taxonomy in the field and how it responds to the need for the creation of an open e-learning platform in OS, by collecting learning objects and creating an online educational portal in OS.

4. OPEN SCIENCE TAXONOMY

Since the OS field is relatively new, we wanted to specify the OS concept with the use of a taxonomy. The reason that FOSTER created an OS taxonomy was twofold. First, we attempted to map the field and offer an in-depth representation of the concepts around OS; FOSTER's vision was to present the OS components to those who were not familiar with the concept. The second goal was to provide structured and consistent terminology that would reduce the current descriptive conflicts in the field of OS and promote its development through the consistency of the open practices that relate to the OS terminology. Therefore, the project's goal was not only to use the taxonomy to classify the subject field, but also to take advantage of its organising ability. Since taxonomies are tools that can be used to classify content, at FOSTER we are using the taxonomy to systematise the educational resources hosted in the portal, which would also assist both the portal managers and the general public with the material and events review process.

More specifically the need for a topic classification for the portal was essential for the following purposes:

- provide facilities for navigating and browsing the FOSTER content
- use it as a structure to which users can subscribe to receive updates of content hosted in the portal



Figure 2. Research Data Management and Legal Issues Taxonomies

- provide a structure to identify reviewers who would be experts in specific fields
- provide facilities for linking and recommending related content in the portal
- provide a map of topics to inform learners on the areas of OS
- ensure that the FOSTER training content covers all areas in the field
- serve as a structure for the helpdesk service.

The creation of the taxonomy was not a straightforward task. FOSTER is a multi-partner project where each partner specialises in different aspects in the field forming a complementary consortium. Consequently, each partner viewed the organisation of OS from a different perspective. During the creation of the taxonomy we encountered four main issues. The:

- number of hierarchies that should be created,
- terminology that should be used,
- organisation of the terms, and
- level of depth for each term.

We managed to resolve these problems in the following ways. First, we organised online meetings with all the partners after each new taxonomy version, where we would discuss which sections to keep and which to amend. To address the hierarchy problem, we decided to separate hierarchies rather than use them in parallel, so that a source can be annotated with multiple tags from one or more of these hierarchies. To avoid the disagreement about the terminology we would use, we intentionally decided not to create a deep taxonomy and removed certain sections that were thought to be repetitive. In addition, we had to regularly update the taxonomy terms to follow naturally the broader and narrower term criteria. Finally, we made sure that all “children” of broader terms corresponded to mutually independent topics.

When we agreed on the predominant terms, we mapped the taxonomy relationships in an intuitive way, which also fitted in the general structure of the OS field. Therefore, it was decided that nine taxonomy terms would be used at a first instance, which are Open Access, Open Data, Open Reproducible Research, Open Science Definition, Open Science Evaluation, Open Science Guidelines, Open Science Policies, Open Science Projects and Open Science Tools (Figure 1). These nine main taxonomy terms

were then further divided into sub-topics, to better describe and classify the field.

Three terms, Open Science Definition, Open Science Guidelines and Open Science Projects are not divided further, but the vast majority of the predominant terms Open Access, Open Data, Open Reproducible Research, Open Evaluation, Open Science Policies and Open Science Tools, were further explored. We thought that the creation of a relationship between broad and narrow terms would not only be essential to achieve the goals for the taxonomy creation and address successfully the aforementioned purposes, but it would also enable us with some flexibility to assign more than one term in an object in the portal in order to better describe it and identify it. Having the same goals in mind, we decided to create a tree-structure of maximum of three branches deep, as the further division of the field would possibly confuse users [24], who would have to deal with many terms in a relatively new subject field.

OS, though, is not a field that stands alone. A large and important component of OS is related to the legal issues behind sharing, reusing and reproducing text, data, research methodologies, practices and experiments. Furthermore, the research data management plans constitute the best approach into organising research data throughout the whole research lifecycle. Overall, the conduction of research stands on a system of moral principles. As a result, these three concepts could not be overlooked and had to be included conceptually in the FOSTER portal objects. Therefore, we decided to approach this complexity with a faceted classification, which would allow us to classify objects using more than a single taxonomy. Thus we created three separate taxonomies, Legal Issues, Research Data Management (Figure 2) and Ethics, which stand at the same level with the Open Science taxonomy. The Legal Issues and Research Data Management taxonomies have only one level of narrower terms, while we did not identify any terms for the Ethics taxonomy, but we left this section open for future expansion, which will be based on the project’s needs. Our goal was to use these three taxonomies to complement the main OS taxonomy. Thus, explored only on those terms that would be useful to describe an object in the FOSTER portal more accurately.

