Towards utilising emerging technologies to address the challenges of using open educational resources: A vision of the future

Ahmed Tlili[1], Jingjing Zhang[2], Zacharoula Papamitsiou[3], Sven Manske[4], Ronghuai Huang[1], Kinshuk[5], H. Ulrich Hoppe[4]

[1]Smart Learning Institute of Beijing Normal University, Beijing, China

[2]Big Data Center for Technology-Mediated Education, Beijing Normal University, Beijing, China

[3]Norwegian University of Science and Technology (NTNU), Trondheim, Norway

[4]University of Duisburg-Essen, Faculty of Engineering, Duisburg, Germany

[5]University of North Texas, 3940 N. Elm Street, G 150, Denton, TX, 76207, USA

ahmed.tlili23@yahoo.com, jingjing.zhang@bnu.edu.cn, zacharoula.papamitsiou@ntnu.no manske@collide.info, huangrh@bnu.edu.cn, kinshuk@ieee.org, hoppe@collide.info

Abstract

The rapid advancements in online education have pointed to a new open learning approach using open educational resources (OER). In this approach, educators and learners can freely access or redistribute educational resources that have been released online in the public domain under an open licence. Whereas this approach looks appealing in reducing learning costs, as well as in enhancing learning quality and facilitating knowledge sharing, several challenges might hinder the adoption of OER, such as locating and selecting the most appropriate resources among the thousands that are published and that are available online, and trusting them. This paper elaborates on those challenges and suggests an emerging technologies-based perspective for addressing the efficient inclusion of OER. To this end, this paper discusses how the integration of emerging yet essential technologies, such as Artificial Intelligence (AI) and blockchain, with big learning data and educational data mining algorithms could have a profound impact on enhancing OER-based learning and teaching. The dynamics of incorporating these technologies to solve several OER challenges are demonstrated through numerous examples, and the potential limitations are also discussed. The paper concludes with visions of the future, possible research challenges and directions.

Keyword: open educational resources (OER), challenges, open education, emerging technologies.

Introduction

With the rapid advancements in information and communication technology in education, new opportunities for free, open and cost-efficient learning have emerged and have started to be

adopted by universities worldwide (McGreal, 2017). One promising approach that supports and promotes openness in learning is the use of Open Educational Resources (OER). OER were first coined at UNESCO's 2002 Forum on Open Courseware, and was recently defined by UNESCO (2019) as "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, re-use, re-purpose, adaptation and redistribution by others." OER are considered as one of the most significant educational movements in the 21st century (Shear, Means, and Lundh, 2015). Specifically, the use of OER can reduce education costs and make knowledge accessible for everyone, since learners and educators do not have to pay learning fees or for accessing learning and teaching materials, such as textbooks. For instance, Tlili et al. (2019) presented how OER could be beneficial in rural education, where one of the biggest challenges is accessing good learning and teaching materials. More importantly, OER can be employed for both learning and teaching purposes due to their capacity to be freely adapted, re-used, and shared in different contexts under open licences (Hassler, Hennessy, Knight, and Connolly, 2014). In this context, several universities, organizations and governments worldwide have made clear plans by launching several policies to support the OER movement. For instance, several universities and organizations provided OER trainings and workshops so that educators acquire the needed competencies to develop their educational resources as OER (Huang et al., 2020). Additionally, more than half of the United States have considered OER legislation to enhance education and make it affordable by everyone, and it is expected that this trend will increase in the future (SPARC, n.d.). UNESCO (2020) has recently launched the OER Dynamic Coalition, which aims to create groups of international experts that can work on the OER recommendation. This initiative was supported by several Ministries of Education worldwide.

