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Abstract

This chapter begins by reviewing the many definitions of the term open educational resources and concludes by discussing challenges and opportunities for the approach. Open educational resources (OER) are educational materials either licensed under an open copyright license or in the public domain. Neither the term “open educational resources” nor the term “open” itself has an agreed upon definition in the literature. Research regarding open educational resources focuses on methods of producing OER, methods of sharing OER, and the benefits of OER. Significant issues relating to OER remain unresolved, including business model and discovery problems.

Keywords

Open educational resources • Reuse • Remix • Affordability

Defining Open Educational Resources

While a large number of competing definitions of the term “open educational resources” exist, with each focusing on different nuances of the copyright permissions structure or the different motivations for sharing open educational resources, a review of these definitions reveals a common baseline understanding. Educational materials which use a Creative Commons license or which exist in the public domain and are free of copyright restrictions are open educational resources. A rich collection of work and writing underlie this common understanding.

As an emerging construct, a significant amount of the existing literature is dedicated to defining the term open educational resources and clarifying the motivations underlying this body of work (Atkins, Brown, & Hammond, 2007; Baraniuk & Burrus, 2008; Brown & Adler, 2008; Geser,

2007; Gurell & Wiley, 2008; Hylén, 2006; OECD, 2007; Plotkin, 2010). Mike Smith, Director of the Hewlett Foundation Education Program which provided much of the early funding for work in the area of open educational resources, wrote, “At the heart of the open educational resources movement is the simple and powerful idea that the world’s knowledge is a public good and that technology in general and the World Wide Web in particular provide an extraordinary opportunity for everyone to share, use, and reuse that knowledge” (Smith & Casserly, 2006, p. 10).

Writing in 1975, MacKenzie, Postgate, and Scupham said, “Open Learning is an imprecise phrase to which a range of meanings can be, and is, attached. It eludes definition. But as an inscription to be carried in procession on a banner, gathering adherents and enthusiasts, it has great potential” (p. 15). Rumble (1989) added, “Nearly 15 years later, one has to ask oneself whether there is a greater degree of clarity” (p. 29). In fact, the situation with regard to this word “open” is largely unchanged almost 40 years later.

The most frequently used definition of “open educational resources” comes from the report of the meeting where the term was first coined. In 2002, UNESCO convened the Forum on the Impact of Open Courseware for Higher Education in Developing Countries. It was in this Forum

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where Saul Fisher from the Andrew W. Mellon Foundation recommended that the group adopt the phrase “open educational resources” to describe the new model of sharing educational materials that had brought the group together. The group agreed and offered the following definition:

The open provision of educational resources, enabled by information and communication technologies, for consultation, use and adaptation by a community of users for non-commercial purposes (UNESCO, 2002, p. 24).

Forum participants set an idealistic goal for the idea of open educational resources later in this same document, inadvertently providing a second definition for the term: “a universal educational resource available for the whole of humanity” (UNESCO, 2002, p. 28). Since 2002, many other definitions have been offered. While none can be considered authoritative, a review of the definitions provides a more nuanced understanding of the term’s meaning.

Defining the Term “Open”

Rather than try to define the entire term open educational resources, some researchers split the term up in order to define its components separately. Hylén (2006) problematized each of the three concepts in the name, questioning what is meant by “open,” “educational,” and “resources,” as did Mulder (2007) and OECD (2007).

Wiley (2010) assumed common understanding of the term educational resources, and argued that open is a matter of (1) cost and (2) copyright licensing and related permissions. For Wiley, open means that a resource is available free of cost and that four permissions (called the “4Rs”) are also made available free of cost. These permissions include:

- 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, the revisions, or the remixes with others (e.g., give a copy of the content to a friend).

Wenk (2010) repeated the definition put forth by FreedomDefined.org in defining openness:

- The freedom to use the work and enjoy the benefits of using it.
- The freedom to study the work and to apply knowledge acquired from it.
- The freedom to make and redistribute copies, in whole or in part, of the information or expression.
- The freedom to make changes and improvements, and to distribute derivative works (p. 435).

Both the 4Rs framework established by Wiley and the “Freedom Defined” framework promoted by Wenk focus on granting permissions regulated by copyright. This is the reason many definitions of open educational resources include open licenses as a critical component. For example, Patricia, del Rocio, and Elizabeth (2010) defined OER as “resources that provide educational content with an open license that facilitates their use, adaptation and modification.”

