# Guest Editorial: Open Educational Resources in Engineering Education: Various Perspectives Opening the Education of Engineers

***Abstract*—Open Educational Resources (OER) provide a strategic opportunity to improve the quality of education as well as facilitate policy dialog, knowledge sharing, and capacity building. One of the fundamental concepts of OER is "the ability to freely adapt and reuse existing pieces of knowledge." Reuse of educational resources by both individuals and organizations may have significant creative and economic benefit for the educational environment. This Special Issue editorial introduces six interesting experiences, representative of the use of OER in engineering education in important areas such as the production of open content at various scales, reuse of contents, institutional open Web site initiatives, and technological applications to support the exploitation of OER, all at different degrees of maturity. Since some readers will be unfamiliar with prior work on OER, this Special Issue also outlines the hot topics in OER and the critical factors for success when joining the Open Educational Movement. Finally, the editorial provides a set of recommendations and examples offered by the Special Issue editors from their over 6 years of experience leading a research group in semantic Web technologies applied to Open Education. A key requirement, in their opinion, is to improve the metadata interoperability between various collections of open material, so as to facilitate the discoverability and subsequent combining, remixing, or adapting OER; that is, OER data should be easily accessible to any user.**

***Index Terms*—Linked data, Open Educational Resources, open learning, reusability, semantic Web.**

## I. Introduction

OPEN Educational Resources (OER) have assumed an increasing impact since the Massachusetts Institute of Technology (MIT) started publishing educational resources online as OpenCourseWare (OCW) in 2001. In 2007, the OCW Consortium was founded; since then, more that 300 institutions have joined. The OCW Consortium, now named the Open Education Consortium, is the largest international OER organization, but there are many other OER initiatives. Currently, hundreds of higher education institutions worldwide produce, reuse, and remix educational materials. The fact that educational content is becoming more widely available, free and online, leads to the question: What role will colleges and universities play in the future?

OER can help institutions provide higher education to the rapidly increasing numbers of students and lifelong learners. Traditional colleges and universities, with their experience and reputation, are in a good position to further develop online teaching and testing, learning communities, and certification. Those that produce high-quality knowledge, teaching, and students have little to fear, and much to gain, from OER. This movement has challenged the traditional value chain by employing new methods to deliver high-quality educational content. In this new paradigm for educational content consumption, OER are expected to play a decisive role for learning. Thus, OER are becoming a popular topic for new research techniques, and significant challenges need to be addressed.

The recent boom in massive open online courses (MOOCs) has reawakened interest in OER, but not all those interested in open education are equipped with the key elements required to support OER and to ensure its success. Section II thus describes the conditions, factors, and guidelines necessary for successful implementation of the OER concept and considers the following: the several definitions of OER; open licenses; use reusability, enhancing the discoverability of OER; open policies; opening access to OER repositories and datasets; and OER quality. Section III analyzes the manuscripts published in this Special Issue, emphasizing their significant contributions, and how their limitations drive the next steps to be done.

The Special Issue editors are members of the Higher Education Institution Quality Management Innovation Group, GICAC, and researchers from Universidad Politécnica de Madrid (UPM, Spain) and Universidad Técnica Particular de Loja (UTPL, Ecuador). Section IV presents their recommendations, based on their experience of applying semantic technologies to the various challenges of using OER. Finally, conclusions are drawn in Section V.

## II. OER Background

This section provides an oversight of OER since some readers may be unfamiliar with prior work in this area. The Special Issue editors consider key factors for OER to be the following:

- definitions of OER;
- use, reusability, and discoverability in OER development;
- open licenses;
- open policies;
- opening up OER repositories and datasets;
- quality.

### A. Open Educational Resources: Definitions

OER has numerous working definitions. The term was first coined at UNESCO's 2002 Forum on Open Courseware [1] and designates OER as "teaching, learning and research materials in any medium, digital or otherwise, that reside in the public

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domain or have been released under an open license that permits no-cost access, use, adaptation and redistribution by others with no or limited restrictions." In this sense, open licensing is built within the existing system of intellectual property rights as defined by relevant international conventions. It respects the authorship of the work, with the purpose of promoting the reuse of OER.

