Towards the Development of Open Educational Resources: Challenges and Issues

***Abstract*—The fast evolution of the Internet and the Information and Communication Technologies has leveraged and multiplied the possibilities of learning. Additionally, the advent of free and open software has also motivated research and development in the education area. As a result, there has been a change in the way that educational resources are designed, developed and delivered to learners. The term *Open Educational Resources* (OERs) has emerged as an attempt to standardize the educational content available in a free and open way through the Internet. The establishment and adoption of innovative processes, methods and tools for creating well-designed and highly flexible OERs are challenging for the scientific community in general and, especially, for software engineers. Indeed, Software Engineering practices and principles should be reviewed, updated and adapted for adequately deal with the developmental aspects and needs in this emerging scenario. Having this goal in mind, in this paper we identify some challenges and issues to be considered by software engineers in order to provide an adequate and efficient infrastructure to the development and adoption of OERs.**

I. Introduction

Education has been through enormous changes in the last decades. The need for a global education, capable of crossing international, cultural and social borders to prepare the learners for the global market has rapidly changing the concept of learning [1]. Moreover, the advent of the Internet and the fast evolution of Information and Communication Technologies has leveraged and multiplied the possibilities of learning.

Faced with these transformations, in recent years education and training issues have been attracting more and more interest from researchers around the world. Actually, it is ever more important for (under)graduates and professionals to be able to take their place in the changing world scene and to be adaptable and creative within the organization that employs them [2]. Also, in addition to a diversified student population in terms of ethnicity, social status and expectations, the proportion of nontraditional older adult re-entry students is increasing significantly.

The growing worldwide demand for more flexible, self-directed, informal and formal learning opportunities points out the need for more efficient and productive learning development scenarios. For instance, the changes within education have brought about changes to the roles of teachers and students and to the nature of the learning process. As stated by Koper [3], students can now be (co-)producers of learning materials, can perform assessments, and can support other students. Indeed, learning implies on exploiting the heterogeneity of learners by setting up learning communities in which novices collaborate with more experienced people. Similarly, teachers and experts can teach and learn at the same time in a certain field of expertise.

The challenge in building innovative learning experiences is how to provide ways to establish flexible and quality educational resources, capable of stimulating the learners (and teachers) and effectively contribute to their knowledge construction processes in active learning environments. Learning objects have emerged as interesting alternatives in this scenario. Shortly, a learning object can be characterized as a reusable digital content used as educational support. The idea is to allow the content be "broken into small pieces", which can be reused in different learning contexts and scenarios [4].

In a different but complementary perspective, the advent of Free/Libre Open Source Software (FLOSS) has also motivated research and development in the education area [5]. Recently, there arose the term *Open Educational Resources* (OERs) in an attempt to standardize the educational content available in a free and open way through the Internet. Basically, an OER encompasses [6]: (1) learning resources, such as learning objects, full courses and educational modules; (2) tools, such as supporting systems and platforms to the development, (re)use and delivery of learning content; and (3) implementation resources, such as intellectual property licenses to promote the publication, reuse and dissemination of the educational content.

In many aspects of development, the production of OERs is similar to software development. In the case of software, processes, methods and tools have been established aiming at contributing to the development of quality software products [1]. Similarly, the use of appropriate mechanisms to ensure the productivity of the development process and the quality of the resultant products are also critical to OERs.

The establishment of an adequate and efficient infrastructure to the development and adoption of well-designed and high-quality OERs is challenging for the scientific community in general and, especially, for software engineers. Indeed, Software Engineering practices and principles should be reviewed, updated and adapted for deal with the developmental aspects and needs in this emerging scenario. In this paper we point out some challenges and issues on Open Educational Resources, which have the potential to significantly advance the Software Engineering area in the next decade.

This paper is organized as follows. In Section II, an overview of OERs is provided. Challenges and issues in OERs as well as their impact on future research directions on Software Engineering are discussed in Section III. Concluding remarks are presented in Section IV.

