frontiers | Frontiers in Education

ORIGINAL RESEARCH
published: 09 May 2022
doi: 10.3389/feduc.2022.866917

Increasing Sustainability in Open Learning: Prospects of a Distributed Learning Ecosystem for Open Educational Resources

Daniel Otto and Michael Kerres*

Learning Lab, Chair of Educational Media and Knowledge Management, Faculty of Educational Sciences, University of Duisburg-Essen, Essen, Germany

The proliferation of Open Educational Resources (OER) constitutes an essential element for establishing education as a "public good" on the internet. A core objective of OER is to broaden access to educational material and improve the overall quality of teaching and learning. In this manner, OER contributes to the sustainable (re)use and (re)distribution of (educational) resources. The goal of sustainability is also visible in the latest UNSECO recommendation concerning OER, which intends to support the 2030 Sustainable Development Agenda, namely SDG 4 (Quality education). The support of SDG 4 is combined with the call to create sustainability models for OER at national, regional and institutional levels and the planning and pilot testing of new sustainable forms of education and learning. As a result, several repositories and referatories for OER provision have been developed and tested in educational institutions worldwide. However, each of these platforms contains only a relatively limited number of resources. In our article, we argue that when considered through the lens of learning innovation and sustainable development, it would be necessary to increase the discoverability of available resources at the different locations and platforms that currently are visible to only a limited number of teachers and students. To achieve this goal, the focus needs to shift from the creation and growth of new and competing platforms to intelligent ways of linking and increasing their interconnectedness. We use the concept of "learning ecosystems" to illustrate this approach of interconnected resources. Ecosystems go beyond the spatial dimension of learning by focussing on actors' diversity and interactions. Digital (networked) learning technology is part of an ecosystem and has itself to be understood as an actor. However, we discuss that ecosystems should be reflected with caution as they can themselves entail opening and closing mechanisms. Therefore, ecosystems that rely on mechanisms of opening their contents to other platforms can realise the full potential of open learning. We describe the implications of the concept of a distributed ecosystem by presenting case studies that show how technical solutions, including metadata standards and plugins, can link contents in repositories and referatories within ecosystems. The overarching objective is that the different repositories and referatories expand and improve the sustainable use of OER by merging into a distributed learning ecosystem.

Keywords: open education, open educational resources, sustainability, learning ecosystems, distributed

OPEN ACCESS

Edited by:
Diana Hernández Montoya, Universidad Estatal a Distancia, Costa Rica

Reviewed by:
Stephanos Mavromoustakos, Indiana Institute of Technology, United States
Marcela Morales, Open Education Global, United States

****Correspondence:***
Daniel Otto
daniel.otto@uni.due.de

Specialty section:
This article was submitted to Digital Learning Innovations, a section of the journal Frontiers in Education

Received: *31 January 2022*
Accepted: *20 April 2022*
Published: *09 May 2022*

Citation:
Otto D and Kerres M (2022) Increasing Sustainability in Open Learning: Prospects of a Distributed Learning Ecosystem for Open Educational Resources. Front. Educ. 7:866917. doi: 10.3389/feduc.2022.866917

INTRODUCTION

The experiences of the COVID-19 crisis and the various studies conducted during this period (Bond et al., 2021; Khan, 2021) have made evident the lack of the digitalisation of education and demonstrated that a fundamental shift is necessary to empower learning and teaching in the digital world. However, neither pure "digital" nor pure "analog" teaching and learning can be considered as the solution but amalgamating the two based on a proper instructional design as well as a critical analysis of the respective educational context (Kerres and Otto, 2022).

Another key observation is that the internet has emerged as the central place where teaching and learning occur. Consequently, when reflecting on the consequences of the Corona-19 crisis for education, online teaching must be considered in any teaching scenario. However, one aspect rarely addressed in the discussion about online teaching is the space in which it takes place. Instead, we often treat the internet as an amorphous space and seldom ask questions about how we should design a learning architecture on the internet that enables educational practices.

In our article, we argue that the concept of open education needs to be the starting point of any deliberations. From a broader perspective, open education is on vogue, and its main ideas to lower social injustice, inequity, and the digital divide have turned out to be decisive during the phase of "emergency remoted teaching" (Hodges et al., 2020). These principles of open education are particularly vital as first analyses of the experiences gained through the COVID-19 pandemic have reinforced that teaching and learning can no longer be considered a practice bound to specific locations or places where people gather in groups or classes (Bozkurt et al., 2020). Therefore, it is hard to envisage returning to the old status before the COVID-19 pandemic. It also became manifest that various (digital) tools and resources are available for educational purposes that can support teachers in designing learning scenarios and help learners manage and steer their distinct learning paths.

During the COVID-19 pandemic, both teachers and learners were forced to leave their familiar environment and engage in their (often first) experimentation with online teaching (Khan, 2021). One problem that arose was making the (right) choices in recognising suitable educational material for online activities. In this regard, open education and the related concepts can unfold their full potential. With its core objective of broadening access to and participation in education and improving collaborative learning and teaching quality, open education can facilitate teaching and learning in the digital age (Otto et al., 2021; Otto and Kerres, 2021).

All of these characteristics of open education make it predestined for triggering learning innovations regarding the design of learning infrastructures in the digital age. Ramirez-Montoya (2020), based on her systematic literature review on challenges for open education with educational innovation, concludes that particularly Open Educational Resources (OER) should play a key role here.

From a fundamental perspective and through the lens of a hierarchical logic, OER is considered a subordinate approach to open education that addresses its design characteristics and components (Otto and Kerres, 2021). Thus, OER is an essential element of open education, with the core objective being to broaden access to educational material and improve the overall quality of teaching and learning (see **Table 1**). Both approaches are based on ideas of collaboration and common knowledge construction using digital technologies to create a wide range of open, shared and demand-driven educational resources. Making OER broadly available can thus support training processes so that students are empowered to continue learning from home on open platforms and with open materials or courses. Furthermore, by using OER, teachers can create and provide innovative open content that fits the needs of learners. Finally, it offers ways to collaboratively develop educational practices with other teachers that contribute to improving teaching quality in education. In this manner, OER can lead to new educational and pedagogical practices that enable participatory and collaborative practices.

Accordingly, it can be argued that the proliferation of OER constitutes an essential element for establishing learning innovation in open education and education in general. The latest reports on teachers' experiences with emergency remote education revealed that it led to an increased awareness of OER and showed its relevance for online teaching and learning. Exemplarily, a survey across seven European countries on teachers' practices during remote education revealed that 54% of the teachers claim that they have regularly used this type of resource (Biernat et al., 2021). This underlines that OER constitutes one of the critical pillars for online teaching.