OER have pedagogical and financial advantages in higher education and can complement – if not replace – traditionally employed resources in future learning scenarios (Hilton, 2016; Watson, Clouser, & Domizi, 2014). However, in open learning contexts, the originator and providers of learning content are also different: instead of specific learning materials that are provided to learners in classrooms by educators at the university/school, online learners can have access to thousands of published OER, but they may not know the reliability of the publisher, or the quality of the resource itself. Additionally, the learners can be anywhere and can set their own learning objectives. It has been clearly shown that these open forms of learning created new challenges (Kinshuk, Chen, Cheng, and Chew, 2016). Addressing those challenges can increase the adoption of OER and enhance both learning and teaching experiences.

However, while the majority of studies have investigated the perception of educators about using OER in learning, and the cost-saving benefits from using them (e.g., Hilton, Bliss, Robinson, and Wiley, 2013), limited studies have focused on the efficient use of OER, and the challenges arising from them. Those challenges might hinder OER adoption at-scale and might negatively affect the expected benefits in terms of learning outcomes (Richter et al., 2013). Therefore, there is a need to identify what those challenges are, and to create a framework for opening the discussion about how to address them.

The Cape Town Open Education Declaration (2007) stated that "Open education is not limited to just open educational resources. It also draws upon open technologies that facilitate collaborative, flexible learning and the open sharing of teaching practices that empower educators to benefit from the best ideas of their colleagues" (p. 4). In a sense, the Cape Town Declaration turns on the "green light" in regard to taking advantage of emerging technologies with the potential to facilitate open formats in teaching and learning, through open, yet safe sharing of best practices. For instance, combinations of technologies, such as machine learning and blockchain, could support secure recommendation of appropriate and personalized open materials to learners, through unobtrusive identification of trusted OER. The OpenEduChain is an example of a public blockchain designed as a repository for open educational assets (OER, open pedagogies and scenarios), and promises to maintain reputation and trust in certification (Holotescu, 2018).

Overall, it is expected that combining emerging technologies such as artificial intelligence (AI), Internet of Things (IoT) and blockchain in a harmonic balance could facilitate the efficient detection, selection, retrieval, and reuse of OER, and address issues of trust, as well. Emerging technologies have created new OER sustainability models that need further investigation (Tlili et al., 2020), taking also into consideration the instructional design models when developing OER (Tsang & Choi, 2020). However, to the best of our knowledge, although a great number of researchers have studied the OER field "*per se*", investigating the application of emerging technologies from a holistic viewpoint in OER-based learning remains an open issue. Based on the above, the objectives of the present contribution are twofold: (1) reviewing the relevant literature to identify *challenges related to the use of OER* that should be considered by stakeholders in terms of improving learning outcomes and experiences; and, (2) suggesting *feasible technological means to address the identified challenges*, with a focus on the adoption of emerging technologies.

Research method

The first goal was pursued by exploiting the literature as a rich source of data. Specifically, several search keywords were used, including "OER challenges", "OER difficulties", "difficulties in open educational resources", "challenges of open educational practices", "Open Educational Practices (OEP) limitation", and "OEP difficulties". The search was conducted in the search engine Google Scholar and in different electronic databases, including ScienceDirect, IEEE Xplore Digital Library, and JSTOR. Additionally, two of the authors independently examined the title, abstract, and skimmed the full text based several exclusion criteria, including: (1) papers which are not written in English; (2) papers that do not report challenges related to the use of OER in learning; (3) papers that do not give detailed description about the discussed OER challenges; and, (4) papers not published between 2015 and 2020.

During this five-year period (2015–2020), the rapid growth and adoption of online learning technologies have resulted in a changing image of OER; new technological challenges have

risen and need to be addressed when using OER in learning. The new challenges are different to the ones investigated since the UNESCO Paris Declaration of 2012 (UNESCO, 2012), i.e., the perception of OER in learning, OER as cost-saving methods, and the learning effectiveness of OER compared to textbooks (e.g., Hilton, Bliss, Robinson, and Wiley, 2013). Several policies and strategies are being adopted to fulfil the post-2015 education agenda proposed by UNESCO (Jemni, Kinshuk & Khribi, 2017). This agenda focused on the effective use of information and communication technology to provide free and open access to educational resources for lifelong and inclusive learning. Additionally, with the rapid evolution of the open education concept during the last years, researchers have shifted their focus from content-centred approaches, which focus on educational resources, to more practice-centred ones that foster collaboration between learners and teachers for creating and sharing knowledge using OER, referred to as Open Educational Practices (OEP) (Cronin, 2017).

