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Volume 22, Number 2, May 2021

URI: <https://id.erudit.org/iderudit/1078414ar>
DOI: <https://doi.org/10.19173/irrodl.v22i1.5110>

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Publisher(s)

Athabasca University Press (AU Press)

ISSN

1492-3831 (digital)

[Explore this journal](#)

Cite this article

Moon, J. & Park, Y. (2021). A Scoping Review on Open Educational Resources to Support Interactions of Learners with Disabilities. *International Review of Research in Open and Distributed Learning*, 22(2), 314–341.
<https://doi.org/10.19173/irrodl.v22i1.5110>

Article abstract

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May – 2021

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Abstract

This scoping review explored the trends in open educational resources (OER) that support the interactions of learners with disabilities and the challenges of supporting these interactions in such environments. Emerging OER and open educational practices allow learners to interact with digital learning resources in self-regulated learning. Since OER assume learners' self-regulation, research has explored how to promote learner interactions to facilitate better engagement and motivation. Emerging research on OER-enabled pedagogy corroborate this trend. However, despite increasing interest in OER and open educational practices, few studies have demonstrated how OER support various types of interactions for learners with disabilities. Learners with disabilities are likely to experience challenges in interacting with OER due to their modality constraints. A comprehensive literature synthesis is essential to investigate the needs of learners with disabilities in their interactions in OER. In this study, we reviewed and synthesized existing research on how OER and open educational practices support the interactions of learners with disabilities across different OER platforms. Our findings suggest both research and design implications for future OER designs suited for learners with disabilities.

Keywords: open educational resources, scoping review, learner interaction, learners with disabilities

Introduction

Open educational resources (OER) have expanded due to their potential use in teaching and learning. For example, Web-based OER, such as open courseware and massive open online courses (MOOCs), have increasingly attracted learners' attention by encouraging interconnectedness and allowing for remote access. OER generally refer to educational resources that are publicly sharable through multimodal data (e.g., text, audio, and visual stimuli). OER include various types of learning environments, as well as sharable and electronic materials that are publicly accessible. The variety of OER platforms range from Web-based learning materials to stand-alone computing applications across different learning contexts.

Research faces a new challenge in determining how to promote learners' interactions in OER environments. Emerging research on learners' 21st-century skills, such as collaboration and creativity (Amornrit, 2019; Okada et al., 2014), has increasingly focused on how OER and open educational practices can develop these skills. This research considers learners' deeper learning, which comprises the mastery of domain-generic problem-solving skills, through OER. While most studies have focused on the principles of OER design and use, such as the 5Rs (i.e., reuse, retain, revise, remix, and redistribute), they rarely discuss ways to enhance learners' interactions in OER. Correspondingly, the emerging notion of OER-enabled pedagogy (Wiley & Hilton III, 2018) suggests a new role for OER that better emphasizes learners' interactive and hands-on experiences.

OER-enabled pedagogy expands the significance of learners' interactions with OER, with an understanding that learners not only use OER for information retrieval but also interact with OER by creating, modifying, utilizing, and recreating artifacts from OER-driven environments. Despite emerging views on OER that are aligned with OER-enabled pedagogy, the question remains: How do existing OER support the interactions of learners with disabilities? Although a new paradigm of OER supposes learner-centered manipulation of learning resources, the current discussion on the role of OER in developing 21st century skills has failed to suggest ways to embrace learners with disabilities in this paradigm. Specifically, the issue of how existing OER can support the various interactions of learners with disabilities is not well understood.

According to the National Center for Education Statistics at Institute of Educational Sciences (IES; NCES, 2020) in the United States, the percentage of learners aged 3–21 years who are served under the Individuals with Disabilities Education Act (IDEA) is quite large (13% of all learners, 7.1 million in total). Furthermore, more than 10% of learners with disabilities spend less than 40% of their time taking general classes. This statistic shows that OER can be particularly beneficial for learners with disabilities, who are more likely to face challenges in accessing learning opportunities than typically developing learners. Research on open learning is essential to understand how OER can be designed and implemented to guide the meaningful learning experiences of individuals with disabilities.