The prospects of OER have also resulted in the UNESCO's recommendation on OER in 2019 (UNESCO, 2019). While the UNESCO ostensibly highlighted the importance of OER,

TABLE 1 | Current approaches in the context of open education.

Approach	Goal	Authors
Open Education	Widening access to and participation in education	Peters (2008), Deimann and Farrow, 2013
Open Educational Resources, Open Textbooks, Open Courseware	Teaching and learning materials with an open licence, e.g., textbooks, course materials, online training	Hilton (2019), Wiley (2020)
Open Pedagogy	Consistent opening of all pedagogical design dimensions (including lesson planning, teaching, examinations, etc.) through transparency and joint participation of teachers and learners	Hegarty (2015), Wiley and Hilton (2018)
Open Educational Practices	Willingness to share, cooperate and reflect together with others (teachers and students)	Ehlers (2011), Cronin and MacLaren (2018)
Open Informational Ecosystem	An environment that provides and shares access to materials, e.g., via metadata	Kerres and Heinen (2015)

it also pointed to some critical challenges that OER is facing, especially regarding the sustainable use of OER and the lack of respective innovations. The goal to increase the sustainability of OER is also visible in the intention to support the 2030 Sustainable Development Agenda, namely SDG 4 (Quality education). The support of SDG 4 is combined with the call to create sustainability models for OER at national, regional and institutional levels and to plan and pilot new sustainable forms of educational models.

With our article, we want to contribute to the debate about increasing the sustainability of OER by introducing educational innovations. Following Ramirez-Montoya (2020), we understand educational innovations as contributing to the generation of new products (technology, instruments, devices, prototypes), services (care, assistance, dependence, benefits), or solutions (transformation, models, systems, methods). Therefore, producing learning innovations requires recognising puzzling situations, analysing their contexts, and critically evaluating changes that contribute to their improvement.

Based on the educational discourse on OER, its adoption into educational practices appears to be a persistent overall challenge (Mishra, 2017; Bozkurt et al., 2019; Otto, 2019). Over the last two decades, numerous studies have emerged on overcoming this lack of adoption. While in the beginning, these studies were predominantly based on individual experiences or single case studies, a recently published systematic mapping study has investigated trends and gaps in empirical research on OER (Otto et al., 2021). The emphasis of this mapping study on the empirical evidence is crucial, as many of the available studies have remained conceptual without presenting any hard evidence to validate their assumptions. One of the key findings of the systematic mapping study is that empirical research on OER mainly concentrates on the awareness of OER or the lack thereof and barriers to its use. Marginal consideration is given to the decisive matter of the infrastructure's role and a corresponding design to stimulate OER adoption (see **Figure 1**).

Against the backdrop of these findings, we argue that innovation is required to design and conceptualise a learning infrastructure for OER that increases its adoption. Due to the literature, one of the main problems is the limited availability of OER to potential users (Rolfe, 2012; Otto, 2019), Larson and Murray (2019, p. 92) pointedly state, "challenges for OER users include, first, the ability to locate the resources and second, assurance about their quality".

While, on the one hand, we acknowledge that OER is presently not available in a sufficient amount worldwide on the other hand, studies demonstrate an increase in repositories and a growing amount of resources (Santos-Hermosa et al., 2017, 2021). While the latter sounds promising at first sight, a critical distinction is needed regarding availability between a resource's existence and its discoverability. If a resource exists, but its existence is not detectable by search engines or portals, it is not available for potential users as such. Furthermore, when a resource is hypothetically available to the user in a search engine or portal, it might not be detectable because of the search strategy applied by the user or the limited description (metadata) of the resources.

In order to address this slippery slope and increase the availability of OER through learning innovations, we propose the idea to conceptualise and designing the OER infrastructural architecture as distributed learning ecosystems (DLE). We use the metaphor of "ecosystem" to illustrate our notion to establish an interconnected system of resources, repositories, and referatories. Ecosystems go beyond the purely spatial dimension of learning infrastructures and incorporate various actors and consider their interactions. Digital (networked) learning technology, in this understanding, is not distinct but part of a learning ecosystem and must itself be understood as an actor. Because of the latter, ecosystems for open education should be reflected with caution as they can themselves entail opening and closing mechanisms. Only learning ecosystems based on mechanisms of opening their contents to other repositories and

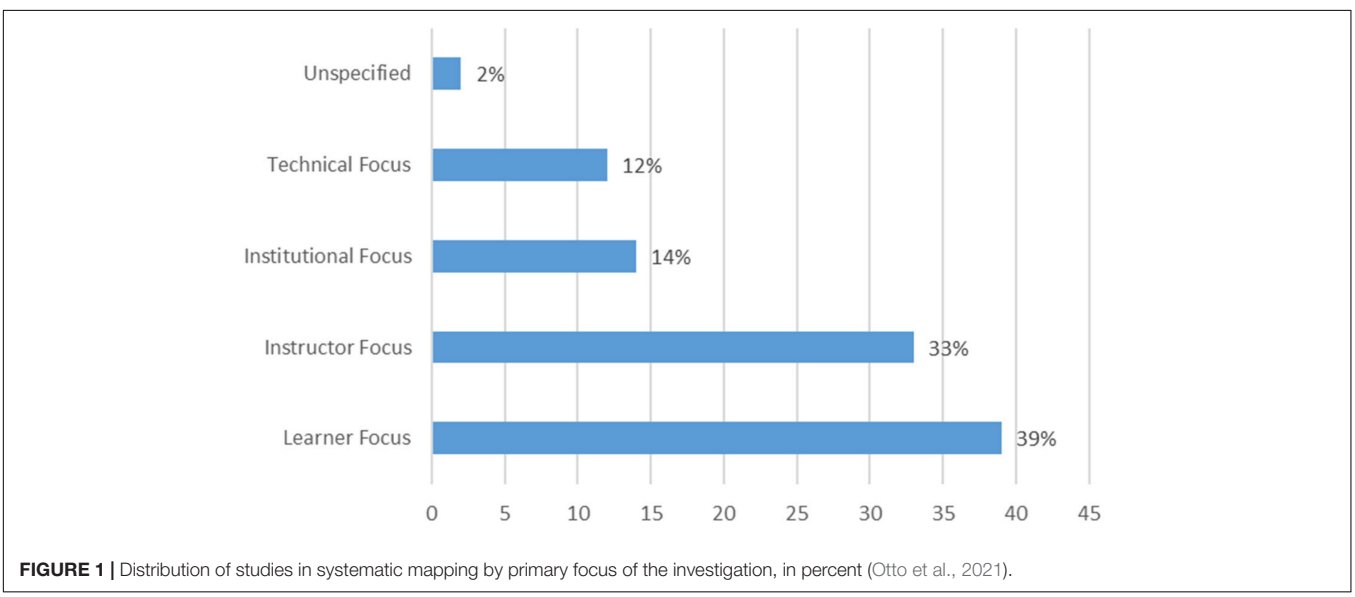

FIGURE 1 | Distribution of studies in systematic mapping by primary focus of the investigation, in percent (Otto et al., 2021).

referatories can unfold their full potential for OER in the context of open learning.