5. FOSTER PORTAL

The FOSTER portal is a web-based e-learning platform created at the Knowledge Media Institute (KMi), Open University (OU). Both the OU and the KMi have a long tradition and extended experience in online distance teaching based on state-of-the-art technology to support it. The FOSTER portal is the tool that

conceptualises the project's goals, which are to collect, manage and adequately present quality training resources, including materials and courses to help educate researchers in OS and initiate collaboration. For the last two parts, the pedagogy and quality behind OS training material, the project has managed to create a close cooperation with well-established and trusted organisations in scholarly communication, such as the Electronic Information for Libraries (EIFL), the European Scholarly Publishing and Academic Resources Coalition (SPARC Europe) and Open Access Infrastructure for Research in Europe (OpenAIRE).

Currently, the portal hosts both existing and new material; users can retrieve scientific outputs with an open license that allows reuse, or access brand new material that were created to close the information gap in the OS agenda. All resources submitted in the portal are assigned one or more taxonomy terms, which enhances the material's discoverability and reuse. The portal administrators use also the taxonomy as an assisting tool, which informs them whether there is a high traffic in specific OS topics, or, even, potential gaps. New material can only be uploaded to the portal by authenticated users, but all uploaded materials need to be accompanied with adequate bibliographic and metadata information to assist its proper classification in the portal. Every time a new resource is added, experts in the field review the material to assess the content's quality, which then gets promoted for public use. The portal and the resources are openly accessible to everyone in the world.

Table 1. Audience and Knowledge Based Categories

Type	Categories
Audience Based	Librarians and Repository Managers PhD Students Policy-makers and Funders Project Managers Publishers Research Administrators Researchers and Students
Knowledge Based	Introductory – no previous knowledge is required Introductory: aware of Intermediate: able to Advanced: apply

5.1 Output file types

FOSTER attempted to develop a flexible e-learning platform to help stakeholders practice OS in many different ways using a variety of methods. According to Gordon [25], an adaptable educational environment supports a variety of teaching pedagogical approaches supported by systems that make the teaching and learning possible. Having that in mind, the FOSTER portal supports four main file types for new content for upload: documents, articles, videos and links (Figure 3).

When users need to upload MS Word, Powerpoint Presentation and PDF files, they can use the “Document” functionality. In our

attempt to create an extensible learning environment, the portal supports the upload of vast majority of formats will automatically convert them to PDF and ePub to support the documents' accessibility on different devices, such as computers, mobile phones and e-readers. Users are also allowed to add material directly to the portal, by typing all the content in the “Article”

section, which, for example can be used to write an article or a blog post. All the text and the accompanying images in the second section can be added in Markdown¹¹, a markup language with a simple formatting syntax.

An adjustable learning environment also requires the use of multimedia and should allow their streaming and sharing. This functionality is embedded directly in the FOSTER portal and it is enabled via embedding popular video sharing websites, for example YouTube and Vimeo. In addition to video, the portal supports live streaming of events through existing platforms that offer this service. Those types of outputs that cannot be uploaded or hosted directly in the portal, for example full websites, services, blog posts, can be linked from the portal. The linking requires that the user inserts the resource's bibliographic information and its metadata information in the available data fields that describe the resource. The training material presented in the portal uses the OpenGraph protocol¹², to accurately represent the page's content.

5.2 User-centred portal functionality

The core aim of the FOSTER portal was not only the creation of a platform that would hold a rich collection of OS material, but also a tool that would respect and successfully accommodate the stakeholders' need to explore and discover this brand new field. Since OS is a fairly new term and there are many components that compose it, FOSTER wanted to create an easy to use platform, where the information would be useful for its audience, informative, and addressed at all audience types. To accomplish this, the FOSTER portal can be explored in three different ways: audience based, knowledge level based and topic based. Thus, when users submit resources to the portal, apart from the taxonomy (topic based), they can use other hierarchies, such as the level of expertise (audience based) and the educational awareness of the topic (knowledge based).

To determine the portal's audience and create an analysis of the targeted group, who would be using the training material, the project participants were surveyed at the beginning of the project (March – April 2014) and the results were used to identify the possible audience of the portal. An educational path was then tailored to the expected audience. Seven different stakeholder groups were identified: “Librarians and Repository Managers”, “PhD Students”, “Policy-makers and Funders”, “Project Managers”, “Publishers”, “Research Administrators”, “Researchers and Students” (Table 1). These groups constitute part of the descriptive metadata for every resource and are a mandatory field for every resource or lesson in the portal.