Aligned with the goal of our study, we chose to adopt the interactionist model's definition of disability (Howard, 2003), among the various approaches to the definition (e.g., medical and social models). The interactionist model focuses on individuals' social processes and dynamics instead of their heterogeneous medical diagnoses. This model admits the social barriers and limitations of some impairments and the relationships among them and emphasizes the significance of a system or an environment as a social place where interactions between individuals and environments occur (Howard, 2003). From this perspective on

disability, we explored how OER facilitate the different interactions types of learners with disabilities in OER environments (i.e., learner–learner, learner–instructor, learner–interface, and learner–content interactions). Specifically, this scoping review aimed to reveal the gap between current OER, in terms of learner interaction design, and what learners with disabilities need.

OER in the 21st Century

OER refers to digital learning materials that are open to anonymous users. OER include various types of educational materials for teaching, learning, or assessment, such as textbooks and digital toolkits that consider human modalities (e.g., video and narrations). Since OER focus on the openness of learning resources, OER can contribute to digital equity (Park et al., 2019). Digital equity indicates that each learner has an equal opportunity to access and experience learning resources without physical constraints (Solomon, 2002). Hence, OER can ensure digital equity by supporting learners' access to educational materials. Recent reviews on open education support this perspective (Lambert, 2019; Leahy et al., 2016).

In addition to existing OER, advances in computing technologies have significantly changed the role of OER. Emerging OER do not limit their online platforms but flexibly embrace various learning environments (e.g., open-source software and games) that meet the 5R standards. Wiley and Hilton III (2018) suggest OER-enabled pedagogy as a framework for expanding the role of OER in view of constructionism and openness in education. Constructionism believes that learners actively construct new knowledge from their learning experiences, particularly when they engage in creating personally-meaningful artifacts (Resnick, 1996). In the same vein, OER-enabled pedagogy emphasizes learners' creative and critical thinking through learning-by-doing exercises. Guided by this epistemological foundation, researchers have highlighted the importance of learners' interactions and actions that revise and re-create existing OER and result in deeper learning. From a constructionist perspective, OER highlight open-access to learning materials and underscore learners' creations and artifacts through the use of digital tools. Similarly, OER-enabled pedagogy assumes learners' interactions, including artifact creation through OER. In other words, OER-enabled pedagogy describes learners' highly-interactive and experiential learning as comprising manipulation, modification, and re-creation of OER (Van Allen & Katz, 2019; Wiley & Hilton III, 2018).

Despite attention to OER and OER-enabled pedagogy, studies have rarely investigated how existing OER and open educational practices can embrace learners with disabilities and how they can promote their interactions. In terms of digital equity, research has failed to identify clearly the contextual challenges that learners with disabilities face when using OER (Park et al., 2019; Willems & Bossu, 2012). Considering such challenges, we noticed a possible discrepancy between OER designs and learners' disabilities, which may interrupt the expansion of OER-enabled pedagogy for learners with disabilities. This discrepancy underscores the importance of a scholarly review that identifies the types of learner interactions that are supported across different OER platforms. A comprehensive review of how OER support the interactions of learners with disabilities is essential to identifying relevant design indications and implications.

Accessibility and Universal Design for Learning (UDL)

Digital equity denotes a learner's right to access educational resources without barriers. Prior research has explored how to embrace learners with disabilities through OER as a practice of digital equity (Park et al., 2019; Treviranus, 2018). Research on OER for learners with disabilities have been rooted in two concepts:

accessibility and universal design for learning (UDL; Spencer, 2011; Spooner et al., 2007). According to the IMS Global Learning Consortium (2012), accessibility refers to the ability of a learning environment to adjust to individual learners. A major goal of accessibility design is to consider the visibility of information to allow learners with disabilities greater understanding in OER. Specifically, accessibility considers information presentation that enables individuals to better access and comprehend information without interruption by physical body constraints.