The Cape Town Open Education Declaration[1] is a major international statement on open access, open education, and open educational resources, intended to accelerate efforts to promote open resources, technology, and teaching practices in education [2]. To increase the reach and impact of OER, the Declaration calls on educators, authors, publishers, and institutions to release their resources openly, suggesting: "These open educational resources should be freely shared through open licenses which facilitate use, revision, translation, improvement and sharing by anyone."

The William and Flora Hewlett Foundation[2] states OER 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 and re-purposing by others" [3]. By this definition, OER 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 Organization for Economic Co-operation and Development (OECD) defines OER as "digitized materials offered freely and openly for educators, students, and self-learners to use and reuse for teaching, learning, and research" [4]. This definition includes as OER "learning content, software tools to develop, use, and distribute content, and implementation resources such as open licenses." Wikiversity[3] cites this definition and says "OER are documents, media, software and processes that are useful to teaching, learning, education and assessment, and that are made openly accessible and reusable by anyone for any purpose, free of barriers or restrictions."

Wikipedia suggests that OER refers to "digital materials that can be reused for teaching, learning, research and more, made available free through open licenses, which allow uses of the materials that would not be easily permitted under copyright alone." The Wikieducator OER Handbook[4] says that the term OER, "refers to educational resources (lesson plans, quizzes, syllabi, instructional modules, simulations, etc.) that are freely available for use, reuse, adaptation, and sharing."

OER Commons[5] says that OER are "teaching and learning materials that you may freely use and reuse, without charge. That means they have been authored or created by an individual or organization that chooses to retain few, if any, ownership rights. OER often have a Creative Commons or GNU license that state specifically how the material may be used, reused, adapted, and shared.

Downes defines OER as "materials used to support education that may be freely accessed, reused, modified and shared by anyone" [5]. The Commonwealth of Learning[6] defines OER as "materials offered freely and openly to use and adapt for teaching, learning, development and research."

### *B. Open Licenses: Free and Open Access to Educational Opportunities*

In 1998, David Wiley announced the first open content license. This license was based on the premise that educational content should be freely developed and shared "in a spirit similar to that of free and open software" [6]. Furthermore, it stipulated that content would be licensed in a manner that provides users with the right to more types of use than those normally permitted under the law [7]. The idea that content should be free and openly available quickly became popular. The primary permissions or usage rights with which open content is concerned are expressed in the "5Rs Framework": retain, reuse, revise, remix, and redistribute. These permissions are granted to users free of charge.

The non-profit organization Creative Commons, founded by Lawrence Lessing, released the first set of ShareAlike copyright licenses, partly inspired by the GNU General Public License, that helped content producers license their content for reuse [8]. Creative Commons licenses are freely available copyright licenses that enable a standardized sharing of copyright works for reuse in forms that are layman-, lawyer-, and machine-readable. Project Gutenberg, a collection of over 45 000 free e-books,[7] is a good example of how open educational resources can be repurposed for education.

### *C. Use, Reusability, and Discoverability in OER Development*

All human beings have the capacity to learn, improve, and progress; educational opportunity is the mechanism by which that happens. An implicit ethical obligation may follow from educational materials that can be electronically copied, reused, adapted, and transferred around the world at almost no cost. For OER to increase the reach of opportunity [8], two fundamental concepts—and problems to overcome—are reusability and discoverability.

*Reuse* is "the ability to freely adapt and reuse existing pieces of knowledge" [9], that is, to use a resource for another aim, usually for a purpose unintended by the original creator. OER *reusability* means that the content is relevant to the specific needs of a user, is technologically accessible, and is sufficiently open for use, reuse, remixing, adapting, and redistribution. Open educational digital materials and repositories take a rich diversity of types and representations and are linked to the specific application packages used to create or manage them. They are easily misidentified and are generally poorly described or annotated; they often have insufficient metadata attached to them to

[1]This emerged from a conference on open education hosted in Cape Town, South Africa, on September 14–15, 2007, by the Shuttleworth Foundation and the Open Society Institute.

[2]Since 2002, the Hewlett Foundation has worked with OER grantees to improve education globally by making high-quality academic materials openly available on the Internet (http://www.hewlett.org/programs/education/open-educational-resources).

[3]Wikiversity is hosted by the Wikimedia Foundation, a non-profit organization (http://en.wikiversity.org/wiki/Open_educational_resources).