As it has already been mentioned in the introduction, some researchers have already experimented with OS, while others are still trying to understand its concept. To address this problem in the FOSTER portal, the materials are categorised based on the audience's level of expertise. One of the metadata fields that accompany every resource in the portal is the “level of knowledge”, which provides four options - “introductory – no previous knowledge is required”, “introductory: aware of”, “intermediate: able to”, and “advanced: apply” (Table 1). This is a mandatory field in the portal and it is used to identify the user

¹¹ <https://daringfireball.net/projects/markdown/syntax>

¹² <http://ogp.me/>

groups that could be benefited from the available resources in the portal.

To assist the stakeholders with the learning process, FOSTER wanted to encourage them to explore the variety of topics that relate to OS by navigating through the different OS related terms. Via this method, the learners would reach the information they are interested in to discover and learn new topics, and gain an understanding of their relationship and application. With the use of the taxonomy described in the section above, the users are in the position to navigate the portal's content with ease and flexibility and focus not only on their field of interest, but also examine new topics and their connections. In addition, researchers can see how the OS components fit in the whole research lifecycle. Therefore, the portal is offering an adaptable educational environment, where the selection of the resources can be created on the fly, based on the user's knowledge level. Whenever a user is interested in a specific topic can subscribe to it and an email notification will inform the user when new materials are uploaded in the portal. Each topic in the taxonomy is assigned to one or more experts from the FOSTER partners, who appraise the content's quality and the educational value of the topic. Moreover, these experts are able to address and answer questions on the topic enabling the creation of a common knowledge base in each field.

FOSTER is a two years project and in its last six months, September to February 2015, there are plans for content growth and future sustainability of the portal content. Currently, the consortium partners are still testing the quality and functionality of the first FOSTER courses, therefore 653 unique OS resources can be accessed by the portal's visitors. Some resources have only one taxonomy term assigned to them, while others may have more. The first level taxonomy term coverage in the portal is shown in Table 2. Four topics are not yet covered in the portal's resources - "irreproducibility studies", "reproducibility guidelines", "reproducibility testing" and "webometrics" - which indicates possible gaps both in the FOSTER portal and the OS agenda.

6. COURSES

It has already been mentioned that FOSTER considers e-learning to be a substantial component in the OS teaching and has decided to educate research stakeholders interested in OS through online learning. To achieve that, FOSTER has created a platform that contains the majority of the pedagogical and technological criteria required for the creation of a successful online course. According to Yousef et al. [26] the components relating to the pedagogical criteria are the instructional design and assessment, while the technological criteria are divided into four categories; user-interface, video content, learning and social tools, and learning analytics. Further down we explain how the FOSTER courses fulfil these quality components.

Table 2. Open Science Taxonomy Term Coverage

Taxonomy Term	Number of Resources
Open Access	335
Open Data	185
Open Reproducible Research	33
Open Science Definition	12
Open Science Evaluation	49
Open Science Guidelines	2
Open Science Policies	95
Open Science Projects	3
Open Science Tools	87

The FOSTER portal, apart from the collection of resources and the training material related to OS, offers also a powerful learning platform to help stakeholders learn how to practice OS. The portal offers a course creation functionality with self-learning and blended-learning capabilities. The portal's first course is an introduction to OS, entitled "Open Science to Science Research", while the project is building six more courses on the topics of Horizon2020 and open science, open research data, open access policies, good practice approaches to populating open access repositories and open reproducible research, to name a few. While the first courses were created by the FOSTER project partners, the overall goal is to open up the course creation to other experts in the OS field. Perspective course instructors first need to create a course proposal, which will then be reviewed by an educational and technical team, who verify the didactic and informational value of the course and identify possible technical requirements. The inclusion of the course functionality in the FOSTER portal enables a spherical focus on the topic of OS, building not only a list of resources, but also serving as a pedagogical tool in the same platform, where the two components can be combined to achieve the best learning results.