In terms of Web accessibility, previous research has focused on building more accessible Web resources that consider learners with disabilities. Similarly, the international World Wide Web Consortium (W3C, 2020) has offered the Web content accessibility guidelines (WCAG) since 2008. Following these guidelines, two examples demonstrate how accessibility in OER has been considered: 1. The FLOE Project is an online learning resource that incorporates user-interface options and inclusive-technology resources (Treviranus et al., 2014). The project aims to offer personalized and “one-size-fits-one” learning materials for learners with disabilities. 2. Hashey and Stahl (2014) suggest a voluntary product accessibility template, which demonstrates how educational devices are tailored to learners’ contexts, involving modality preferences. This template also helps designers to conceptualize multimodal interactions in a Web-based platform.

In addition to accessibility, research has considered UDL as a major framework to envision instructional strategies to promote learners’ engagement in a digital learning environment (Meyer et al., 2014). UDL refers to instructional products or practices that are optimized for all learners, including individuals with disabilities. While accessibility refers to enhanced information visibility that is tailored to learners with disabilities, UDL seeks to provide a set of learning strategies with digital tools that inclusively support learners’ engagement (Spencer, 2011). In this sense, UDL demonstrates three principles regarding learners’ improved participation in learning (Spooner et al., 2007): a. *representation*, which refers to providing multiple formats of representation (e.g., visual and auditory) to allow learners to choose the optimal channel of information; b. *action and expression*, which denote using methods that enable learners to demonstrate their behaviors and thoughts in various ways; and c. *engagement*, which refers to choosing a variety of sources that are personally meaningful to an individual learner to enhance their motivation. Although both accessibility and UDL have been pivotal to understanding OER design and development for learners with disabilities, few studies have attempted to bridge the two perspectives and explain how each framework has been incorporated in current OER (Navarro et al., 2016; Ngubane-Mokiwa, 2016).

Supporting the Interactions of Learners with Disabilities

Engagement is a key indicator of the success of OER. Learner interaction determines an individual’s engagement levels in an educational setting. Thus, researchers have been interested in boosting learners’ engagement through OER (Panke & Seufert, 2013). Since OER depend on learners’ self-regulation (Kocdar et al., 2018), such as time management and strategic planning, research has underscored the promotion of learners’ interactions to maintain their engagement. In particular, an emerging concern for learners’ hands-on practices in OER-enabled pedagogy (Wiley & Hilton III, 2018) emphasizes ways to promote learner interaction.

Multiple lines of OER research provide clues on how to better facilitate learners’ interactions. In terms of accessibility, research has investigated how to improve perception, navigation, and interaction in Web

environments that serve as OER. Such research has focused on designing and developing graphical user interfaces (GUIs), which allow learners to control multimodal inputs and navigation paths in a Web system (Bittencourt et al., 2016; Navarrete & Luján-Mora, 2018). In addition, the field of human-computer interaction suggests an ability-based design, which intends to optimize learners' existing capabilities in their interactions (Wobbrock et al., 2011). Such research aims to provide a system interface that corresponds to an individual's characteristics. Research on UDL considers the external design factors of a learning environment, such as peer- or instructor-interaction settings. UDL research aims at designing multiple modes of instruction that enable learners with disabilities to choose their preferred learning materials to assist in their learning. UDL focuses on optimizing individuals' learning experiences (Spooner et al., 2007) across different instructional settings.

Despite the various streams of OER for learners with disabilities, a comprehensive review of learner interactions in OER is lacking. The ways in which OER and open educational practices specifically guide and support the interactions of learners with disabilities are not well understood. Few studies encompass the breadth of literature, including current trends and knowledge gaps in studies, on how learners with disabilities interact in OER environments. Thus, we aimed to map the landscape by collecting and synthesizing existing OER studies. This study proposed two research questions:

1. How have OER supported the interactions of learners with disabilities?
2. What are the major challenges of supporting interactions in OER for learners with disabilities?