Tuomi (2006) took another approach to defining openness, though one still focused on permissions. Tuomi described OER as “sources of services” that:

- (a) Provide nondiscriminatory access to information and knowledge about the resource (level I openness).
- (b) The services of which can be enjoyed by anyone with sufficient nondiscriminatory capabilities (level II openness).
- (c) Can be contributed to (level III openness) (p. 34).

Because definitions of OER place such an emphasis on copyright permissions and licensing, a basic understanding of the most commonly used open licenses, the Creative Commons licenses, is critical to understanding what OER are.

Creative Commons Licenses

In practice, an open educational resource is any educational material that uses a Creative Commons license or resides in the public domain (i.e., outside of copyright regulation). The Educause (2010) report, *7 things you should know about open educational resources*, stated that “such materials are generally released under a Creative Commons or similar license that supports open or nearly open use of the content.”

The Creative Commons licenses comprise several components that can be mixed in a number of ways. The “Attribution” component (BY for short) requires individuals and organizations that use the openly licensed material to give credit to the original creator of the material. The “ShareAlike” component (SA for short) requires any revised or adapted versions of the material to be licensed under exactly the same Creative Commons license as the original material. The “Noncommercial” (NC for short) component prohibits individuals and organizations from using the material for commercial purposes. These components can be mixed in a number of ways to make different licenses. The most popular licenses for OER include the BY license, the BY-SA license, and the BY-NC-SA license. Creative Commons also provides a “No Derivatives” component (ND for short) which prohibits individuals or organizations from making any changes to materials, but because revise and remix are critical components of all definitions of OER, the ND clause and licenses containing it are not used by the OER community and excluded from the discussion below. A detailed legal overview of the Creative Commons licenses is provided by de Rosnay (2010).

The Creative Commons licenses (Lessig, 2003) used for OER guarantee that (1) users will enjoy no-cost (free) access to the materials and that (2) users have permission to engage in the 4R activities. The Creative Commons license guarantees both *in perpetuity* (see Section 3, “License Grant,” in any Creative Commons license). In theory, educational materials using other, similarly architected open licenses can be considered OER, but the overwhelming majority of openly licensed material in the world uses the Creative Commons licenses—over 400 million resources as of 2010 (*Creative Commons Corporation*, 2011). By comparison, a Google search for the two licenses most commonly used before Creative Commons reveals almost no modern usage—the Open Publication License and GNU Free Documentation License combine for fewer than 5,000 inbound links.

OER Definitions Operationalized in Policy

As the requirement to produce and use OER becomes common in grant policies and programs, a bright line definition of OER becomes necessary for compliance and reporting purposes. The Washington State Board of Community and Technical Colleges’ (2010) policy on Open Licensing on Competitive Grants states that all “digital software, educational resources and knowledge produced through competitive grants, offered through and/or managed by the SBCTC, will carry a Creative Commons Attribution License” (p. 4).

At the federal level, the 2010 Trade Adjustment Assistance Community College and Career Training Grant Program (TAACCCT) committed \$2 billion in federal grant funding over four years to “expand and improve their ability to deliver education and career training programs” (p. 1). The intellectual property section of the grant program description requires that all educational materials created with grant funding be licensed under a Creative Commons BY license.

Summary of OER Definitions

Educational materials which use a Creative Commons license or which exist in the public domain and are free of copyright (thus providing permission for users to engage in the 4R activities) are open educational resources. Consequently, OER is an overarching term that encompasses open textbooks, opencourseware, and other designations. Open textbooks are simply OER organized as a textbook. Likewise, opencourseware are simply OER organized as online courses.

Major Categories of OER Research

OER research clusters into four categories: models of sharing OER, models of producing OER, the benefits associated with OER, and the challenges associated with OER. Research in each of these categories is reviewed below.

Different Models of Sharing OER

Open educational resources can be structured and shared in a number of different ways, including being shared as individual OER, being compiled and shared as open textbooks, and compiled and shared as open courseware.

First, like the learning objects that came before them, open educational resources can be tagged with metadata and stored individually in databases or repositories for later discovery and reuse as individual components. Sites such as OER Commons (<http://oercommons.org>) and MERLOT (<http://merlot.org>) take this approach to sharing OER.