In the inclusion/exclusion process, Cohen's Kappa was calculated to test the inter-rater reliability between the decisions made by the two authors. Results showed a very good reliability ($\kappa = 0.81$; Cohen, 1960). As a result, 20 studies were obtained. Each study was examined to extract the following attributes: year of study, OER challenge, stakeholders and potential category (teaching intervention, learner/educator support, or trust and security). Those attributes provided information to conduct the synthesis. Particularly, card sorting method was used to extract the challenges from the identified studies and classify them into categories. It is an established method for knowledge elicitation by creating different categories of collected information, where it has been widely applied in several fields, including psychology, knowledge engineering, software engineering, and web site design (Nurmuliani, Zowghi, & Williams, 2004). To ensure the reliability of the final obtained categories, two researchers also participated in the categorisation process based on the definitions of the reported challenges in each study. In cases that the categorisation was different, an agreement was reached through discussions. To this end, eight new challenges concerning OER use were identified. Tables 1–3 summarise the obtained studies associated with the identified challenges, potential stakeholders, as well as the associated applications of emerging technologies related to each challenge.

It should be explicitly noted that the aim of this study is not to carry-out a systematic review of existing literature in OER; the goal of a systematic review would be to *map* the field so far, and drive our understanding on how it has evolved, the major topics developed so far, the previous overarching objectives that guided research, and the most important findings from the previous research conducted. We should clarify that the main aim of this paper is to take us *a step ahead of the-state-of-the-art*, thus focus on future research directions by identifying critical needs, drawbacks, and opportunities. This objective is facilitated by conducting the *environmental scan* of relevant literature in order to gain insight *only* on emerging topics with a potential to provide insights to upcoming challenges and to shape a vision of the future. In other words, and in line with this, the aim of the literature scan was to *discover challenges* in using OER and *future opportunities* for fully exploiting openness and freedom in education.

Identified challenges and associated emerging

technologies applications in OER

This section discusses how emerging technologies can be applied to address each OER challenge in the three categories identified from the literature (see Tables 1–3). Different emerging technologies and methods that best fit each challenge are proposed in the last column, with a detailed explanation of their integration in learning using OER (contribution of this paper). The role of these technologies is to efficiently use OER, resulting in better learning or teaching experiences and outcomes.

Teaching intervention

Lack of innovative teaching strategies: Innovative teaching strategies are strategies that create stimulating learning environments based on learning objectives while considering the needs of students (Lowenstein, 2011; Oliver, & Utermohlen, 1995). Learning using OER faces the challenge of incorporating innovative teaching strategies, such as the hands-on strategy, which is needed for different programming subjects (Baran, & AlZoubi, 2020; Kinshuk, Chen, Cheng, and Chew, 2016). In this context, it is now possible to use machine learning and gesture-based technologies, allowing learners to be engaged in the learning process using their body movements. This helps to provide hands-on learning experiences for learners, hence increase their learning motivation (Chao, Huang, Fang, and Chen, 2013). Kinshuk, Chen, Cheng, and Chew (2016), on the other hand, have stated that the absence of design principles and guidelines for systematic development is the major concern of designing gesture-based learning.