Methods

We conducted a scoping review to identify key concepts, theoretical accounts, and scholarly evidence that correspond with the research questions. A scoping review is a data-synthesis method that organizes and synthesizes the literature on a specific topic. The major goal of a scoping review is to identify the "extent, range, and nature of the literature" that is aligned with a research interest (Pham et al., 2014, p. 371). In contrast to a systematic review, which answers specific and narrow research questions, a scoping review focuses on identifying a body of literature on a subject area, as well as gaps between current practices and the research questions.

Data Sources and Search Strategies

We searched multiple electronic databases (i.e., Web of Science [WoS], ERIC, Google Scholar, ScienceDirect, ACM, and IEEE Xplore), using several sets of keywords related to OER and disabilities, to gather relevant literature. Keywords on OER included terms, such as "open educational resources," "OER," "open learning," "open education," and "MOOC." Keywords on disabilities included terms, such as "accessib*," "disab*," "universal design," and "inclusive design." We also included the term "interaction" to search for literature on the types of interaction that are designed and supported in existing OER. To complement the search results, we conducted snowball sampling to identify additional literature (see Wohlin, 2014). Snowball sampling is a data-collection technique used to explore and then include feasible evidence that is aligned with the research questions. This method aligns with Arksey and O'Malley's (2005)

“hand-searching of key journals” approach (p. 24), which recommends manually checking articles because the results of keyword searches in select electronic databases are incomplete. In addition, we searched the Horizon Report 2020 (EDUCAUSE, 2020), an academic resource that demonstrates significant trends and emerging educational practices (e.g., maker education and computational thinking), to identify relevant literature. Table 1 shows the inclusion and exclusion criteria used to select the articles for this study. As this scoping review aimed to identify and explore the themes and issues of OER and OER-enabled pedagogy, we included peer-reviewed conference proceedings that address emerging issues in addition to journal articles.

Table 1

Inclusion and Exclusion Criteria for Data Collection

Inclusion criteria	Exclusion criteria
<ul style="list-style-type: none"> • Empirical studies that apply accessibility and universal designs for learners with disabilities. • Empirical studies that demonstrate educational practices, including OER aligned with the underlying notions of OER-enabled pedagogy. • Studies with a conceptual framework for OER design, especially for learners with disabilities. • Studies that use emerging educational practices from the Horizon Report, such as OER. 	<ul style="list-style-type: none"> • Studies not written in English. • Studies unrelated to the research questions. • Duplicates of the same study results. • Studies that implement systematic or scoping reviews.