Regarding the structure of our article, we first define and delaminate our concept of a learning ecosystem. Then, the third chapter describes the implications of a DLE for OER and identifies the most significant challenges. As a fourth step, based on an explanatory literature review, we present case studies that demonstrate how technical solutions comprising metadata standards and plugins can link repositories and referatories within DLE. Finally, we conclude how merging the different repositories and referatories into a distributed learning ecosystem supports the goal of sustainability and OER.

LEARNING INFRASTRUCTURES AS LEARNING ECOSYSTEMS

As aforementioned, to illustrate our idea of DLE, we first conceptualise an ecosystem. Ecosystems should be regarded as a metaphor rather than an established concept, illustrating how systems think and operate. Usually, metaphors are used in education to clarify complex objects or relationships by replacing them with something more vital, descriptive, or linguistically more substantial. A competing metaphor that can be found in educational technology is "ecologies" (Sangrá et al., 2019; Conrad and Prinsloo, 2020). However, we argue that learning ecologies' concrete meaning and impact are somewhat vivid and unclear. The concept tries to capture innovative ways of learning and shape the connection between formal and informal learning across several learning contexts through digital technologies. The problem of this bright understanding is backed by a recent systematic review that confirms the concept's vagueness and divulges that there are limited practical applications of the concept, particularly in technology-enhanced learning (Sangrá et al., 2019).

By introducing the concept of learning ecosystems, we want to reach beyond the spatial dimension, which is a subtle assumption in many concepts of learning infrastructures.

Ecosystems as a mental construct accentuate that a learning architecture is a complex ensemble of different influencing variables that are themselves in a dynamic interplay. In addition to the spatial dimension, learning ecosystems are themselves considered to be dynamically evolving. There is progress, unforeseen deviations, and parts die off, reinforce themselves, and mature in an evolutionary way. For that reason, advances in learning ecosystems can no longer be perceived linearly; instead, they have to be understood as an emergent process. Agents' actions have mutual effects and can also give rise to new developments. Knowledge no longer occurs (only) in the mediation via algorithms, programmes or designed spaces and in the exchange between teaching and learning instances. On the contrary, additional actors are incorporated: The creators of knowledge resources, the editorial offices and agencies that select, evaluate and provide them, and other intermediate actors that have a pivotal influence on knowledge environments. Consequently, digital technology itself has become the status of an actor, and alongside human actors (teachers, learners), digital technology must be understood as an actor [actor-network theory (Fenwick and Edwards, 2010)].

In conclusion, the ecosystem metaphor allows us to seize a more comprehensive perspective on a learning architecture that combines various actors and their interactions that all contribute to its composition and evolution.

Our elucidations underscore why the concept of ecosystems originates from describing living entities. Learning here is not (only) bounded in specific spaces available to teachers and learners. Knowledge is constantly transformed and (re)constructed in networks and renewed through (re)use activities. Computers and digital media remain technical objects, and thus it is debatable whether the term ecosystem is adequate or may produce misrepresentations. The technical objects comprise hardware consisting of computers, networks, and the associated operating software and must be understood as the "habitat" in which subjects create, provide, and use digital tools, applications, and content. There are certain autonomous areas in the living environment in an ecosystem where hardware and software elements interact on different levels. These areas are self-organised and mature only in a comparatively small exchange with other ecosystems. The users play an essential role by contributing to the ecosystem and keeping it "alive" through making new contributions and producing content.

Digital technology as an ecosystem was initially shaped by viewing the internet through an economic lens. Very early, the computer industry recognised that it could be attractive not only to sell a device or a software programme but also to attract people by making more comprehensive offers. Bea and Haas (2016) stress the importance of this kind of ecosystem for strategic management: Thinking in ecosystems unwraps new perspectives on customers and competition. A digital ecosystem encompasses several companies that jointly produce values for customers and are themselves part of the system. Messerschmitt and Szyperski (2005) state that software can neither be considered an intangible nor a tangible product and is thus subject to different laws of production and dissemination than traditional goods. Therefore, the creation of software takes place in ecosystems of technology providers, and producers and suppliers work in an environment that depends on the products and services of the respective provider. Interaction between the actors plays a key role here. When a connected group of entrepreneurs and users emerges, it serves as a community that creates shared value over time. Thus, in contrast to the market concept, digital ecosystems underline the distinct interconnectedness of networks of actors well known in the IT world.

THE PIVOTAL ROLE OF OPEN EDUCATIONAL RESOURCES IN DISTRIBUTED LEARNING ECOSYSTEMS

As above-mentioned, OER constitutes a critical element of open education. OER was initially coined by the UNESCO's (2002) Forum on the Impact of Open Courseware for Higher Education in Developing Countries (2002) and can meanwhile look back on

a history of 20 years. Although competing definitions exist, the UNESCO defines OER as being

> *"learning, teaching and research materials in any format and medium that reside in the public domain or are under copyright that have been released under an open licence, that permit no-cost access, reuse, re-purpose, adaptation and redistribution by others."* (UNESCO, 2019, p. 3 f.)

The core idea embedded in OER is to facilitate access to educational material and empower people to the 5Rs; to retain, reuse, revise, remix and redistribute them (Wiley, 2014). Consequently, engaging in these 5Rs can broaden access to education, reduce material costs, and improve teaching and learning quality. The pedagogical benefits of OER also manifest in the concepts of Open Pedagogy and Open Educational Practices (OEP), which have evolved in the debate about the educational implications of OER (See **Table 1**). Even though no rigid definition for both concepts exists, OEP describes open practices that can but do not have to involve the use and creation of OER (Cronin and MacLaren, 2018). Open Educational Resources-enabled Pedagogy, as one strand of Open Pedagogy, defined by Wiley and Hilton (2018), captures educational practices that are only possible due to the 5R activities.

While this brief reflection on the advantages of OER points to its added value for education in the digital age, OER overall adoption and use worldwide are low (Zawacki-Richter et al., 2020; Otto et al., 2021). A glance at the available literature reviews proves that numerous empirical studies have been conducted to identify reasons for this absence (Koseoglu and Bozkurt, 2018; Otto, 2019). They found that explanations for the absence are legal uncertainty, lack of time, and institutional barriers. Following Abri and Dabbagh's (2018) literature review, discovering proper OER materials is also a significant challenge for OER adoption. Consequently, many teachers and learners who are aware of OER and keen to use it in their teaching and learning scenarios face the challenge of not finding high-quality OER suitable for their needs. From a research perspective, this problem has only been addressed inadequately. Predominantly, studies are learner- or teacher-focussed, and only a tiny percentage concentrates on institutional or technical issues (Otto et al., 2021). However, insights into infrastructural challenges would be necessary as they can contribute to designing DLE. This is critical as DLE provides access to OER and increases the discoverability of the desired teaching and learning materials.