In addition, Virtual Reality (VR) and Augmented Reality (AR) can provide teachers and learners with new open learning experiences, with a better understanding and visualisation of the subject matter. AR projects virtual objects or information on physical environments in a meaningful way to augment learning experiences (Arvanitis et al., 2009; Dunleavy, Dede, and Mitchell, 2009). For instance, the YouTube platform is offering a new experience for its users by using open VR-based videos (e.g., Jiang, Swaminathan, & Wei, 2017). The barrier for users of AR authoring kits is the lack of content (Langlotz et al., 2012), thus, for AR/VR kits, it is essential to provide appropriate sets of assets, which can be achieved through (searchable) open repositories and automatic tagging of objects and markers (Palmarini et al., 2018).

Difficulty in monitoring the learning process: In OER-based learning and OEP, the learners actively participate in their learning process by, for instance, consuming (reading) or creating (publishing) learning materials, while the role of the educator becomes more that of a curator of the learning process (Ozdemir and Bonk, 2017). However, since hundreds or thousands of learners, from all over the world, can access a particular open resource, the educator's role becomes very difficult: it is almost impossible for the educator to monitor and manage the huge number of learners and the educational artefacts that they consume or create. For instance, teachers might not be willing to apply OEP because they might be afraid of losing control over the learning process (Huang et al., 2020). Therefore, to further enhance learning using OER and its practices, it is possible to develop smart virtual assistants that can instantly help learners. These assistants are software agents that, for instance, answer learners' questions if something is not clear or if there is something they want to know regarding the learning materials. To do

so, Natural Language Processing (NLP) can be applied so that the assistant takes the inquiries of learners as its input and provides the appropriate answers (Kumar et al., 2016; Sidorov et al., 2014). The virtual assistants should be easily programmed via simple interfaces so educators/publishers, even those without or with low programming skills, can program and use them. The YouTube platform provides smart bots that can be easily programmed by streamers to answer the viewers' inquiries while they are streaming (Michael, 2017; Winkler, & Söllner, 2018). Those bots detect specific keywords in the viewers' inquiries and then generate the needed answer accordingly.

Table 1. Emerging technologies application to solve OER challenges (teaching intervention)

Challenges	**Stakeholders**	**Application of emerging technologies in other fields**	**Link between emerging technologies application and the OER challenge**
Lack of innovative teaching strategies (Baran, & AlZoubi, 2020; Kinshuk, Chen, Cheng & Chew, 2016)	OER publishers, educators, Learners	YouTube platform is applying VR to provide new strategies of watching online videos (Jiang, Swaminathan, & Wei, 2017)	Machine learning techniques can be applied with VR, AR and gesture-based technologies to provide educators and learners new open learning experiences with a better understanding and visualization of the subject matter.
Difficulty in monitoring the learning process (Huang et al., 2020; Ozdemir & Bonk (2017)	OER publishers, educators	YouTube platform uses smart bots to help streamers control and manage their streams (Michael, 2017)	Smart virtual agents should be used in OER to help educators manage their courses and answer the learner's questions instantly

Learner/educator support

Searching and locating OER: OER could be beneficial for both learners and educators, as they enhance the learning and teaching processes, as well as reduce the cost of both learning and teaching materials, such as textbooks, by providing open-access to these materials. However, with so many OER available online, it can be very difficult for learners or educators to search and locate the most appropriate for them. This can overload their learning and teaching processes. A review of recent literature showed that searching and locating OER is still a major problem (Al Abri & Dabbagh, 2018). Search engines particularly use metadata, which are data that describe data, to find a searched resource. Rossi (2017) claims that providing poor metadata on a resource will make it difficult for users to retrieve this resource. In this context, de Oliveira et al. (2018) have stated that OER are usually published with poor metadata, which makes it difficult for learners to locate them. Sheu and Shih (2017) have also stated that reducing

metadata requirements may encourage OER adoption. Therefore, to facilitate the finding of resources and to make the search of OER more accurate, it is possible to apply AI, specifically machine learning and NLP techniques, to analyse the OER and create automatic tagging of metadata, resulting in an OER with rich and more accurate metadata that can be found easily by learners and educators. In this context, several companies, such as Netflix, are using automatic tagging to help users to easily find their videos and to make automatic video recommendations based on the users' interests (e.g., Salehinejad, & Rahnamayan, 2016).