Figure 1

A PRISMA Diagram of the Data Collection Procedures

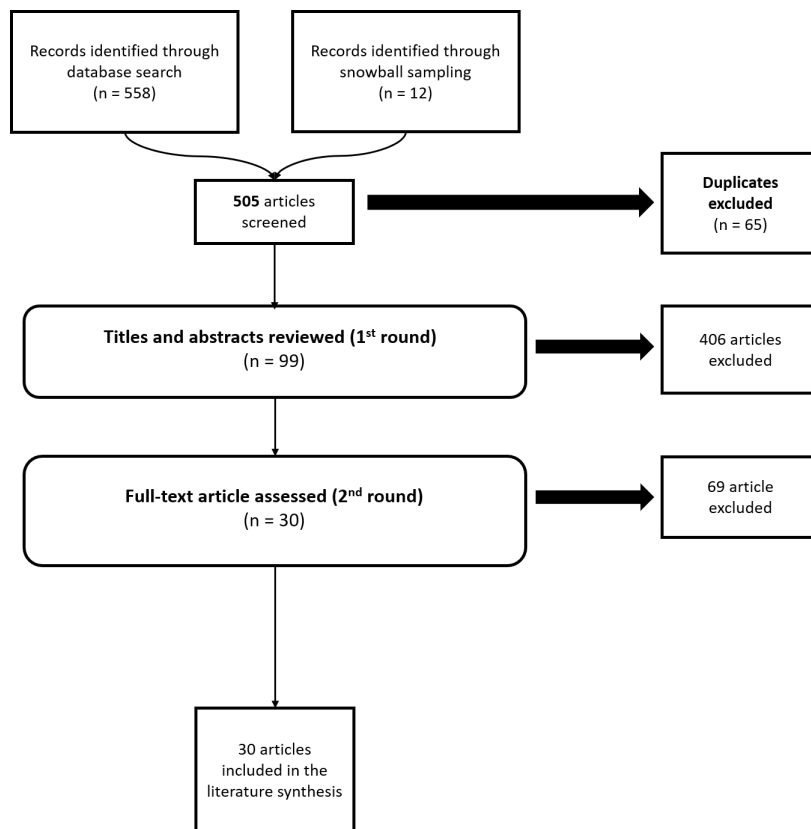


Figure 1 displays a PRISMA diagram of our data collection procedures. Using both database searches and snowball sampling, we identified a total of 570 articles with a combination of the keywords mentioned above. We then carefully read the titles and abstracts of all articles and selected the applicable articles for further review. We retained 99 articles for full-text screening and excluded 406 articles. Each of the researchers subsequently read the full texts of the selected articles and rated evaluated them. We iteratively discussed any discrepancies between the ratings until we reached an agreement. After excluding 69 articles, a total of 30 articles remained for the literature synthesis.

Data Analysis and Procedures

We conducted a content analysis of the selected articles to organize and synthesize the studies. To this end, we developed and implemented a coding scheme to systematically review the collected literature. The coding scheme was designed based on Moore's (1989) and Hillman et al.'s (1994) classifications of learner interactions, which primarily appear in online education. The scheme consisted of several categories: bibliographic information, article types, study foci, OER platform types, intervention types, learner interaction types, and design implications and challenges. Investigating the types of learner interactions in OER can contribute to understanding how learners interact with peers, instructors, content, or computing systems. Specifically, learners with disabilities may face difficulties in interacting with peers or digital platforms because the platforms are not inclusively designed and optimized for all learners.

Correspondingly, our coding scheme addressed four interaction types: 1. learner–learner interactions, which indicate learners’ social interaction patterns or collaborations through OER; 2. learner–instructor interactions, which focus on the instructional supports that appear in OER; 3. learner–interface interactions, which describe how OER directly support learners’ self-discipline through system elements; and 4. learner–content interactions, which indicate learners’ use of educational content in OER for knowledge acquisition and the transformation of their cognitive state. Two coders were trained to conduct the coding. They first randomly coded 20% of the collected articles and iteratively discussed the results until they reached 100% agreement. After the coders completed training through the discussion process and learned the coding scheme, they individually coded the remaining articles. The collected literature was then categorized into major themes, which were used to determine how this body of the literature answers the research questions (see Arksey & O’Malley, 2005).