Viewing the problem of the lack of suitable OER through the lens of DLE, it appears that the challenge is not the non-existence of OER but rather its discoverability. While in the emergence phase of OER, only limited repositories and relevant resources were available to users, the situation has noticeably changed, not least due to the Corona pandemic (Zhang et al., 2020a,b). A closer look at the current OER landscape suggests that several repositories and referatories exist – with a concentration in Europe and Northern America – which comprise a substantial amount of open teaching and learning materials (Santos-Hermosa et al., 2017, 2021), Drabkin (2016), for instance, states that plenty of OER is available in the United States as several states and districts have started to produce content. However, it is only available in the respective repositories and digital libraries, and because these are decentralised, there is no connection between them.

This example illustrates that resources are often not discoverable for potential users in their familiar learning ecosystem. One reason is that OER has grown out of a dispersed system, where repositories are primarily located at educational institutions such as universities or colleges. As a result, decentralised structures of OER are dominant worldwide, so users in one country cannot find or access material that is available in other countries or regions. While decentralised structures are not a problem for OER *per se*, the lack of communication between them is (Drabkin, 2016). Hence, teachers and learners that are keen to use OER find themselves discouraged because they cannot identify appropriate resources that are relevant, up-to-date, and of high quality (Heck et al., 2020). Therefore, when teachers search for OER to enrich their learning scenarios, they habitually start by searching their institutions' repository for OER availability. If search results are insufficient, teachers can search other OER repositories that are available worldwide. However, teachers will only spend a limited time examining repositories separately, and some will end by considering OER as being demanding and time-consuming (Davis et al., 2016), which explains the success of search engines such as Google as one size fits it all offers.

ESTABLISHING DISTRIBUTED LEARNING ECOSYSTEMS FOR OPEN EDUCATIONAL RESOURCES: CHALLENGES AND PERSPECTIVES

The challenge of OER adoption is manifold and can meanwhile look back on a history of almost two decades. We can distinguish between two prominent causes here: agent and structure for OER adoption (Otto, 2021b). As individual causes (agent), the literature highlights that perceived ease of use and usefulness are the main predictors that strengthen a person's volition which is also a critical factor influencing teachers' intention to adopt OER (Baas et al., 2019). Distributed learning ecosystems support the structural component of OER in creating a system that supports and guides agents in their use of OER. It explicitly assists agents by increasing the amount of OER available and accessible to them.

Looking at the current OER infrastructure, it could be argued that more and more repositories and referatories have become available to assist teachers in searching for OER and contribute to overcoming the decentralised structure. However, this underestimates that referatories have only limited (technical) access to the various OER repositories. This underscores that OER is not automatically visible in DLE despite continually growing. Their discoverability depends on open technological infrastructures and respective open services designed as an open informational ecosystem (Kerres and Heinen, 2015).

Hitherto, even in the case of OER repositories, we regularly find closed informational ecosystems that preserve educational

resources within specific boundaries. This is confirmed when we look at the situation of repositories in higher education, where the educational landscape is highly fragmented (Santos-Hermosa et al., 2017; UNESCO IITE, 2019; Otto et al., 2021). One reason is that most countries' higher education systems guarantee their universities a high degree of independence and autonomy. Consequently, little by little higher education institutions have set up repositories to store OER and opted for specific metadata standards. Besides, they typically have high data protection and access rights, so most institutions do not grant free access to materials and metadata.

Given this decentralised OER landscape, the discoverability of OER cannot be enriched by merely launching more and more repositories or referatories for OER. Besides, the decentralised structure makes it impossible to establish single, national or European repositories and referatories, which might also not be a desirable goal. The current OER landscape has emerged from a multitude of bottom-up initiatives and services in different educational areas that all value their independence, highlight subsidiarity and rely on user loyalty. All of these causes are ranked higher by the different actors than the possible rewards of a more centralised structure.

The Open Educational Resources Landscape as Distributed Learning Ecosystems

We have shown that the current OER landscape is highly fragmented. While networking and interconnectedness of existing (sub-) OER infrastructures/ecosystems occur erratically, advocating the idea of conceptional permeable distributed learning ecosystems would bring additional benefits. It would enable the development of pragmatic solutions such as aggregation mechanisms for digital learning resources and repositories (e.g., meta-search engines). Thereby disparately distributed and partially disconnected resources and communities could be linked through interoperable verification and exchange routines without restricting the diversity of field-specific offerings. Several international initiatives are on their way to establishing national, European or international ecosystems (e.g., 5Xgon, Open Discovery Space or ENCORE +) with the help of the latest technologies. These various initiatives demonstrate that there is no such thing as an ultimate design of an ecosystem, but the spirit of openness allows scope for experimentation so that diverse approaches can progress for many different requirements.

Competing approaches should also be supported and tested so that in the long term, providers and services can emerge that meet the needs of users in a particular way. DLE should therefore encompass a variety of methods and approaches. Therefore, it is necessary to mediate between different existing platforms, projects and institutions in the diverse ecosystems. Users can only select particularly suitable services and platforms if they are provided with an overview of the existing offerings. Only if services can be used and tested side-by-side users will be able to choose and decide based on their own experience. To this end, it seems appropriate to define technical standards for exchanging information in the medium term, which are regularly reviewed and adapted. In addition, the coordination of measures to create, connect and integrate different approaches into DLE should be subject to the principles of openness and transparency.

Opening and Closing in Learning Ecosystems

As aforementioned, there is no availability of OER *per se*. For becoming full available further than in the respective repository and thus in DLE, a consensus is needed among the relevant stakeholders to mutually provide (meta-) information, especially outside the distinct boundaries. Without this condition, even OER repositories, which are genuinely perceived as open, have to be considered closed ecosystems that retain educational resources within their boundaries and, thus, miss their impact on DLE specifically and open learning in general.

Closure mechanisms in ecosystems can be obvious, for instance, manifest in a paywall that restricts access via pay per view or pay per subscription. Moreover, obligations to register on a website can also be regarded as instruments for "closure" because it limits instant access to resources. When users register on websites and unknowingly accept the conditions, the users might consider that this is merely time-consuming. However, they have revealed and thereby "paid" with their personal information, such as an email or home address. One might claim that specific instructional approaches require registration, such as open learning or collaboration tools and apps. In terms of DLE, concealing information behind walls or hindering their exchange has to be considered severe. As a result, search engines cannot trace and locate the resources behind such (payment or registration) walls. Moreover, if resources are traceable, they are only partially accessible without payment, like many online journalism articles (Benson, 2019).