In addition, searching and locating specifically high-quality OER, among the thousands that are published, is a difficult task (Ozdemir & Bonk, 2017). OER are published in online repositories, which are defined as digital databases that include learning resources, such as applications and tools, documents, pictures and videos (McGreal, 2011). In those repositories, users (e.g., learners or educators) can search for an OER, rate it, give feedback and download it along with its metadata (Atenas, & Havemann, 2013; 2014). Therefore, AI can be applied to classify the quality of OER based on different factors, including learners the users' feedback, number of downloads, or ratings by applying ranking algorithms. This means that the users (e.g., learners or educators) will get to see more highly valued OER ahead of poorly published OER. Additionally, text-mining techniques can be applied to collect and analyse the feedback of users about a particular educational resource in order to draw conclusions about its quality to other OER users. Consequently, the learning and teaching processes become more effective, by providing only good-quality OER. Based on a review of OER, Atkins, Brown, and Hammond (2007) have stated that learning repositories are moving from pre-publication reviews of resources towards post-publication reviews based on an open community of users/reviewers. Wiley, Bliss, and McEwen (2014) have highlighted that rating OER can contribute to the search for a quality OER. In this context, Google also applies AI: for instance, to make its Play Store better by ranking applications and providing good ones on top (Ahaskar, 2017). It analyses several features, including the given feedback of users (given comments and stars on each application) and number of downloads, to order the applications within Play Store by making good ones appear first.

Mapping OER together: Remixing OER-based teaching materials from different published OER, as well as OER-based self-directed learning could be very challenging for both educators and learners. This is because mapping OER together is difficult, as they are stored on different repositories across different countries or states, and there is no communication between these repositories (Drabkin, 2016; Muganda, Samzugi, & Mallinson, 2016). However, it is possible to use sophisticated machine learning and NLP techniques to analyse the generated metadata of the published OER (discussed above) to map all of these resources together and build OER recommender systems. For instance, after a learner or an educator finishes reading an OER about "how to develop an educational game" published by educator A on repository X, the system recommends that they next read about "Game engines for game development" published by educator B on repository Y. This generates automatic learning and teaching paths for both learners and educators, and facilitates the finding of adequate OER for better learning or teaching outcomes. Thus, OER repositories should be smart and open so others can access their metadata and make good use of it to enhance the learning and teaching process. However,

educational and curricular contexts need to be incorporated into metadata schemes in order to aggregate learning resources into such a path. This is still difficult to achieve using state-of-the-art NLP technologies to extract semantic information from content**.**

Feedback: Unlike in traditional classroom settings, educators might not always be present in OER-based learning, since learners can access these resources from anywhere at any time. This can make the learning process difficult for learners as no instant feedback or support is provided to them (Kim, 2018; Tlili, Essalmi, Jemni, Chang, and Kinshuk, 2018). Additionally, during the application of OEP, learners might not know how to self-regulate (Huang et al., 2020). Therefore, machine learning techniques can be applied to analyse the generated learning traces and provide automatic assessments and feedback to learners. The analysis of learning traces is a sub-field of learning analytics (LA). LA dashboards can help learners keep track of their learning progress and achievements, and help educators to keep track of their learners (Park & Jo, 2019). In addition, just like feedback, educators' encouragement and support are much needed for learners, but these are not found in learning using OER. Therefore, it is possible to use LA to provide automatic encouragement for learners, for instance, via gamification techniques (e.g., using badges and points game elements).