II. Open Educational Resources

According to Atkins et al. [7], OERs are teaching, learning, and research resources that reside in the public domain or have been released under an intellectual property license that permits their free use or re-purposing by others. They include full courses, course materials, modules, textbooks, streaming videos, tests, software, and any other tools, materials or techniques used to support access to knowledge.

The OER movement originated from developments in open and distance learning and in the wider context of a culture of open knowledge, open source, free sharing and peer collaboration, which emerged in the late 20th century [5]. The connection between OER and Free/Libre Open Source Software (FLOSS) was first established in 1998 by Wiley [8], who introduced the concept of open content by analogy with open source. The term "Open Educational Resource" was first adopted at *UNESCO's 2002 Forum on the Impact of Open Courseware for Higher Education in Developing Countries* [9].

One of the relevant mechanisms for achieving the OER's goal of creating universal, free content for education is related to the adoption of open content licenses, particularly the licenses available at *Creative Commons*[1] that provide users the rights to reuse and redistribute content. These licenses do not replace copyright law, but rather use copyright to allow the content creator to specify ways in which the content can be used beyond fair use.

A schema for thinking about how OERs should be licensed is the *4R's Framework*, established by Wiley [10]:

- *Reuse*: the right to reuse the content in its unaltered/verbatim form (e.g., make a backup copy of the content).
- *Revise*: the right to adapt, adjust, modify, or alter the content itself (e.g., translate the content into another language).
- *Remix*: the right to combine the original or revised content with other content to create something new (e.g., incorporate the content into a mashup).
- *Redistribute*: the right to share copies of the original content, your revisions, or your remixes with others (e.g., give a copy of the content to a friend).

Among the most well-known OER initiatives is the *MIT's OpenCourseWare*[2] (MIT OCW), an initiative of the Massachusetts Institute of Technology to put all of the educational materials from its undergraduate and graduate courses online, partly free and openly available to anyone, anywhere. The project was announced in 2002 and evolved to the *OCW Consortium* in 2005.

Incorporated as an independent non-profit organization in 2008, the OpenCourseWare Consortium is now a community of over 250 universities and associated organizations worldwide committed to advancing OpenCourseWare sharing and its impact on global educational opportunity. The mission of the consortium is to advance formal and informal learning through the worldwide sharing and use of free, open, high-quality education materials organized as courses. Collectively, OCW Consortium members have published materials from more than 13,000 courses in 20 languages, available through the Consortium's web site[3].

Besides MIT OCW and OCW Consortium, several other OER initiatives can be pointed out: *Connexions*[4] (Rice University), *OpenLearn*[5] (UK Open University) and *Open Learning Initiative*[6] (Carnegie Mellon University), among others.

A. OER and Open Source Software

As highlighted by Wiley [8], the development of educational resources can be conducted in agreement with characteristics and principles of open source software development. Indeed, OER and open source software have many developmental aspects in common [6], [1]. The first one refers to the need for continuous evolution, in which updated versions of the software are released frequently, in response for the users' needs. The same characteristic is essential to the development of educational resources, especially due to the dynamic and evolutionary aspect of knowledge, from which such resources should be continuously evolved in consequence of previous learning experiences.

The geographical distribution of developers, which can participate of the construction process in a collaborative way (several times, as volunteers) is another common characteristic. The main idea is that each developer can contribute for the product (software or educational resource) and these contributions will be filtered in a "darwinian" way, that is, the best code (or the best content) will survive, being incorporated to the product. Obviously, there is a need for strong coordination among developers.

Finally, the development of "open products" also requires a set of collaborative technologies and infrastructure (e.g., e-mail, discussion forums, web, versioning controller systems, information repositories) to guarantee the communication and interaction among developers, geographically dispersed or not. In the case of educational resources, the adoption of collaborative technologies is crucial not only for its development process, but also for delivering and using the module, in order to conduct the activities and evaluations proposed to the learners.