To support the community through the learning process, three functionalities are embedded in the FOSTER courses: Lessons, Quizzes and Forums. The "Lessons" section is where the course instructors could and should present the vast majority of the lesson's content; each lesson is composed of training materials linked and arranged in an order that demonstrate their educational value in the whole module. The assessment of the learners' progress can be done via the creation of quizzes, which are related either to a specific lesson or the whole course. Every quiz offers a variety of question types such as multiple choice, matching sections, free text answers, true/false and scale questions. Quizzes can operate in two different frameworks; they can either be accessible throughout the duration of the course for the learners' self-assessment or they can be taken in a specific time period, defined by the instructor. In order to ensure the creation of moderated courses, to enable a good communication route between the instructor and the course participants and promote the collaboration among the participants, the courses also provide a forum, which is available to registered users only, where both parties share thoughts and questions.

Lesson materials are open for everyone in the world to read and download, while there is the opportunity for the learners to test their knowledge by taking the quizzes. For those who wish to officially participate in the course, there is the option of registering for the course, which offers a virtual classroom experience, with a structured curriculum and collaboration opportunities. In addition, registered users are able to receive a certificate when they successfully complete all the course lessons, quizzes and other assignments. The certificate has been found [27] [28] to be an important motivator for learners to participate in online courses, since learners feel rewarded when they receive an acknowledgement of their efforts.

7. CONCLUSION

Over the past fifteen years the scholarly communications agenda has progressed gradually. Currently we are experiencing a strong tendency among all research stakeholders to engage with the practice of OS. Lately, research funders require the sharing not only of the research results they have funded, but also of the procedures and data that are being generated during the research conduct. Researchers, on the other side, are keen on observing their research results being used for the improvement of the society and are forced by their funders to demonstrate the impact of their research. At the same time, higher academic institutions aim to join the OS agenda as well, since they see the opportunity of great economic benefits and savings. While OS is the possible answer to all these factors, the stakeholders' inability to understand the requirements for the application of OS can be a suspensory factor for the OS implementation and evolution.

The aim of the FOSTER project is to advance the stakeholders' knowledge on the usefulness of OS and explain the technicalities, strategies and best practices using which OS can be applied. As an attempt to educate the largest number of researchers possible, FOSTER has created an e-learning portal, which contains quality assured information relating to the topic and it is open to everyone in the world. The platform contains two types of information: learning material and online courses. The classification of these two types is supported by an OS taxonomy, where related terms are applied both in the portal's material and also in the courses. With the use of the taxonomy, users are in the position to understand the OS domain and the concepts around it.

The main goal of the FOSTER project, which is mainly achieved through the portal functionalities, is not only to educate the research stakeholders on OS, but also to build a community of researchers, librarians, software developers, funders and research administrators who are interested in OS in order to advance the way research is being conducted and shared. In addition, FOSTER attempts to provide tools to this community, such as re-usable content for training and a platform for blended learning and e-learning courses that the community could run. This OS advancement is essential for the research promotion and, consequently, for the benefit of the society as a whole.

8. ACKNOWLEDGMENTS

This project has received funding from the European Union's Seventh Programme for Research, Technological Development and Demonstration under Grant Agreement No 612425. The authors would like to thank Iryna Kuchma and Joy Davidson for their valuable comments on this paper.