Adaptive learning: Learners have different characteristics and individual differences, and for this reason they behave differently when learning. However, OER based-learning environments do not usually take into consideration learners' differences (Casola, Di Blas, Paolini, and Pelagatti, 2018; Brahim, Khribi, Jemni, Tlili 2020). To the best of our knowledge, no OER-based learning environment has been developed to analyse and provide personalized learning process and services. Therefore, it is possible to use the data generated by learners while using OER, and apply machine learning techniques in order to provide adaptive content for each learner based on his/her profile. For instance, IBM Watson started using AI to provide personalised learning for learners (Gohl, 2018). It analyses the interaction of students in real-time to generate a dashboard of their learning performance for educators. IBM Watson then provides personalized recommendations and learning content, based on the profile of each student, to increase his/her learning engagements and motivation.

Table 2. Emerging technologies application to solve OER challenges (learner/educator support)

Challenges	**Stakeholders**	**Application of emerging technologies in other fields**	**Link between emerging technologies application and the OER challenge**
Searching and locating OER (Al Abri, and Dabbagh, 2018; Ozdemir & Bonk, 2017; Rossi, 2017; de Oliveira et al.,	Learners, educators	Several companies, like Netflix, are using automatic tagging to make users easily locate their videos (Salehinejad, & Rahnamayan, 2016). Google is applying AI to make, for instance, its Play	Use machine learning and NLP techniques to analyse the uploaded OER and create automatic tagging of metadata, resulting in an OER with rich and more accurate metadata that could be easily found by learners or educators. Application of AI to classify OER based on different indices, including their quality. This can be done by using ranking algorithms which take into consideration several factors, such as users' feedback (e.g., learners or educators),

2018; Sheu & Shih, 2017)		Store better by ranking applications and providing good ones on top (Day & Lin, 2017; Ahaskar, 2017).	number of downloads or rating.
Adaptive learning (Brahim, Khribi, Jemni, Tlili 2020; Casola, Di Blas, Paolini, & Pelagatti, 2018)	Learners	Application of AI and LA in intelligent tutoring systems to provide adaptive learning (Gohl, 2018)	Incorporating LA approaches to analyse learners' learning traces, for example, in MOOCs and provide adaptive learning accordingly.
Feedback (Kim, 2018, Tlili, Essalmi, Jemni, Chang, & Kinshuk, 2018)	Learners, educators	AI is used in business analytics by gaining insights from data of users to improve business decisions (Ransbotham et al., 2017).	LA can be applied on the data of learners in OER, such as in MOOCs, to create dashboards that can help learners keep track of their learning progress and achievements, as well as educators to keep track of their learners.
Mapping OER together (Drabkin, 2016; Muganda, Samzugi, & Mallinson, 2016)	Learners, educators	AI is applied in recommender systems to recommend something for users based on their interests. YouTube is applying AI to recommend videos on users based on their interests (Covington, Adams, & Sargin, 2016).	Use of sophisticated machine learning and NLP techniques to analyse the generated metadata of published OER to map all of these resources together and build OER recommender systems that can be useful when preparing teaching or learning materials.

Trust and security

Protecting intellectual property: One of the major violations that can occur when (re)using OER is the illegal use of a particular resource, involving a failure to respect the type of licence that it is published under. This can affect the willingness of educators/publishers to publish their OER (Wang and Towey, 2017). Based on a systematic review, Koseoglu and Bozkurt (2018) found that protecting intellectual property is a major problem in OER. To address this challenge, it is possible to apply big data analytics and blockchain technology to automatically delete illegally published OER. Blockchain technology, also known as distributed ledger, is a distributed network of nodes (computers) which use a timestamp service to encrypt and maintain the source of information sharing, as a proof of identity (Chen, Xu, Lu, Chen, 2018). Specifically, when a publisher publishes his/her OER, blockchain-based platforms store the authorship information of this resource (e.g., uploaded time stamp, author name, permissions, etc.) in a decentralised and encrypted way and attribute a licence to this resource. This ensures secure storage of authorship information that cannot be modified (i.e., no one can violate the authorship information for their own benefits) and eliminates doubts about who first created

this resource. Additionally, one of the important OER features is the possibility of reusing them in different contexts and for different purposes. Blockchain could therefore be applied to also record the evolution of OER by tracking the OER adaptations made by other educators (i.e., the new OER versions created by educators). Machine learning algorithms can then be applied to search for instances (new versions) of a given licence or OER and automatically delete them, by removing or blocking the Uniform Resource Locator (URL) of that resource from the server. As a result, no user can access that resource anymore and notify the publisher in the case of unauthorised used permissions. For instance, the KODAKOne platform is using blockchain technology to protect photographers from the misuse of their photos (Eastman Kodak Company, 2019).