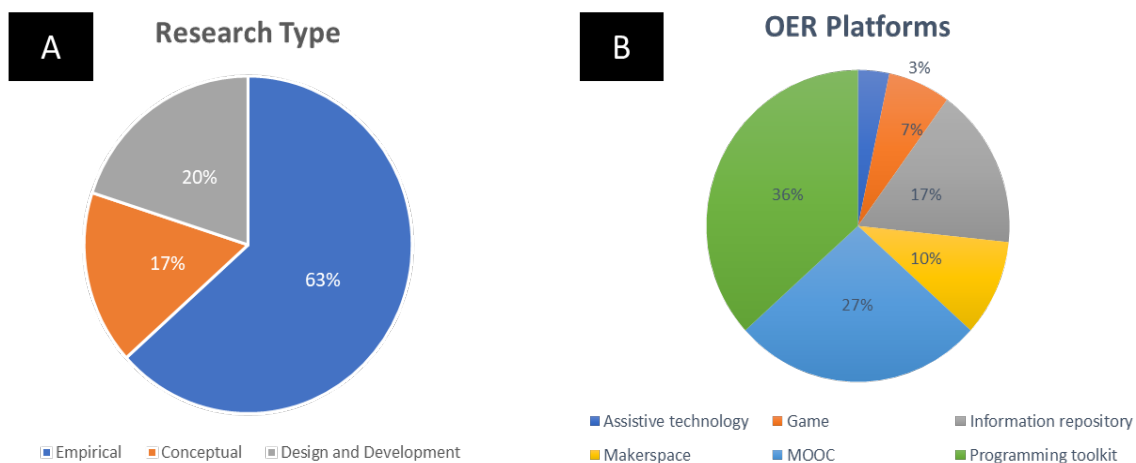
Findings

Descriptive Statistics

Figure 2 illustrates the 30 articles selected for the literature synthesis in terms of the type of study and type of OER platforms they describe. Among the selected articles, 19 articles (63%) describe empirical research on OER implementation for learners with disabilities and include both quantitative (e.g., experimental, or survey-based) and qualitative (e.g., interview) data collection and analyses. Six articles (20%) describe conceptual studies that envision OER design or theoretical frameworks for learners with disabilities. Finally, five articles (17%) illustrate OER design and development across different platforms and hardware.

Figure 2

Research Types and OER Platforms in the Selected Articles



Note. Panel A: Research types. Panel B: OER platforms.

Figure 2 and Table 2 present the different types of OER platforms that support learner interactions in the selected studies, including information repositories ($n = 5$, 16.7%), MOOCs ($n = 8$, 26.7%), programming toolkits ($n = 11$, 36.7%), makerspaces ($n = 3$, 10.0%), assistive technologies ($n = 1$, 3.3%), and games ($n = 2$, 6.7%). The number of OER platforms and the study types in this literature synthesis differ because a single study could include multiple types of learning platforms.