Second, open educational resources can also be created or located and then aggregated into more familiar structures like textbooks before distribution. These collections are called “open textbooks.” Flat World Knowledge (<http://flatworldknowledge.com/>) and CK12 (<http://ck12.org>) publish Creative Commons licensed textbooks that can be broken down into individual OER for revising and remixing. Connexions (<http://cnx.org/>) is a Wikipedia-like site that allows users to create individual modules and compile these with modules created by other users to make textbooks (using a “one module equals one chapter” model). PediaPress (<http://pediapress.com/>) allows users to aggregate Wikipedia articles into printable books as well, where each Wikipedia article appears as an individual chapter in the printed book.

Third, open educational resources can be created or located and then aggregated into familiar structures like courses before distribution. These collections are called “open courseware” (OCW). This is the model pioneered by MIT OCW (<http://ocw.mit.edu/>) which created new OER and organized these as courses. This model has since been adopted by the over 200 member institutions of the OpenCourseWare Consortium (<http://ocwconsortium.org/>, Abelson, 2008).

Aggregating individual open educational resources into larger, familiar looking clusters can be key to enabling their reuse, especially among faculty with lower levels of comfort with technology. Open textbooks, for example, have seen adoption at several levels of formal education (Petrides, Jimes, Middleton-Detzner, Walling, & Weiss, 2010). There are successful open textbook initiatives at the high school level in the US (Wiley, 2011) and South Africa (Petrides &

Jimes, 2008), at the community college level (Petrides et al., 2010), and the university level (Hilton & Wiley, 2011).

Different Models of Producing OER

Two primary models for producing open educational resources emerged during 2001. These are the institutional production model (e.g., models used by MIT OCW) and the commons-based peer production model (e.g., the model used by Wikipedia).

The institutional production model of creating open educational resources involves converting or transforming materials used to teach formal classes (either face-to-face or online) into a format appropriate for open sharing. Experts with traditional academic credentials create these materials.

Lane (2006, p. 12) describes three variations on the institutional production model: the “integrity model,” where the OER are very similar to the original material and as complete as possible; the “essence model” where the source material is cut back to the essential features before publication as OER; and the “remix model” where source material is used as a starting point for OER that are designed specifically for Web based delivery.

While proponents value the expert authorship of institutionally produced OER, critics claim that the model is unsustainably expensive. MIT OCW reports that the original cost to openly publish a course ranges from \$10,000–\$15,000 for courses without video to \$20,000–\$30,000 per course for which video was published (MIT OCW, 2011a). MIT OCW (2011b) now reports a current average cost of about \$8,225 per course for ongoing maintenance-oriented activities.

Johansen and Wiley (2010) report the costs of running other institutionally based OER programs: approximately \$5,000 per course for Utah State University’s OCW, about \$34,000 per course for the Open University of the Netherlands’ OCW, about \$6,000 for the Open University of the UK’s OpenLearn program, and about \$250 per course for Brigham Young University Independent Study’s OCW program. Contextual factors including how much content is published and what format the content was originally produced in contribute to the wide variation in costs to publish institutionally created OER.

Commons-Based Peer Production

Benkler (2002) describes a new method of creating products, including educational resources, which he calls commons-based peer-production, in which “groups of individuals successfully collaborate on large-scale projects following a diverse cluster of motivational drives and social signals, rather than either market prices or managerial commands”

(n.p). Benkler is describing large-scale projects like Wikipedia whose contributors are volunteers that are not motivated by financial interests or employment requirements.

Benkler (2007) later explained that this new means of production is “radically decentralized, collaborative, and nonproprietary,” meaning that an undertaking like Wikipedia has no central coordinator who assigns tasks or tracks their completion and that the results of the group’s work are made available to the public under an open license (p. 60). A variety of open educational resources are created and improved using this model. The creation and ongoing improvement of encyclopedia articles in Wikipedia operate on this principle. Benkler (2005) discusses the Wikipedia example at length. The creation and ongoing improvement of open educational resources in the Connexions repository, which is much like Wikipedia, operate on these principles as well (Baraniuk & Burrus, 2008).