Fraud prevention: One of the major challenges in online learning which persisted even in open learning is fraud prevention (Witt, 2017). This led to the unacceptability of the obtained learning certificates in workplaces, due to certificate fraud or cheating, such as plagiarism (Banks and Meinert, 2016). In this context, it may be asked how we can ensure that the learner who is submitting the learning answers is the same person who receives the final certificate, or how we can ensure that the learner is not copying the answers from other sources. AI-based online proctoring OER platforms can be used to solve this issue. Currently, several proctoring products exist in the literature, such as Examity and ProctorExam, which could be integrated with OER platforms. Specifically, machine learning, along with facial and pattern recognition techniques, can be used to first identify if the person who is sitting at the computer to take the exam is the same person enrolled in the course, based on his/her previously uploaded photo. The system then starts to detect suspicious behaviours related to cheating, based on a training dataset of suspicious patterns. Additionally, the obtained certificates can then be uploaded to blockchain-based platforms where they can be saved securely and checked based on the learner's ID and the issued university, resulting in a reduction of online degree fraud. AI algorithms, which can work even with encrypted data, can be used to search the database and retrieve the needed information to verify that the provided certificate is authenticated. Massachusetts Institute of Technology (MIT) and the company Learning Machine are also cooperating together to provide a blockchain-based learning platform where learners who have attended the online course and passed the final assessment will receive a certificate that is stored on a blockchain network (Skiba, 2017). This network will archive this certificate and store its ownership for future verification if needed (by, for instance, other companies or universities).

Table 3. Emerging technologies application to solve OER challenges (trust and security)

Challenges	**Stakeholders**	**Application of emerging technologies in other fields**	**Link between emerging technologies application and the OER challenge**
Fraud prevention (Banks & Meinert, 2016; Witt, 2017)	OER publishers, educators	AI is applied in proctoring systems to prevent fraud (Gupta, 2018).	Use of AI-based online proctoring OER platforms to detect cheating behaviours. Additionally, the obtained certificates, for instance, from MOOCs can then be uploaded to blockchain-based platforms where they can be saved securely and checked based on the learner's ID and the issued university,

			resulting in a reduction of online degree fraud.
Protecting intellectual property (Koseoglu and Bozkurt, 2018; Myers, 2020)	OER publishers, educators	KODAKOne platform is using Blockchain technology to protect photographers from the misuse of their photos (Eastman Kodak Company, 2019).	Blockchain-based OER platforms should be used to record the evolution of OER (i.e., the different adaptations made by educators) and their associated licence. Machine learning systems can then be used to search for instances of the original OER and automatically delete them in case of unauthorized used permissions.

Discussion and conclusion

While OER are a promising approach as regards a more democratic and cost-efficient education, the review of relevant literature highlighted numerous limitations related to the use of OER, which need to be addressed. This study elaborates on the potential of current emerging technologies to sufficiently resolve some of these issues to make OER-based learning safe and efficient. Current emerging technologies, such as AI and blockchain, can provide new opportunities for placing OER in the epicentre of teaching and learning as regards an open educational approach. For instance, emerging technologies in OER-based learning can allow the "always-on" approach, where learners instantly get learning feedback and interventions regardless of the learning time or location. It can also protect them from any offensive content and facilitate accessing quality OER.