[4]Wiki Educator: http://wikieducator.org/Oer

[5]OER Commons: http://www.oercommons.org/about

[6]Commonwealth of Learning. CoL.org: http://www.col.org/resources/crs-Materials/Pages/OCW-OER.aspx

[7]In August 2014, over 100 000 free e-books are available through partners, affiliates, and resources.

avoid a gradual diminution in their value. OER not only need to be gathered and stored, but must also be made useful and visible, a process that takes substantial human work, even if automation can aid in the process.

Various studies have highlighted the difficulty of finding OERs and how this affects their use. Reasons for OERs being hard to find are identified in [10]: technical issues of search engines and repositories, users' practical search skills, and the volume of resources available in different subject areas. The authors of [10] identified three factors that influence the decision to reuse digital material: improved quality, a teaching need, and peer suggestion.

### *D. Integrating OER Into Higher Education Institutions: Open Policies*

An educational institution can support production and sharing of OER through open access policies. Librarians can promote awareness of OER by preparing appropriate policy guides, as did OER Africa [11] and UNESCO [12], with the objective of encouraging decision-makers in governments and institutions to invest in the systematic production, adaptation, and use of OER and to bring OER into the mainstream of higher education to improve the quality of curricula and teaching.

Toolkits for policy review, such as [13], may help identify some OER policy implications by helping institutions review their policy environment and make any necessary changes to facilitate OER development and sharing. Another policy [14] provides universities with advice and recommendations for formulating a set of actions that can support the realization of successful, lively, and sustainable OER communities.

Recently, the Open Education Consortium (formerly the OCW Consortium) worked closely with Creative Commons to develop an OER policy registry. Furthermore, in May 2014, in partnership with numerous organizations around the world, Creative Commons launched Open Policy Network, whose mission is to foster the creation, adoption, and implementation of open policies and practices.

### *E. OER Repositories and Datasets*

The Open Definition[8] sets out principles that define "openness" in relation to data and content, specifying the meaning of "open" in the terms "open data" and "open content"; this ensures the interoperability and integration of various OER initiatives. It states: "A piece of data or content is open if anyone is free to use, reuse, and redistribute it—subject only, at most, to the requirement to attribute and/or share-alike" [15].

The Open Definition gives full details on the requirements for "open" data and content in the context of Open Educational Initiatives. Open data are the building components of open knowledge. Open knowledge consists of open educational resources and data that can be freely used, reused, remixed, adapted, and redistributed by anyone.

Therefore, the content and data must be available over the Internet, in a convenient, modifiable, machine-readable form, for no more than a reasonable reproduction cost, under terms that permit reuse, redistribution, and intermixing with other OER collections.

[8]Open Definition: http://opendefinition.org

### *F. Quality*

Studies provide quality and pedagogical guidelines for OER use in higher education [16] and a real-world quality model for OCW/OERs [17]. The latter emphasizes the technological aspects and interoperability requirements for OERs, in addition to other distribution and licensing models and user interface quality requirements. Quality guidelines that serve as a baseline for OERs in institutions of higher education are given in [18]. The main objective of the guidelines is to support education by the creation of educational resources that may be freely accessed, reused, modified, and shared. They outline key issues and make suggestions for integrating OER into higher education. A further interesting study on the reuse and adaptation of OERs [19] has the objective of exploring the current technology landscape with respect to both proprietary and free and open-source software (FOSS) technologies; it identifies techniques, existing and in development, for reuse of OER. Some of the quality assurance opportunities and challenges for OER are considered in [20], which covers internal institutional quality assurance mechanisms and the quality controls required on learning materials.

OER materials are scrutinized and used by a large audience worldwide; this incentivizes their authors to review and update the materials as necessary. Institutions that take the OER initiative seriously have strengthened their internal quality controls accordingly.

## III. Current State of OER-Based Practices in Engineering Education

This Special Issue on OER in Engineering Education in part addresses current practices. The call for papers focused on innovative experiences using OER to demonstrate the theory and practice of electrical and computer engineering, presenting both scientific and educational studies using OER-based novel educational research techniques such as social Web, semantic Web, and linked data that are within the scope of interest of the IEEE TRANSACTIONS ON EDUCATION. The target audience was educators and researchers across the fields of electrical and computer engineering, as well as practitioners wanting an insight into the future of OCW and the overall OER value chain.