Prospects to Open and Connect Distributed Learning Ecosystems

We have problematised the role and function of OER and repositories in DLE and that this is not a trivial pursuit. It has become evident that educational resources are not automatically open to learners.

Consequently, we must acknowledge that there is a silent network behind the salient network that is crucial in DLE. It would be naïve just to consider the use and availability of "open" material as the most pressing issues. When teachers put resources "on the web" for others' there are no intermediary entities or institutions – private or public – that are ultimately accountable for making this resource accessible and traceable on the web. However, this production chain behind resources developmental processes to make them available is less visible, and the processing is seamless. But precisely this determines whether and how users can find resources, communicate with other users and services, eventually find a course, and how modifications or improvements to an (open) resource can be traced back. As a result, the discussion about OER specifically and open education more broadly frequently ignores the relevance of the openness of

repositories and related intermediary services like, for instance, referatories and how they operate (see **Figure 2**).

For that reason, numerous learning ecosystems cannot be considered open. On the contrary, they comprise tendencies that contribute to opening and closing their boundaries. For serving as a prospering learning ecosystem, on the one hand, it must be open enough to empower teachers and learners to develop new resources and services in the ecosystem. On the other hand, it must also be close enough to allow teachers and learners to remain in control or track their resources and control and monitor how they are further used. Recent studies with OER experienced lecturers about the design of OER repositories confirm that they want to be informed about changes or improvements of their resources performed by others and desire to receive feedback on their published material (Otto, 2021a). Moreover, they require assistance and support systems, for instance, to upload resources into repositories or assign metadata to resources. The lack of quality in metadata that adequately and comprehensively describes resources is an eminent problem, and many inconsumable standards hamper harmonising metadata (Cortinovis et al., 2019). Another significant problem is that many authors of resources fail or are reluctant to deliver any metadata at all. Numerous studies have recommended metadata sets that describe OER more systematically and thereby enrich and facilitate the metadata report to improve the OER description and, therefore, the OER discoverability (Herrera-Cubides et al., 2022).

In order to address this problem of metadata standards, a communicative and collaborative approach involving as many stakeholders as possible seems advisable. In a case study, Menzel (in press) shows how commonly agreed metadata standards contribute to DLE development. The author describes how operators from OER repositories in higher education in Germany collaboratively developed a standard metadata profile. In Germany, the federal system resulted in several federal state-specific solutions for repositories from which six participated in the project (HOOU, OERNDS, ORCA.nrw, VCRP, VHB, and ZOERR). Based on the FAIR principles (Findability, Accessibility, Interoperability, and Reuse), meaningful metadata description was achieved by balancing the *prima facie* antagonistic demands of describing resources as detailed and accurate as possible by likewise only providing essential information to keep the threshold for authors as low as possible. In conclusion, Menzel stresses that metadata standards are crucial for connecting OER repositories, thereby permitting federated search and harvesting of metadata, e.g., by search engines or other interested parties.

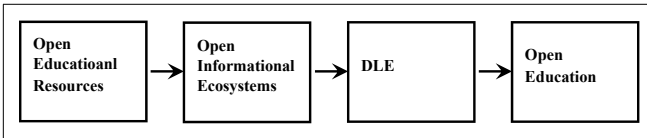

FIGURE 2 | An incremental representation of open educational resources (OER) and distributed learning ecosystems (DLE).

The standard metadata issue also points to the second underlying challenge of the discoverability of OER, for which there are numerous attempts to address it (Cortinovis et al., 2019; Otto et al., 2021). However, efforts mostly contain creating new OER repositories with advanced search services or federated repositories that accumulate resources from diverse repositories or institutions. Despite this being a desirable development, one may question whether establishing another OER repository or search engine improves or rather fragments the current OER landscape and, thereby, the discoverability of OER further.

The chances are that teachers and learners get lost when trying to find OER resources because of the problems with searching and locating them. The latter is reinforced by recent literature reviews confirming that searching and locating OER is still a significant problem (Abri and Dabbagh, 2018).

As already described, poor metadata assignment is one key component to locating resources. Therefore, DLE can help here by connecting the different repositories to establish an overall structure. Thus, networks of connected servers or services on the internet conjointly or cooperatively establish an environment for finding and providing resources to a larger public. This comprises functions for delivering content and related, more or less complex, value chain functions, like generating, editing, assembling, annotating, tagging, commenting, or linking information resources. Several providers correspond in such ecosystems; hence, their collaboration depends on common standards to interface content and metadata (see **Figure 1**).

When ecosystems are open, they enable a content provider to "plug into" into the ecosystem by providing metadata that can be retrieved from a reference platform (referatory) (see **Figure 3**). Contrary, closed ecosystems only provide a one-stop solution that conglomerates all the described functions. However, this is also imaginable in a network of confederated servers that conjointly maintain the system's boundaries close.

Looking into the literature, we find examples demonstrating how repositories can contribute to open ecosystems. For example, Ladurner et al. (2020) present a practical bottom-up solution to broaden access to resources for students at their university. Teachers here are enabled to use their own learning management system (LMS) for the publication of OER. The resources are thereby offered to a broad public via the university's own OER repository and the Austrian OER portal by assigning adequate metadata.

Abdel-Qader and Tochtermann (in press) provide a perfect model of how the DLE concept must be implemented from a technical perspective. In a research project, they developed a tool for connecting OER repositories using the Learning Object Metadata (LOM) standard (see **Figure 4**).

Their goal was to increase the accessibility of OER for more learners. Their article provides detailed specifications and requirements for connecting different OER repositories from a technical point of view. However, their idea is to allow non-technical staff to replicate this process to harvest data from the web.