9. REFERENCES

- [1] RIN/NESTA. (2010). *Open to all? Case studies of openness in research*. URL <http://www.rin.ac.uk/our-work/data-management-and-curation/open-science-case-studies>
- [2] Grand, A., Bultitude, K., Wilkinson, C. and Winfield, A.F. (2010). Muddying the waters or clearing the stream? Open Science as a communication medium. In: *Public Communication of Science and Technology*, New Delhi, India, 6-9 December 2010.
- [3] Grand, A., Wilkinson, C., Bultitude, K. and Winfield, A.F. (2010). On Open Science and public engagement in engineering. In: *European Association for Studies in Science and Technology*, Trento, Italy, 1-4 September 2010.
- [4] Suber, P. (2012). *Open Access*. Boston: MIT Press
- [5] *Budapest Open Access Initiative* (2002). URL <http://www.budapestopenaccessinitiative.org/read>
- [6] Murray-Rust, P. (2008). *Open Data in Science*. *Serials Review*, vol.34, no.1, pp.52-64. doi:10.1016/j.serrev.2008.01.001
- [7] Altenhören, R. Open Source Software - definition, licensing models and organizational consequences (introduction). In *Proceedings of the 71 IFLA General Conference and Council "Libraries – A voyage of discovery"* (Oslo, 2005) URL <http://archive.ifla.org/IV/ifla71/papers/121e-Altenhoener.pdf>
- [8] Stodden, V. (2009). Enabling Reproducible Research: Open Licensing for Scientific Innovation. *International Journal of Communications Law and Policy*, vol.13, pp.1-25
- [9] Gezelter, D. (2009). *What, exactly, is Open Science?* URL <http://www.openscience.org/blog/?p=269>
- [10] Wynholds, L., Fearon, D.S., Borgman, C. and Traweck, S. (2011). When use cases are not useful: Data practices, astronomy, and digital libraries. In *Proceedings of the 11th Annual International ACM/IEEE Joint Conference on Digital Libraries (JCSL '11)*, (pp.383 – 386). New York: ACM.
- [11] Bowker, G.C. (2000). Biodiversity datadiversity. *Social Studies of Science*, vol.30, no.5, pp.643-683.
- [12] Borgman, C. The conundrum of sharing research data. *Journal of the American Society for Information Science and Technology*, vol.63, no.6, pp.1059-1078.
- [13] Stodden, V., Leisch, F. and Peng, D. (eds). (2014). *Implementing Reproducible Research*. Chapman and Hall, 2014
- [14] Kraker, P., Leony, D., Reinhardt, W. and Beham, G. (2011). The case for an open science in technology enhanced learning. *International Journal of Technology Enhanced Learning*, vol.3, no.6.
- [15] Scanlon, E., Morris, E., Di Paolo, T. and Cooper, M. (2009). Contemporary approaches to technologically mediated practical work. *Studies in Science Education*, pp.73-114.
- [16] Conole, C., Lasuat, M.D., and Darby, J. (2006). *Jisc LXP student experiences of technologies. Final Report*. URL http://www.webarchive.org.uk/wayback/archive/20140615041434/http://www.jisc.ac.uk/media/documents/programmes/el_earningpedagogy/lxpprojectfinalreportdec06.pdf

- [17] Scanlon, E. (2012). Open educational resources in support of science learning: tools for inquiry and observation. *Distance Education*, vol.33, no.2, pp.221-236.
- [18] OER Commons. (2007). *OER Community*. URL <http://www.oercommons.org/community>
- [19] Hoy, M.B. (2014). MOOCs 101: An introduction to Massive Open Online Courses. *Medical Reference Services Quarterly*, vol.33, no.1, pp.85-91
- [20] (2003). *Towards a unified e-Learning Strategy*. Consultation Document. URL <https://www.education.gov.uk/consultations/downloadableDocuments/towards%20a%20unified%20e-learning%20strategy.pdf>
- [21] López-Borrull, A. (2014). Prom-Open: Promoting open science in an on-line e-learning environment. In *Proceedings of EDULEARN 14 Conference*, 7th – 9th July 2014, Barcelona, Spain.
- [22] (2012). *Open Access Guidelines for researchers funded by the ERC* URL http://erc.europa.eu/sites/default/files/document/file/open_access_policy_researchers_funded_ERC.pdf
- [23] (2012). *Survey on open access in FP7* URL http://ec.europa.eu/research/science-society/document_library/pdf_06/survey-on-open-access-in-fp7_en.pdf
- [24] Hedden, H. (2010). Taxonomies and controlled vocabularies best practices for metadata. *Journal of Digital Asset Management*, vol.6, pp.279-284. doi:10.1057/dam.2010.29
- [25] Gordon, N. (2014) *Flexible Pedagogies: technology-enhanced learning*. The Higher Education Academy. URL https://www.heacademy.ac.uk/sites/default/files/resources/TEL_report_0.pdf
- [26] Yousef, A.M.F., Chatti, M.A., Schroeder, U. and Wosnitza, M. (2014). *What drives a successful MOOC? An empirical examination of the criteria to assure design quality of MOOCs*. 2014 IEEE 14th International Conference on Advances Learning and Technologies.
- [27] Zutshi, S., O'Hare, S., Rodafinos, A. (2013). Experiences in MOOCs: The perspective to students. *American Journal of Distance Education*, vol.27, no.4. doi: 10.1080/08923647.2013.838067
- [28] Lorenz, A., Pscheida, D., Dubrau, M., Lissner, A. and Kahnwald, N. (2014). *Open Online Courses in the context of higher education: an evaluation of the German cMOOC*. EMOOCS 2014. URL http://www.researchgate.net/publication/263543544_Open_Online_Courses_in_the_context_of_higher_education_an_evaluation_of_a_German_cMOOC