III. Challenges and Future Research Directions

The development of OERs characterizes an important research issue to be addressed in long-term. Particularly, there is a need for innovative processes, methods and tools for creating well-designed and high-quality open educational resources. Software Engineering plays a fundamental role in this emerging scenario but, at the same time, advances are required as well. At the very end, the goal is to provide an infrastructure

[1] http://creativecommons.org
[2] http://ocw.mit.edu
[3] http://ocwconsortium.org
[4] http://ocx.org
[5] http://openlearn.open.ac.ul
[6] http://oli.web.cmu.edu/openlearning

for the development of OERs, which could effectively support new learning approaches and opportunities. Having this goal in mind, some challenges and their impact on the Software Engineering research are identified and briefly discussed next.

A. Web 2.0 Technologies and their Implications – Social and Personalized Learning, Learning Networks

The term *Web 2.0* (or the *Social Web*) refers to a web development stage which harnesses the power of the users, in which, for instance, web-based communities and social networking sites, wikis, blogs, mashups and folksonomies are integral parts [11]. The infrastructure of Web 2.0 also allows new ways of learning, where the learners are able not only to read but also to write (rate, comment, contribute with ideas, etc.) to communities, collaborating to achieve specific goals. Such communities provide not only significant OERs but also ease information sharing and cooperation between experts and peers.

According to Tapscott and Williams [12], the shift toward the Web 2.0 concept is changing the manner in which content and services are being produced. In the learning (and OER) setting, this change can be seen as the type of communication in which learners can exchange with their teachers the role of being active and leading the processes of learning and knowledge construction.

Personal Learning Environments (PLEs), for instance, are a result of the evolution of Web 2.0 and its impact on the learning process, being pointed out among the promises to the next generation of active and lifelong learning. The term PLE describes the tools, communities, and services that constitute the personal educational platforms used by learners to drive their own learning and achieve their educational goals [13]. In short, PLEs represent a shift away from the model in which learners consume information through independent channels (e.g., libraries, textbooks, LMSs) moving instead to a model where learners draw connections from a growing matrix of (open) resources that they select and organize. Hence, PLEs put students in charge of their own learning processes, challenging them to actively consider and reflect on the specific tools and resources that can lead to a deeper engagement with content to facilitate their learning.

As stated by Downes [14], the values that underlie the PLEs and Web 2.0 are the same: (1) the fostering of social networks and learning communities; (2) the emphasis on creation rather than consumption; and (3) the decentralization of content and control.

- *Learning in communities*: Communities of practice are formed by people who engage in a process of collective learning in a shared domain – people share a concern or a passion for something they do and learn how to do it better as they interact regularly. So, the necessary condition to learning occurs is the active participation in the community, what involves, essentially, a conversation between the learner and the other members of the community. Such conversation, in the Web 2.0 era, consists not only of words but of images, video, multimedia and much more. Furthermore, this conversation should form a rich matrix of (open) resources, dynamic and interconnected, created not only by experts, but by all members of the community, especially the learners.
- *Creation over consumption*: PLEs highlight the idea of making learners move beyond content consumption and memorization into stages of critical thinking, collaboration, and content creation. On the other hand, content creation sites have formed the vanguard of Web 2.0, emphasizing the idea that the web is a place where people can create and communicate, i.e., to network. The possibility of making the content creation occur, or be largely supported, online, converts the act of creating content into a social and connected act, broadening the learning opportunities to actively involve learners in their own knowledge construction process. Learning therefore evolves from being a transfer of content and knowledge to the production of content and knowledge.
- *Context over class*: When learning becomes the creation of content in the context of a community of practice, it also becomes something that is characterized not by instruction in a classroom, but rather by dialogue and communication within a given context. In an increasingly global world, learning environments are becoming ever more multi-disciplinary, i.e., learning from a large number of disciplines is required. Such environments cut across disciplines. Instead of studying subjects in an isolated way, students will learn the subjects as need, progressing more deeply into them as the need for new knowledge is provoked by the demands of real world applications. Learning opportunities – either in the form of interaction with others, in the form of learning objects and/or OERs, or in the form of interaction with mentors or instructors – will be embedded in the learning environment, sometimes presenting themselves spontaneously, sometimes presenting themselves on request.