The Editor-in-Chief, guest editors, and reviewers selected six manuscripts considered representative of relevant practices in the following areas:

- production of open content, at various scales, promoted by teachers and by institutional networks;
- reuse of contents;
- institutional open Web site initiatives;
- technological applications to support the exploitation of OER.

### *A. Production of Open Content*

The first two papers in this issue pay special attention to the production of experiments and the skills they engender. Although in both cases the material produced is accessible only to the students enrolled in each course, thus losing the original

"open" characteristic, it is a step forward to create awareness among faculty, students, and policy-makers of the importance of creating open content and the need for institutional policies on OER.

*Generating OER by Recording Lectures: A Case Study, by Martín Llamas-Nistal and Fernando A. Mikic Fonte*, presents an experience of recording lectures and generating the corresponding videos under an institutional policy of the University of Vigo, Spain, that makes all teaching material generated by its teachers freely available. Benefits offered by recorded lectures include: students being able to review material to complement in-class interactions, clarify misunderstandings, and catch up on missed classes; improved test scores; improved retention of class material; and flexible schedules. Emergent technological systems that easily capture and process lecture recordings support this kind of initiative. The main contribution of the paper is the definition of a process to show the organizational effort required to produce lecture recordings, manage existing video, serve designated distribution channels, and provide user interfaces. Records are made available through the Institutional Learning Management System.

*Improving Aerospace Engineering Students' Achievements by an Open Aero Control Experiment Apparatus, by Zeng QingHua, Zhang WeiHua, Huang ZheZhi, and Dong RongHua*, describes the development of an aero control experiment apparatus (ACEA) for use in aerospace control practical courses. The approach adds pedagogical value by allowing students to conduct experiments at various levels of difficulty (basic, case study, and independent design) to improve their skills. Critical to this effort was the redesign of the practical work curriculum according to the principles of multihierarchy learning and systematic practical teaching, and grouping the experimental resources by the subject of the experiment. OER allowed various resources to be reused and revised independently so as to meet the needs of students at different proficiency levels. This work can be considered as an example of integrating OER in the curriculum; although distribution is limited to the institution, it may be possible in future to exploit the open features.

A third manuscript, *The VLAB OER Experience: Modeling Potential-Adopter Student Acceptance, by Raghu Raman, Krishnashree Achuthan, Prema Nedungadi, Shyam Diwakar, and Ranjan Bose*, envisages building a large OER repository by a consortium of 12 top-ranked institutions whose goal is to develop over 1650 experiments across nine engineering disciplines, mapped to the engineering curriculum. Each lab's multiple experiments, remotely interfaced to a variety of equipment, combine animations, interactive simulations, and mathematical modeling of physical phenomena.

The consortium had to manage big-project issues, such as the development, deployment, and scaling of an OER model for engineering labs, and student learning outcomes. A multidisciplinary lab team, assembled to build the labs and guarantee quality of content, consisted of subject-matter experts, instructional designers, graphic designers, animation experts, and software developers, as well as coordinators and a review committee consisting of experts from academia and industry. Over 56 hands-on workshops were conducted in over 200 colleges, and more than 1200 faculty members and over 50 000 students were trained during these workshops.

A more mature experience in that it proposes a design of the organizational structure and an associated pedagogical model, challenges still remain. To sustain use of VLAB beyond the initial government funding will require innovative business models and integrated evaluation of student learning.

### B. Reuse of OERs

*OER Approach for Specific Student Groups in Hardware-Based Courses, by Nevena Ackovska and Sasko Ristov*, analyzes the interaction between OER and a specific target group of "busy" students, usually marginalized, in carrying out the laboratory exercises of a challenging hardware-based computer science course. It suggests a specific approach to teaching busy students in hardware-based courses that require significant laboratory work and thus the students' regular attendance.

The authors emphasize that teachers and institutions should not just provide open access to their educational material, but should openly share their experiences, case studies, lessons learned, and suggestions to improve the teaching and learning processes. In this case, OER had to accommodate students who could not attend the classes regularly by encouraging students to use OERs from other distinguished universities, such as MIT OCW, and to use books from open libraries, redirected by their authors to prestigious institutions' OER. These resources, however, are not remixed or readapted.