Despite the recent advancements in technology and computing research, it should be noted that technological limitations might hinder the application of emerging technologies in using OER. For instance, the standardisation of data coming from multiple and different sources (sensors, log data, voice, etc.) remains a challenge, which affects the analysis of these data to extract useful information. Additionally, more advanced and accurate algorithms need to be developed in order to identify and extract learning information and patterns about learners from big learning data (Kumar et al., 2014). Additionally, several challenges have been highlighted by several researchers related to collecting and analysing big data, such as the privacy of learners, the right to collect data, and ownership of the collected data (Tlili, Essalmi, Jemni, Kinshuk, and Chen, 2018).

Social challenges can also limit the application of emerging technologies in OER, by pushing educators outside of their comfort zone. For instance, the provided learning content is now open to everyone and emerging technologies can help highlight the reported gaps in this content and show them to educators for future improvements. This can make educators uncomfortable, since they are not accustomed to learning criticism in traditional learning. Additionally, educators or publishers may not have the needed skills to develop sophisticated OER-based environments that can be used to provide learning outcomes. Therefore, it may be asked how we should prepare faculty members and even learners for the era of OER and emerging technologies?

Covering all these challenges (technological and sociological) will need serious efforts from different stakeholders, such as educators, policy makers, learners, etc.

Furthermore, since OER are free and users (learners or educators) do not have to pay the registration fee like in traditional online learning environments, financial challenges to maintain OER projects are one of the biggest challenges to consider. Langen and Bitter-Rijkema (2012) stated that the absence of a clear revenue model to keep providing open learning is a major problem when using OER. Wiley, Williams, DeMarte and Hilton (2016) also highlighted that there is an urgent need for universities to find a successful revenue model that can support the creation and publishing of OER. Therefore, there is a need to think about new revenue models using emerging technologies and OER for a sustainable open education.

Finally, while this study shed the light on the technological solutions that could be implemented to overcome the OER challenges (the study focus), more attention should also be paid regarding the human factor to successfully implement those technological solutions. For instance, more investigation should be conducted to understand how a specific culture might impact the perception toward OER adoption and technology (Hodgkinson-Williams, & Trotter, 2018). In addition, more OER and ICT trainings should be designed to address the inequality between users (learners or educators) in different regions, in terms of competencies, knowledge, and infrastructure (Hill, & Lawton, 2018; Lambert, 2019).

Implications of this study

This paper reported several challenges related to the use of OER in learning and teaching that should be considered by different stakeholders (e.g., researchers, practitioners, learners and educators). Overcoming these challenges can enhance the adoption of OER in universities and the provided learning and teaching experiences. In order to achieve this, the paper presented several emerging technologies-based to address these challenges. These solutions can further open up new future directions in relation to developing smart OER environments and repositories to achieve better learning outcomes. We identified several key technologies, such as semantic technologies or blockchain, that have been perceived as being cross-sectional regarding their applicability and their respective challenges. Finally, this paper highlighted additional technological limitations that should be taken into consideration while developing these OER environments and repositories.

Limitations and future research directions

This study has several limitations that should be acknowledged and further researched. For instance, some OER challenges might not have been considered in this study due to the search keywords used within a selected period (2015-2020). Additionally, this study is based on the findings reported in the literature and has not conducted an experimental validation. However, despite these limitations, this study provides a solid basis for employing emerging technologies in order to solve different challenges related to the use of OER in learning.

This paper defined and clarified major issues that are still confusing at this earlier developmental stage of emerging technologies, and more empirical studies could reference this

study to further conduct case studies or large-scale survey research. In practice, future directions could focus on developing a smart repository. This repository would use machine learning and NLP techniques to automatically: (1) analyse and tag the uploaded resources, resulting in a rich OER with accurate metadata that will make it easier to locate online; (2) delete uploaded OER which contain abusive information (e.g., text, image, sound, etc.); and (3) apply ranking algorithms, based on the rating of learners, to make more highly valued OER appear on top of other OER.

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