The main goal of PLEs is to allow a learner (or anyone) to engage in a distributed environment consisting of a network of people, services and resources. Taken together, the ideas that underlie the PLE constitute an instance of a more general approach that may be characterized as *Learning Networks*. If properly designed, such networks can represent reliable producers of high-quality knowledge and learning. Through the process of interaction and communication, the entities that constitute the network will form a mesh of connections. Knowledge is embedded in this mesh of connections, and therefore, through interaction with the network, the learner can acquire the knowledge [14]. In this sense, talk about Learning Networks implies on considering not only the use of networks to support learning but also networks that learn. The core concept of Learning Networks is that these two things are one and the same.

Downes [14] also describes the properties of the network that are known to most reliably lead to network knowledge:

- Diversity: entities in the network should be diverse.

Diversity allows us to have multiple perspectives, to see things from a different point of view. As a consequence, the learner can reach beyond him/her groups and to connect with, and learn from, a wide range of influences.
- Autonomy: Each entity operates independently of the others. The network operates according to an individual and internal set of principles and values. Autonomy is what allows diverse entities to respond and react in a diverse manner.
- Interactivity or connectedness: The knowledge produced by a network should be the product of an interaction between its members, rather than a simple aggregation of the members' perspectives.
- Openness: Each entity in a network must be able to contribute to the network, and each entity needs to be able to receive from the network. Particularly, openness offers the opportunity to narrow the boundaries between producers and consumers as consumers themselves become producers, through creating and sharing. One implication is the potential for open educational resources, through learners themselves becoming producers of open content, books, multimedia, and so on (Attwell, 2007).

To sum up, Web 2.0 has significant implications in the development and adoption of OERs. Clearly, they complement each other and the benefits are numerous for both. On the other hand, as pointed out by Cristea et al. [11], with the massive amount of information available through Web 2.0, it is becoming harder for learners to learn or even to find, related communities, peers and content, what can make the learning process less efficient and narrow the OERs application. This scenario, in turn, also drives to advances in Software Engineering in order to provide innovative processes, methods and supporting tools, capable of deal with the ever-wider range of technologies in favor of an adequate and efficient development infrastructure for OERs.

As a final remark, the sucessors to Web 2.0 – Web 3.0, where the semantic search and browsing are made possible by natural language processing and Semantic Web technologies (Social Semantic Web), and Web 4.0 and beyond – are already being discussed [15]. These new technologies arguably impact OERs production and originate new issues, implying on Software Engineering long-term research endeavors in order to be addressed.

B. Collaborative and Distributed Work

In the previous section we have explored collaboration in OERs mainly under the learning perspective (collaborative learning), i.e., where learners can learn together and from each other by using OERs. However, collaboration is a key element under a developmental dimension as well. Indeed, the development of OERs can involve people from different knowledge areas, working on multi-disciplinary and heterogeneous teams, geographically dispersed or not. Such teams should cooperate and interact, sharing data and information related to the project (e.g., specifications, domain models, content, and results from learners' performance, among others). Furthermore, the teams' skills can vary, not only due to the human resources but also in terms of the technological, computational and economical resources available. Finally, the activities conducted by a given team can be required for another team, characterizing dependence relations among them.

Maidantchik [16] highlighted that the quality of the software products developed by geographically dispersed teams depends of effective communication, coordination of the distributed teams, systematic traceability of activities and artifacts, and availability of information regarding the development process. Similarly, the characteristics and needs identified in the distributed software development can also be observed in the context of OERs [1]:

- *Teams coordination*: A strong and effective coordination among the development teams should be provided as well as the establishment of each team capability and the allocation of activities and responsibilities accordingly.
- *Activities coordination*: A work flow regarding the development activities and tasks should be established and managed. Concurrent tasks requiring collaboration among teams should be identified and controlled.
- *Artifacts control*: Integration problems regarding the OER's components, distributed authoring and modeling, visibility of evaluations and performance results, changes notification, and configuration management should be addressed.
- *Communication support*: Development teams should interact, exchanging experiences, problems, solutions and results. Also, all project information should be available in order to guarantee the effective management of the module development process.