### C. Institutional Open Web Site Initiatives

*UNED OER Experience: From OCW to Open UNED, by Salvador Ros, Roberto Hernández, Timothy Read, Miguel Rodríguez Artacho, Rafael Pastor, and Gabriel Díaz-Orueta*, shows how a distance university can adapt and evolve to the changes in the open movement more easily than other institutions. Universidad Nacional de Educación a Distancia (UNED, Spain), in the early years, published OCW materials to supplement standard teaching in a variety of educational applications, among them induction and competence transfer courses. OCW materials were used as a starting point for a comprehensive OER policy at UNED for OER creation and distribution. The research and innovation in these 2004–2009 initiatives were the basis for the evolution of the OCW Web site toward the MOOC platform. The current method of course certification offering, for the first time in the history of the university, uses open content and practices from various parts of the university under the Creative Commons license, accessible from a single entry point or Web portal.

UNED's OCW success is due to its campus architecture strategy, as a traditional distance university, allowing the integration and efficient control of selected on-campus teaching tools with the main university management systems.

### D. Technological Applications That Support the Exploitation of OER

*A Semantically Enriched Context-Aware OER Recommendation Strategy and Its Application to a Computer Science OER Repository, by Almudena Ruiz-Iniesta, Guillermo*

*Jiménez-Díaz, and Mercedes Gómez-Albarrán*, describes a knowledge-based strategy for recommending educational resources to provide support for personalized access to the resources that exist in open educational computer science repositories. This is an example of challenges to technologies, such as the current inability of potential users (educators, students, or lifelong learners) to effectively search for OER adapted to their needs. The approach to enhancing the OER repository search experience uses a description of the educational resources tagged by metadata standards (IEEE LOM[9]) and enriched by ontology-based semantic indexing and contextual information about the OER user. Future versions of this work will have to manage interoperability between repositories and reduce workload to create the taxonomy and the pedagogical knowledge from scratch.

## IV. Analysis of Critical Factors for OER Practices in Engineering Education

The contributions described above indicate that OER are predominantly used to support teaching and learning activities or simply to provide access to learning materials by making course content available in online repositories under open licenses. In a small number of cases, OER are integrated in the curriculum; that is, students are expected to use OER as part of their course requirements, and the learning is formally evaluated through exams. In some cases, the evaluation process counts toward students' final course marks. In other cases, it creates opportunities for students to earn a credit or to obtain a certificate of completion.

Some OER initiatives are aligned with their institutional vision/mission or existing policies to provide, increase, or widen access to education/educational materials. Furthermore, such initiatives are also considered to be important in the context of an institution's marketing activities. OER materials are used to showcase educational quality to the rest of the world, to develop new partnerships or collaborations, or to attract new students into formal degree programs. Not all of these are OER experiences, although heading in that direction. Other cases must consider issues of sustainability to guarantee their success.

These results coincide with those of research carried out as part of the project on "OpenCourseWare in the European Higher Education Context: How to Make Use of its Full Potential for Virtual Mobility" [1]. The findings provide important insights into factors that both enable and inhibit implementation and use of OER in higher education. This survey only included questions considered relevant to identifying modes for successful use of OER. The results suggest that the main aims of these initiatives are to promote creation, sharing, and use of OER at their institutions and to improve existing educational materials and students' learning experiences [21].

The lessons learned from this research indicate that several factors need to be considered in the successful use of OER in higher education. Institutional support and positive attitudes from faculty members have been identified as the most important enablers.

[9]http://ltsc.ieee.org/wg12/ (Last accessed January 30, 2014)

## V. Special Issue Editors' Recommendations and Examples

This section begins with the Special Issue editors' recommendations for the future of OER.

First, the notion that OER conveys open education to all embodies a simple but powerful idea: Knowledge is a public good, and the Web provides an extraordinary opportunity for everyone to share, use, reuse, and adapt this knowledge.

Second, all educational material should be created and licensed under a Creative Commons or other "open" license for it to be legally used in an educational environment.

Third, OER should be designed to be easily found and to be adaptable to specific situations. Reusable OER should maintain the content, provenance, quality, and semantic meaning of the educational material, retain its interrelatedness, and collect information about its creation, use, reuse and adaptation, its proper semantic representation, and the data used to describe it.