As an outlook, Tlili et al. (2021) investigate how the current emerging technologies, such as Artificial Intelligence (AI) and blockchain, can contribute to OER development. Although the

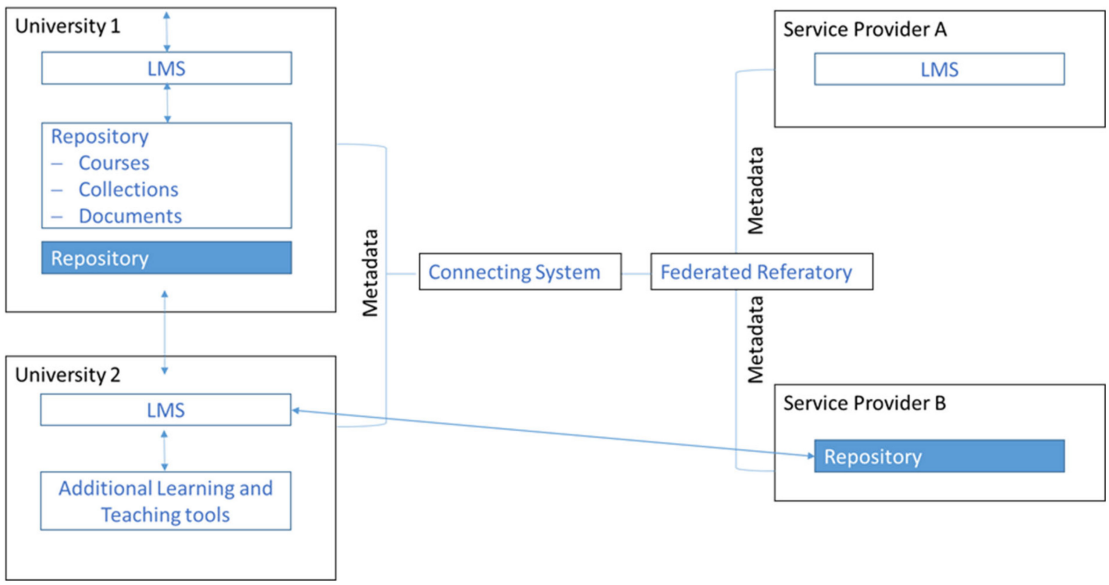

FIGURE 3 | Illustrative presentation of a distributed learning ecosystems (DLE).

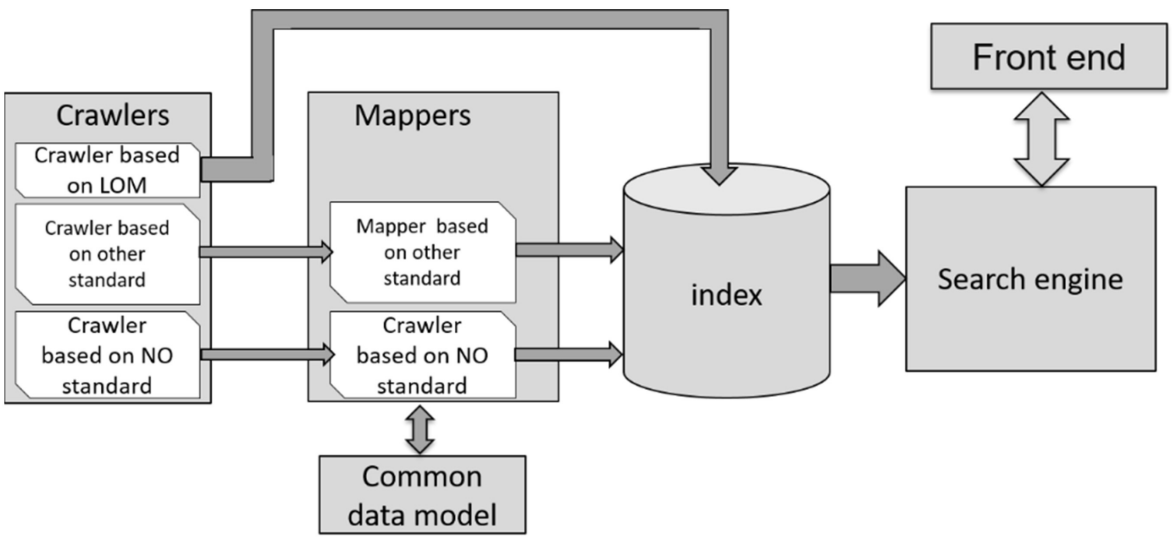

FIGURE 4 | A scenario of harvesting and mapping the open educational resources (OER) metadata that are modelled using the learning object metadata (LOM) standard (Abdel-Qader et al., 2021).

authors concede that technological limitations might hinder the application, emerging technologies, specifically machine learning and Natural Language Processing (NLP) techniques, can lead to automatic metadata tagging, resulting in OER with rich and more accurate metadata, which can be found more easily. In DLE, as we proposed, it would also be possible to implement the other recommendation of Tlili et al. (2021), which is to use sophisticated machine learning and NLP techniques to analyse generated metadata of the published OER to map all of these resources together and build OER recommender systems. Time and the associated technical (and political) developments will reveal whether the actual implementation of emerging technology is realisable.

CONCLUSION: TOWARD DISTRIBUTED LEARNING ECOSYSTEMS IN OPEN EDUCATION

With our article, we contributed to the overall challenge of OER adoption in education. OER contributes to the sustainable (re)use and (re)distribution of (educational) resources. This

sustainability objective is also visible in the latest UNSECO recommendation concerning OER, which intends to support the 2030 Sustainable Development Agenda, namely SDG 4 (Quality education). The support of SDG 4 is combined with the call to create sustainability models for OER at national, regional and institutional levels and the planning and pilot testing of new sustainable forms of education and learning. As a result, several repositories and referatories for OER provision have been developed and tested in educational institutions worldwide. Yet, each of these platforms contains only a relatively limited number of resources. We consider the discoverability of OER to be the major challenge here. Too often is argued that more resources are needed to increase OER adoption. However, we find that it is not solely the number of lacking resources but their availability to teachers and learners worldwide.

In our article, we argued that when considered through the lens of learning innovation and sustainability, it would be necessary to increase the discoverability of available resources at the different locations and platforms, which currently are visible to only a limited number of teachers and students. For achieving this goal, the focus needs to shift from creating and growing new and competing platforms and repositories to intelligent ways of linking and increasing their interconnectedness.

For the identified challenge of the discoverability of OER, we proposed the concept of DLE as a learning innovation. The concept of "ecosystems" illustrates this approach of interconnected resources. Ecosystems go beyond the spatial dimension of learning by focussing on actors' diversity and interactions. Digital (networked) learning technology is part of an ecosystem and has itself to be understood as an actor. Given the current fragmented nature of the OER infrastructure, we understand DLE as a design approach to contribute to the interconnectedness of repositories and referatories. However, we pointed to the pitfalls and hurdles to achieving such DLE by introducing and separating closed and open ecosystems. Therefore, ecosystems should be reflected with caution as they can themselves entail opening and closing mechanisms. Ecosystems that rely on mechanisms of opening their contents to other platforms can realise the full potential of open learning by making a valuable contribution to DLE.

We described the implications of the concept of DLE by presenting case studies that show how technical solutions, including metadata standards and plugins, can link content in repositories and referatories within ecosystems. The overarching objective is that the different repositories and referatories expand and improve the sustainable use of OER by merging into DLE.