Institutional production and commons-based peer production fall at opposite ends of a spectrum. On one end, open educational resources are created and vetted by a highly respected institution like MIT, Stanford, or Yale and published with the institution’s imprimatur. On the other end, open educational resources are created and vetted by a decentralized group of individuals who may or may not be credentialed or formally qualified to participate in their creation and vetting and are published under the brand of a Web site like Wikipedia or Connexions. Several hybrid models exist between the polar institutional and commons-based models. For example, Burgos and Ramirez (2011) describe a model encouraging students to share their homework as OER, which might then be used by other students.

Benefits of OER

Education institutions have mixed incentives for engaging in open educational resources initiatives (Smith, 2009). Some of these incentives are mission-aligned. Hylén (2006) and D’Antoni (2009) provide good overviews of these mission-aligned motivations for producing and sharing OER, including the public outreach mission of publicly funded universities to educate the entire public whose funding supports their operation.

There are several self-interested reasons institutions, and faculty choose to create and share open educational resources that may or may not articulate clearly with the mission of the institution. The majority of the benefit claims in the literature fall into this category. For example, Caudill (2011) claims that access to OER makes the course development process quicker and easier—a claim that is echoed elsewhere (e.g., Hylén, 2006). Describing the Open University of the UK context, Hodgkinson-Williams (2010) notes the significant international attention, improved public relations, improved

relationships with strategic partners, and improved internal publishing and production capabilities that come from well-publicized OER projects. Steve Carson (2006) describes these same benefits in the MIT OpenCourseWare context, while also demonstrating that MIT OCW positively influences freshmen decisions to attend MIT.

Explain from an economic perspective how “hybrid message and product (brand) placement concepts could be applied to open education resources by HEI [higher education institution] brands and be used to justify investment by HEIs in OER development on marketing grounds” (p. 8). They go on to demonstrate an applied instance of this concept, showing that distance learning programs can actually increase revenue using OER as a marketing channel. This particular form of cost recovery for OER programs has been the subject of a growing amount of research, as reported by Johansen and Wiley (2010). Almost 2 % of Open University of the UK enrollments over a 2-year period came from OCW users who became paying university students. The Open University of the Netherlands reported 18 % of users of its OCW site were “inspired to purchase an academic course.” The University of California-Irvine (UCI) also reported that their OCW site consistently generates more sales leads for their online courses than any other form of advertising. After reviewing this literature, Johansen and Wiley (2010) demonstrate in financial detail an empirically validated model for increasing distance education enrollments using open educational resources—enough revenue to more than pay for the cost of the open sharing efforts.

The financial benefits that accrue to students who use open educational resources has been the subject of study as well. Hilton and Wiley (2011) received full access to the sales records of Flat World Knowledge, a commercial publisher of open textbooks. These textbooks are both available to be read online for free under a Creative Commons BY-NC-SA license and are available for purchase in print, audio, and other formats. After reviewing the sales database, Hilton and Wiley report that about 30 % of students whose faculty formally adopted a Flat World Knowledge textbook purchased a printed copy of a Flat World textbook, while about 20 % purchased a digital product through the company’s Web store. With approximately 50 % of students opting to read the assigned texts online for free and not purchase anything, and the average purchase amount for the other 50 % being around \$30, Hilton and Wiley report that students clearly save a significant amount of money under this model compared to the typical \$150 college textbook.

Challenges for OER

In addition to ongoing research in sharing models, production models, and the benefits of OER, a number of unresolved issues remain open for future researchers to tackle. These

include making OER easier for people to find (the discovery problem), making OER programs financially self-sustaining (the sustainability problem), dealing with the pervasive perception that, because they are free, OER are necessarily of inferior quality (the quality problem), improving our understanding of how to make OER more useful in a wide range of contexts (the localization problem), and understanding why people do not exercise their revise and remix permissions in OER (the remix problem). These five difficulties structure the discussion of research challenges that follows.

The Discovery Problem

Like the learning objects that came before them, OER can be difficult to find. Learning objects researchers undertook a significant amount of technical work on metadata and other standards and specifications in order to make learning objects easier to find (e.g., the IEEE Learning Objects Metadata standard). OER researchers build on top of this work with efforts like the Learning Resource Metadata Initiative (LRMI, 2011) which maps IEEE Learning Objects Metadata and Dublin Core fields focusing on licensing information and educational outcomes (like the Common Core standards for US K-12) into the Schema.org metadata framework to be used by major search engines like Bing, Google, and Yahoo. Being enabled to search the Internet by license and learning outcome would be a significant step forward for making OER easier to find.