To deal with the needs for collaborative development imposed by OERs, aspects of Computer-Supported Cooperative Work (CSCW) [17] should be reviewed and improved in a close relation with advances and innovative practices in Software Engineering. Traditionally, both research communities share a common research question: how to support the collaboration and coordination of interdependent work activities. In the Software Engineering community solutions have concentrated on formalizing the coordination of work practices, while CSCW researchers have focused on increasing the ability of people to communicate. Although appropriate, in the new and ever changing world scene, it is fundamental to explore how to best take advantage of the great potential for new collaborative opportunities provided by the emerging information and communication technologies.

C. Quality Evaluation

Evaluation of OERs (including learning repositories and learning environments) is usually integrated in the overall learning design and development plan [18]. It is considered a vital component of a quality assurance strategy and the expectation is that evaluation activities can contribute significantly to the development of high-quality OERs. On the other hand, the establishment of *quality metrics* (and criteria) for judging OERs is complex and challenging.

The challenge for quality metrics for OER is twofold. First, given that OERs are, by definition, subject to derivation and re-mixing, how can we know whether any given OER has been properly evaluated or meets specific quality metrics? Even if a specific OER has passed certain quality-control criteria, how can we be sure that those criteria are associated with that exact version of the resource alone? Second, what are the metrics that we might use, and how can we obtain them? Given the global nature of the OER movement, we should expect that any metrics will be highly variable, though we would also be surprised if some shared criteria did not emerge. In addition, the situation is complicated by the fact that such metrics have to be provided and obtained in a manner that does not fundamentally undermine the openness of the OER.

In this scenario, technical dimensions of "OER quality" should be considered separately from the social dimensions (that are beyond the scope of this paper). Technical quality criteria refers to the specific characteristics and properties that OERs must adhere to, including best practices, guidelines and standards specifications, in order to be regarded as OERs.

Architectural issues (in terms of separation of data, logics, presentation, and implementation of interaction interfaces) can also be considered in this regard. As pointed by Paulsson and Naeve [19], there is a lack of explicit definitions and clear architectural models, together with technical (as well as other) quality criteria that are directly related to technical architecture. Actually, many of the pedagogical dependencies and shortcomings of OERs seem to be caused by technical bindings of content to presentation and application logics as well as built in instructional design elements.

Regarding standards, they should be extended to go beyond descriptive information, such as metadata, sequencing and packaging, to also embrace standards for interfaces, machine-readable descriptions of technical properties and interaction interfaces. There is also a need for standards and recommendations that address the internal use of data formats and data structure. General technology standards of this kind exist, but seem to be rarely used in the OER community.

Finally, it is worth to notice that in addition to technical criteria, pedagogical and functional quality criteria should also be defined. In the end, a quality framework for the whole life cycle of OERs can also be established.

The demand for OERs quality evaluation also imposes challenging issues to Software Engineering, especially regarding to the establishment of quality models capable of dealing with complex and high variable metrics and criteria.

IV. Concluding Remarks

According to the ideas discussed in this paper, planning for the future in Software Engineering assumes investigating innovative principles, processes, methods and tools to foster the development and adoption of OERs. In this regard, dealing with emerging web technologies, collaborative and distributed work, and quality models in the context of OERs are challenging issues that motivate advances in Software Engineering.

By providing an adequate and efficient development infrastructure for OERs, the resulting educational resources should be capable of promoting autonomy, encouraging diversity, enabling interaction and supporting openness. At the very end, the envisioned scenario is to put the learner as the main responsible for designing customized, adaptable, evolvable, reliable and quality OERs.

Particularly, we believe that OERs, supported by well-defined and innovative Software Engineering practices, will be the basis from which the learner will draw connections to acquire, evolve, disseminate and collaborate in using the knowledge information.

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