Lastly, it has to be noted that our concept accompanies an invitation to the many researchers and practitioners engaged in the context of OER and open education. Looking at the current landscape, it is visible that many initiatives and research projects are underway that are expected to deliver essential impulses and results in the coming years. Therefore, we consider it crucial that they take on board the idea of DLE as an essential conceptual basis and try to let their project or initiative make a contribution to its concrete implementation. It might especially be promising to explore how lasted educational technology like learning analytics, blockchain, or even Artificial Intelligence (AI) can support or facilitate DLE. OER and related efforts have always benefitted from the fundamental belief of approaching new concepts and developments with an open mind to accomplish and foster open education.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

Both authors wrote, read, and approved the final manuscript for submission.

FUNDING

The authors wrote the manuscript as part of the project EduArc that was funded by the Federal Ministry of Education and Research (BMBF) in Germany under the grant number: 16DHB2126. The content of the publication lies within the responsibility of the authors.

REFERENCES

Abdel-Qader, M., Saleh, A., and Tochtermann, K. (2021). "on the Experience of Federating Open Educational Repositories Using the Learning Object Metadata Standard," in *EDULEARN21 Proceedings* (Valencia: IATED Academy), 4819–4825. doi: 10.21125/edulearn.2021.0998

Abdel-Qader, M. S. A., and Tochtermann, K. (in press). *The Technical Specifications and Requirements for Connecting OER Repositories Using the LOM Standard in Distributed Learning Ecosystems: Concepts, Resources and Repositories.* Berlin: Springer Nature.

Abri, Al, and Dabbagh, N. (2018). Open Educational Resources: a Literature Review. *J. Mason. Graduate Res.* 6, 83–104. doi: 10.13021/G8JMGR.V6I1.2386

Baas, M., Admiraal, W., and van den Berg, E. (2019). Teachers' adoption of open educational resources in higher education. *J. Interact. Media Educ.* 2019:9. doi: 10.5334/jime.510

Bea, F. X., and Haas, J. (2016). *Strategisches Management (7th ed.)*. Konstanz: UVK Verlag. doi: 10.24053/9783739802565

Benson, R. (2019). Paywalls and public knowledge: how can journalism provide quality news for everyone? *Journalism* 20, 146–149. doi: 10.1177/1464884918806733

Biernat, M., Urbańska, A., Nobre, T., Tarkowski, A., and Bogataj, M. (2021). *Remote education during the pandemic: the teachers' perspective*. Available Online at: https://centrumcyfrowe.pl/remote-education-during-the-pandemic, CC0 (accessed January 8, 2021).

Bond, M., Bedenlier, S., Marín, V. I., and Händel, M. (2021). Emergency remote teaching in higher education: mapping the first global online semester. *Int. J. Educ. Technol. High. Educ.* 18:50. doi: 10.1186/s41239-021-00282-x

Bozkurt, A., Jung, I., Xiao, J., Vladimirschi, V., Schuwer, R., Egorov, G., et al. (2020). A global outlook to the interruption of education due to COVID-19 Pandemic: navigating in a time of uncertainty and crisis. *Asian J. Distance Educ.* 15, 1–126.

Bozkurt, A., Koseoglu, S., and Singh, L. (2019). An analysis of peer reviewed publications on openness in education in half a century: trends and patterns in the open hemisphere. *Australas. J. Educ. Technol.* 35, 68–97. doi: 10.14742/ajet.4252

Conrad, D., and Prinsloo, P. (2020). *Open(ing) Education: Theory and Practice*. Leiden: Brill.

Cortinovis, R., Mikroyannidis, A., Domingue, J., Mulholland, P., and Farrow, R. (2019). Supporting the discoverability of open educational resources. *Educ. Inf. Technol.* 24, 3129–3161. doi: 10.1007/s10639-019-09921-3

Cronin, C., and MacLaren, I. (2018). Conceptualising OEP: a review of theoretical and empirical literature in Open Educational Practices. *Open Praxis* 10, 127–143. doi: 10.5944/openpraxis.10.2.825

Davis, E., Cochran, D., Fagerheim, B., and Thoms, B. (2016). Enhancing Teaching and Learning: libraries and Open Educational Resources in the Classroom. *Public Serv. Q.* 12, 22–35. doi: 10.1080/15228959.2015.1108893

Deimann, M., and Farrow, R. (2013). Rethinking OER and their use: open education as Bildung. *Int. Rev. Res. Open Distrib. Learn.* 14, 344–360. doi: 10.19173/irrodl.v14i3.1370

Drabkin, R. (2016). *From Silos to Sharing: Why Are Open Educational Resources Still So Hard to Find? | EdSurge News*. Burlingame: EdSurge.

Ehlers, U.-D. (2011). Extending the Territory: from Open Educational Resources to Open Educational Practices. *J. Open Flex. Distance Learn.* 15, 1–10. doi: 10.4018/978-1-7998-1200-5.ch001

Fenwick, T., and Edwards, R. (2010). *Actor-network theory in education*. Oxfordshire: Routledge, doi: 10.4324/9780203849088

Heck, T., Kullmann, S., Hiebl, J., Schröder, N., Otto, D., and Sander, P. (2020). Designing Open Informational Ecosystems on the Concept of Open Educational Resources. *Open Educ. Stud.* 2, 252–264. doi: 10.1515/edu-2020-0130

Hegarty, B. (2015). Attributes of Open Pedagogy: a Model for Using Open Educational. *Educ. Technol.* 4, 3–13. doi: 10.1016/j.calphad.2007.10.001

Herrera-Cubides, J. F., Gaona-García, P. A., Montenegro-Marín, C. E., and Sánchez-Alonso, S. (2022). Improving OER descriptions to enhance their availability, reuse, and enrichment. *Educ. Inf. Technol.* 27, 1811–1839. doi: 10.1007/s10639-021-10641-w

Hilton, J. (2019). Open educational resources, student efficacy, and user perceptions: a synthesis of research published between 2015 and 2018. *Educ. Technol. Res. Dev.* 68, 853–876. doi: 10.1007/s11423-019-09700-4

Hodges, C., Moore, S., Lockee, B., Trust, T., and Bond, A. (2020). *The Difference Between Emergency Remote Teaching and Online Learning | EDUCAUSE*. Washington, DC: EduCause, 1–15.

Kerres, M., and Heinen, R. (2015). Open informational ecosystems: the missing link for sharing educational resources. *Int. Rev. Res. Open Distance Learn.* 16, 24–39. doi: 10.19173/irrodl.v16i1.2008

Kerres, M., and Otto, D. (2022). "Digital Undergraduate Research," in *Cambridge Handbook on Undergraduate Research*, eds H. A. Mieg, E. Ambos, A. Brew, W. Deicke, S. Haberstroh, and J. Lehmann (Cambridge: Cambridge University Press).