Researchers try to make OER easier to find by implementing both conventional and advanced discovery solutions. Traditional approaches like referatories, sites that index and provide links to OER across the Web (e.g., <http://oercommons.org> or <http://ocwfinder.org>), are quite common. Minguillón and Rodríguez (2010) show how conventional social networking features, like tagging, rating, and commenting, can be integrated into open educational resources collections in order to make finding OER easier.

More advanced services, like recommender systems, have also been created to help user find the “right” open educational resources. Duffin and Muramatsu (2008) describe an OER recommender service that provides content-based recommendations along the lines of “if you like this OER, you might also like that OER.” Kalz, Drachsler, van Bruggen, and Hummel (2008) describe another OER recommender service created in the context of the EU TENCompetence program.

Despite ongoing research in the area of discovery, finding the right OER remains a challenging task (Kalz et al., 2008) that needs significant additional effort from researchers.

The Sustainability Problem

Numerous articles have been dedicated to the topic of the sustainability of open educational resource programs,

attempting to answer the question “how does one continue to fund, on an ongoing basis, a program whose goal is to give things away for free?” Dholakia, King, and Baraniuk (2006), Downes (2007), Koohang and Harman (2007), Wiley (2006a) have all written at length on the topic, each proposing overlapping taxonomies of sustainability or business models such as the public radio model (voluntary user contributions) and the “give away the razor, sell the blade” model.

The concern with sustainability is well grounded. For example, after the US economy entered a recession in the late 2000s, at least one major opencourseware initiative was forced to close (Parry, 2009). Pegler (2010) writes, “evidence of sustainability, or the potential to achieve this, is increasingly a pre-requisite for engaging in OER activity, whether imposed by funders, by institutions requiring a ‘business case’, or practitioners themselves” (p. 2).

Some of the business model-related writing about OER has been conceptual, lacking specific financial data (e.g., Pegler, 2010). Dholakia et al. (2006) argue that “unless the OEP site is able to *first* gain and maintain a critical mass of active, engaged users, and provide substantial and differentiated value to them in its start-up and growth phases, then none of the available and/or chosen revenue models will be likely to work for the OEP in the long run.” In other words, if a site cannot engage and keep users, there is no need to worry about sustaining it in the long term.

Other research has focused more on the finances of OER, exploring specific impacts on institutional revenue. For example, Hilton and Wiley (2011) describe the income and costs associated with operating the for-profit publisher Flat World Knowledge in detail, examining the potential sustainability of the venture. Helsdingen, Janssen, and Schuwer (2010) also provide specific financial detail about the cost and impact of an opencourseware initiative on an online course provider, as do Johansen and Wiley (2010). These authors identify promising models that appear to work at relatively small scale and in a single context. Many more scaling up and verifying iterations of this work need to be conducted before the field can claim to have robust knowledge in the area of sustaining OER initiatives.

The Quality Problem

There are two aspects to the quality problem faced by OER researchers. The first is related to the common saying “you get what you pay for.” Although the no significant difference phenomenon evident in media comparison studies is well documented (e.g., <http://www.nosignificantdifference.org/>), proponents of OER sometimes struggle to demonstrate that these freely available materials can be of equal or greater instructional effectiveness when compared to more expensive

alternatives. The discovery problem relates to the quality problem. One can easily find 2,840,000 OER in Google relating to “biology,” but which of these are high quality? When it is difficult to find high quality OER, it is difficult to argue persuasively that they exist.

Computational approaches to automatically assessing the quality of resources have shown promise (e.g., Bethard, Wetzer, Butcher, Martin, & Sumner, 2009; Custard & Sumner, 2005), though these techniques necessarily work only for a very specific operationalization of the construct “quality.” Other sites allow users to assign a 1–5 star rating to OER in order to signal the quality of materials to future searchers (e.g., <http://merlot.org/>). Whether the quality of an open educational resource is assessed by a human or machine, one-size-fits-all quality ratings fail to recognize that quality is not a property of an open educational resource alone. The quality of an open educational resource is a joint property of a resource-and-user, the way that item difficulty and learner ability are linked in item response theory (Kelty, Burrus, & Baraniuk, 2008). An OER that is very high quality for an English-speaking community college student may be poor quality for a German-speaking university student.