Fourth, to be successful and sustainable, development of OER cannot be a sideline within an institution or education system. Development of learning resources needs to be integrated into institutional or systemic processes both to leverage their potential and ensure their sustainability. Likewise, policies, particularly on intellectual property rights, remuneration, and promotion, need to be adapted to support and sustain the release of educational materials as OER.

Fifth, based on the principles of Open Government Data,[10] an OER initiative can be considered open if it is the following:

- complete (the repositories, resources and datasets should be as complete as possible);
- primary in nature (primary source digital resources and data, with the highest practicable level of granularity and detail);
- timely (the digital resource and its metadata should be available to teachers, students, and self-learners in a timely fashion);
- easy to access (the repositories and resources should be in convenient, modifiable, and open formats that can be retrieved, reused, remixed, adapted, downloaded, indexed, and searched);
- metadata-documented (in standard and machine-readable formats);
- open to universal participation for use, reuse, and redistribution, in nonproprietary formats;
- persistent (digital resources, metadata, and reference information must be usable well into the future).

Finally, the question of quality should be considered relative to the target audience: teachers creating their own OER in collaboration with their students. Institutions supporting the development and use of OER are also expected to adopt guidelines in their internal quality assurance practices that identify the technology and system, the product and its format, its information and material content, its presentation, and the teaching and learning processes.

[10]Open Government Working Group: https://public.resource.org/open_government_meeting.html Principles of Open Government Data: http://www.opengovdata.org/home/8principles and Sunlight Foundation: 10 principles of Open Government Data: http://sunlightfoundation.com/policy/documents/ten-open-data- principles

Successful OER-based practices rely on research addressing problems or obstacles to greater popularity and maturity. Examples of how the Special Issue editors have addressed these problems include the following.

*First, improving OER discoverability through an enhanced search*. A lexical search based on matching keywords can return OER of little relevance and may omit results vital for the learner's needs. The Special Issue editors' approach was to apply the semantic annotation of OERs and the entity data enrichment available on the Data Web to enable smarter searches. By leveraging the semantic relationships between entities and concepts, the meaning and intent of the user query can be inferred. In a previous work [22], they presented Serendipity, a faceted search engine[11] that can retrieve OERs from OCW courses. The OER metadata are structured, and the main entities found on content resources are linked with DBPedia data.

*Second, reusing OER to rapidly and simply create personalized courses*. Considerable time and resources are needed to produce, from scratch, online courses that have personalized learning contexts and learning styles and that take into account the learner's background knowledge or specific learning needs. Many OER are available free in different languages and on different subjects; the potential for their integration into online courses is enormous.

The Special Issue editors advocate the use of a linked data approach to OER repositories. providing a more interoperable and integrated system for sharing, connecting, and discovering resources, data, and metadata of OER initiatives. This also can be an enabler for the development of the next generation of open educational resources. Moreover, OER resource metadata can be enriched using datasets hosted by the Linked Open Data cloud [23].

*Finally, recommending resources and identifying collaborative networks*. Much of the information available on the Web is published on social media, such as Facebook or Twitter. Each social medium or network has its own scheme of operation and working characteristics. On Twitter, OER can be extracted as links; experts are represented as popular users, virtual communities are user lists, and events are described through "hashtags." The Special Issue editors extract the information posted on social networks through the use of linked data that allow resources to be retrieved and linked with other external sources. Graphical representation of data helps represent a social network's scheme of working. The social network analysis (SNA) technique reveals relevant information that goes beyond the individual properties. Applying SNA to social data answers queries such as "What are the relationships and the level of cohesion of the different organizations and people that produce OER?" [24].

## VI. Conclusion

Current applications of OER in engineering education will continue to mature. Topic-related definitions, open licenses, use and reusability, enhancing discoverability, open policies, opening up OER repositories and datasets, and OER quality are all issues that must be managed and understood.

[11]http://serendipity.utpl.edu.ec/

This Special Issue looks at the current state of OER practice and at issues associated with improving the use and reuse of OER. OER initiatives will make it possible for teaching staff to concentrate on the actual process of teaching and on the teacher–student interactions that are the real core of teaching and learning, rather than on the continual creation of educational materials.

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