Khan, M. A. (2021). COVID-19's impact on higher education: a rapid review of early reactive literature. *Educ. Sci.* 11:421. doi: 10.3390/educsci11080421

Koseoglu, S., and Bozkurt, A. (2018). An exploratory literature review on open educational practices. *Distance Educ.* 39, 441–461. doi: 10.1080/01587919.2018.1520042

Ladurner, C., Ortner, C., Lach, K., Ebner, M., Haas, M., Ebner, M., et al. (2020). The development and implementation of missing tools and procedures at the interface of a university's learning management system, its OER repository and the Austrian OER referatory. *Int. J. Open Educ. Resour.* 3, 1–19. doi: 10.18278/ijoer.3.2.3

Larson, R. C., and Murray, E. (2019). Open educational resources for blended learning in high schools: overcoming impediments in developing countries. *Online Learn.* 12, 85–103. doi: 10.24059/olj.v12i1.1709

Menzel, M. (in press). "Developing a metadata profile for higher education OER repositories," in *Distributed Learning Ecosystems: Concepts, Resources and Repositories*, eds D. Otto, G. Scharnberg, M. Kerres, and O. Zawacki-Richter (Berlin: Springer Nature).

Messerschmitt, D. G., and Szyperski, C. (2005). *Software Ecosystem: Understanding an Indispensable Technology and Industry*. Cambridge: MIT Press.

Mishra, S. (2017). Open educational resources: removing barriers from within. *Distance Educ.* 38, 369–380. doi: 10.1080/01587919.2017.1369350

Otto, D. (2019). Adoption and diffusion of open educational resources (OER) in education: a meta-analysis of 25 OER-projects. *Int. Rev. Res. Open Distance Learn.* 20, 122–140. doi: 10.19173/irrodl.v20i5.4472

Otto, D. (2021a). "Die Förderung von Open Educational Resources (OER) in der Hochschule. Eine Expertenbefragung von Lehrenden zu institutionellen Maßnahmen und der Gestaltung von Repositorien," in *Bildung in der digitalen Transformation*, eds H.-W. Wollersheim and N. Pengel (Münster: Waxmann), 91–100. doi: 10.31244/9783830994565

Otto, D. (2021b). Driven by Emotions! The Effect of Attitudes on Intention and Behaviour regarding Open Educational Resources (OER). *J. Interact. Media Educ.* 2021, 1–14. doi: 10.5334/jime.606

Otto, D., and Kerres, M. (2021). "Deconstructing the virtues of openness and its contribution to Bildung in the digital age," in *Bildung in the Digital Age*, eds D. Kergel, M. Paulsen, J. Garsdal, and B. Heidkamp-Kergel (Oxfordshire: Routledge), 47–63. doi: 10.4324/9781003158851-5

Otto, D., Schroeder, N., Diekmann, D., and Sander, P. (2021). Trends and Gaps in Empirical Research on Open Educational Resources (OER): a Systematic Mapping of the Literature from 2015 to 2019. *Contemp. Educ. Technol.* 13:e325. doi: 10.30935/CEDTECH/11145

Peters, M. A. (2008). "The History and Emergent Paradigm of Open Education," in *Open Education and Education for Openness*, eds M. Peters and R. Britez (Leiden: Brill), 1–15. doi: 10.1163/9789087906818_002

Ramirez-Montoya, M. S. (2020). Challenges for open education with educational innovation: a systematic literature review. *Sustainability* 12:7053. doi: 10.3390/su12177053

Rolfe, V. (2012). Open educational resources: staff attitudes and awareness. *Res. Learn. Technol.* 20, 1–13. doi: 10.3402/rlt.v20i0/14395

Sangrá, A., Raffaghelli, J. E., and Guitert-Catasús, M. (2019). Learning ecologies through a lens: ontological, methodological and applicative issues. A systematic review of the literature. *Br. J. Educ. Technol.* 50, 1619–1638. doi: 10.1111/bjet.12795

Santos-Hermosa, G., Estupinyà, E., Nonó-Rius, B., París-Folch, L., and Prats-Prats, J. (2021). Open educational resources (OER) in the Spanish universities. *Prof. Inf.* 29:e290637. doi: 10.3145/pi.2020.nov.37

Santos-Hermosa, G., Ferran-Ferrer, N., and Abadal, E. (2017). Repositories of open educational resources: an assessment of reuse and educational aspects. *Int. Rev. Res. Open Distance Learn.* 18, 84–120. doi: 10.19173/irrodl.v18i5.3063

Tlili, A., Zhang, J., Papamitsiou, Z., Manske, S., Huang, R., and Hoppe, H. U. (2021). Towards utilising emerging technologies to address the challenges of using Open Educational Resources: a vision of the future. *Educ. Technol. Res. Dev.* 69, 515–532. doi: 10.1007/s11423-021-09993-4

UNESCO (2002). *Forum on the Impact of Open Courseware for Higher Education in Developing Countries Final report*. Paris: UNESCO.

UNESCO (2019). *Draft Recommendation on Open Educational Resources. UNESCO. General Conference, 40th, 2019*. Paris: UNESCO.

UNESCO IITE (2019). *Understanding the Impact of OER: Achievements and Challenges*. Moscow: UNESCO Institute for Information Technologies in Education.

Wiley, D. A. (2014). *The Access Compromise and the 5th R. Iterating toward Openness*. Available Online at: http://opencontent.org/blog/archives/3221 (accessed July 20, 2018).

Wiley, D. A. (2020). Open educational resources: undertheorised research and untapped potential. *Educ. Technol. Res. Dev.* 69, 411–414. doi: 10.1007/s11423-020-09907-w

Wiley, D. A., and Hilton, J. (2018). Defining OER-enabled pedagogy. *Int. Rev. Res. Open Distance Learn.* 19, 133–147. doi: 10.19173/irrodl.v19i4.3601

Zawacki-Richter, O., Conrad, D., Bozkurt, A., Aydin, C. H., Bedenlier, S., Jung, I., et al. (2020). Elements of Open Education: an Invitation to Future Research. *Int. Rev. Res. Open Distrib. Learn.* 21, 319–334. doi: 10.19173/irrodl.v21i3.4659

Zhang, X., Tlili, A., Huang, R., Chang, T., Burgos, D., Yang, J., et al. (2020a). A case study of applying open educational practices in higher education during covid-19: impacts on learning motivation and perceptions. *Sustainability* 12:9129. doi: 10.3390/su12219129

Zhang, X., Tlili, A., Nascimbeni, F., Burgos, D., Huang, R., Chang, T. W., et al. (2020b). Accessibility within open educational resources and practices for

disabled learners: a systematic literature review. *Smart Learn. Environ.* 7:1. doi: 10.1186/s40561-019-0113-2

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.