The Localization Problem

Localization is one of the most important and least understood aspects of open educational resources. Once a user succeeds in finding appropriate resources, those resources likely need to be adapted before they are used. Lane (2006) defines localization as “re-contextualisation of content for the particular situation in which it is experienced by the learner” (p. 16). Smith (2009) describes how “the act of modifying an OER to meet language, cultural, or readiness requirements increases useful access and may be a creative learning endeavor” increases the usefulness of OER (p. 89). However, while one of the primary goals of openly licensing materials is to enable any future users to refactor the materials to meet their needs, this does not guarantee that eventual reusers will be sufficiently competent in the technical or pedagogical skills necessary to make needed changes. The possibility of changing open educational resources so that they function worse for the intended users is always present. Ivins (2011) examines the Nepalese context to determine the factors most salient to the process of localizing open educational resources in the developing world, concluding that “only a local can localize.” Westerners simply do not possess the religious, cultural, and other local knowledge necessary to customize open educational resources for optimal use in Nepal. Building local capacity to engage in what are essentially user-design activities is necessary before OER can provide meaningful educational opportunities for the Nepalese.

The Remix Problem

While authors and creators go to great lengths to correctly license open educational resources, there is little empirical evidence that people actually exercise the additional 4R permissions granted by the Creative Commons licenses. Lane and McAndrew (2010) list several types of reuse—as-is reuse, technical adaptations, linguistic adaptations, cultural adaptations, pedagogical adaptations, and annotation as a form of reuse, but concludes, “the idealised cycle of adoption, reworking and retribution has only had limited success” (p. 8).

Duncan (2009) found that, in the entire collection of over 5,000 modules in the Connexions OER repository, only 15 had been used, translated, or modified more than five times. Examining the same collection, Petrides, Nguyen, Jimes, and Karaglan (2008) also found that significant modification or revision of materials created by others happened very rarely. The Connexions repository may be a best-case research context because the site provides users with tools for revising and remixing OER inside the system, where data can be collected and analyzed.

Reuse can be extremely difficult because pedagogical and other design assumptions are rarely visible. Conole, McAndrew, and Dimitriadis (2010) describe tools that encourage people to separate their designs or pedagogical patterns from specific educational artifacts and upload these designs to a repository for examination and reuse. However, this approach has yet to yield significant uptake by users.

Future Directions for Open Educational Resources

Open educational resources research will likely continue in the areas identified above. However, open educational resources are also influencing neighboring areas of educational research and these crossover efforts are likely to play an important role in future research. Two areas that merit particular attention include open education policy and open assessment.

A number of nations and states have formally adopted or announced policies relating to the adoption of OER and open textbooks. The Open Policy Registry (<http://oerpolicies.org/>) lists several dozen national, state, province, and institutional policies relating to OER, including policies like a national open licensing framework and a policy explicitly permitting public school teachers to share materials they create in the course of their employment under a Creative Commons license. The overwhelming majority of these policies were implemented in 2009 or after. During June 2012, UNESCO convened a World Open Educational Resources Congress and released a 2012 Paris OER Declaration “calling on

Governments to support the development and use of OERs” (UNESCO, 2012). The creation, adoption, and impact of OER policies will warrant ongoing research.

Surprisingly little work has been done in the area of open assessment. As of early 2012, there does not appear to be a single initiative dedicated to creating and sharing openly licensed assessment items in standard formats (like the IMS Question and Test Interoperability format) for use with existing open educational resources. However, if open educational resources are ever to reach their potential, they will need to be paired with open assessment resources that can serve formative and summative assessment roles for learners. This should be an area of intensifying activity and research over the next decade.

Conclusion

While the idea of open educational resources is relatively young, a vibrant literature is growing up around the concept. While no single definition is universally accepted, the literature reveals a broad consensus regarding the central features characterizing an open educational resource. A small but growing body of evidence is substantiating claims made by proponents of OER, but many obstacles remain to be overcome if this latest educational technology is to fulfill its potential.

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