Table 2

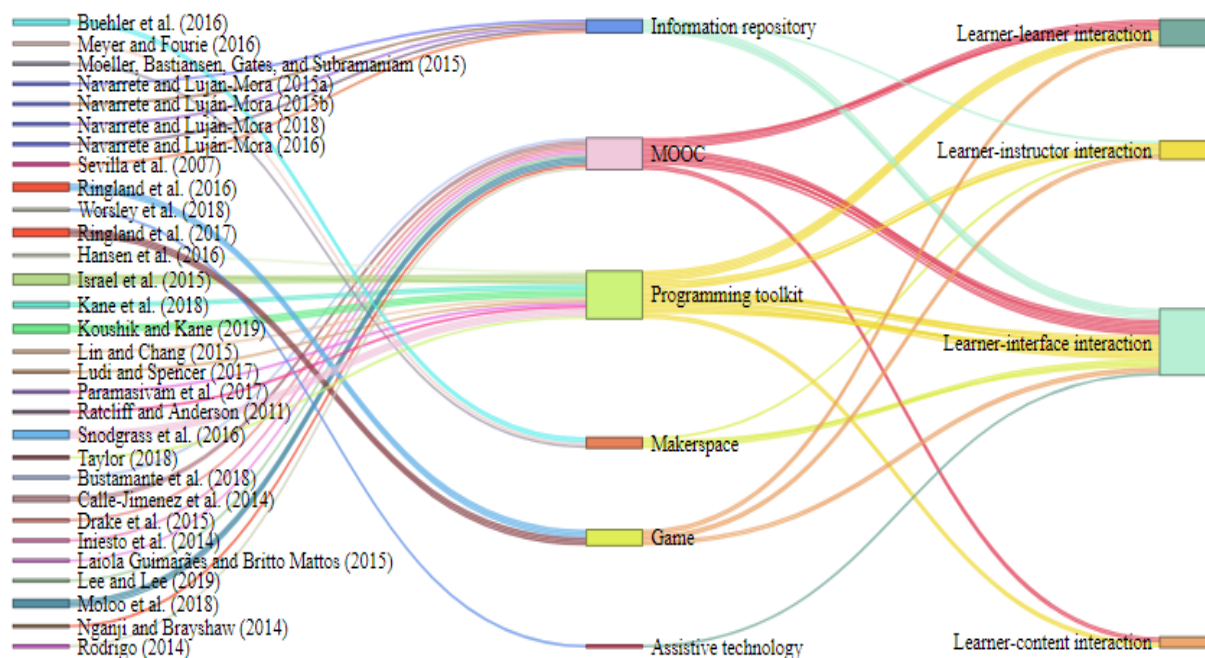
OER Platforms Coded in This Study

OER platform types	Operational definition	Reviewed articles ^a
Information repositories ($n = 5$)	Online platforms that provide either teaching or learning resources for both teachers and learners.	17–20, 27
MOOCs ($n = 8$)	Online platforms that comprise lectures and learning management systems.	2–4, 6, 10, 16, 21, 26
Programming toolkits ($n = 11$)	Computing applications that teach learners the language of object-oriented and block-based programming (e.g., Scratch and Google Blockly).	5, 7–9, 11–13, 22, 23, 28, 29
Makerspaces ($n = 3$)	Informal workspaces that allow learners to experience maker activities and provide various maker equipment (e.g., 3D printer, sewing machine, and e-textures).	1, 14, 15
Assistive technologies ($n = 1$)	Any devices used to support the capacity of learning materials and communication.	30
Games ($n = 2$)	Educational games that encourage learners to play and communicate with peers.	24, 25

^a The identification numbers of the articles included in the synthesis are listed in Appendix A.

Figure 3

Types of Learner Interactions and OER Platforms in the Selected Literature



The sampled literature demonstrates four major interaction types that have emerged in OER research: learner–learner interactions ($n = 9$, 20.9%), learner–instructor interactions ($n = 5$, 11.6%), learner–interface interactions ($n = 23$, 53.5%), and learner–content interactions ($n = 6$, 13.9%). The results suggest that most studies primarily explored how learners behave and interact with OER systems (i.e., learner–interface interaction). We mapped our results on research articles, OER platforms, and types of learner interactions using a Sankey diagram to demonstrate learner interactions (i.e., learner–learner, learner–instructor, learner–interface, and learner–content interactions) across different learning environments (Figure 3). To address the two research questions, we mapped the collected articles according to research type, OER platforms, and types of learner interactions (see Appendix A).

Research Question 1: How Have OER Supported the Interactions of Learners With Disabilities?

Learner–Learner Interaction

A number of studies (4, 7–9, 16, 24–26, 28; see Appendix A) present examples of learner–learner interactions when using OER. These studies coherently demonstrate that peer collaborations were helpful in adaptively supporting learners with disabilities in OER. The learner–learner interactions varied across different OER platforms:

- Programming toolkits (7–9, 28): A group of studies focused on learners’ collaborations when implementing open-source programming toolkits (Israel et al., 2015; Kane et al., 2018; Koushik &

Kane, 2019, Snodgrass et al., 2016). For example, Kane et al. (2018) implemented a toolkit called *Bonk*, which is an accessible game that teaches visually-impaired learners how to use programming language to create, share, and play audio games. Learners joined collaborative programming exercises with peers in informal and loosely formed groups. Collaborations emerged differently in each group: Learners either experienced all roles in a project or were individually assigned a role (e.g., programmer, tester, designer, and debugger). Learner–learner interactions mostly occurred when learners contended with programming task challenges.

- MOOCs (4, 16, 26): A few studies discussed learner–learner interactions in MOOC environments (Drake et al., 2015; Moloo et al., 2018; Rodrigo, 2014). They focused on enhancing the accessibility and usability of MOOC platforms and, in particular, peer to peer modalities (Rodrigo, 2014), which foster learners’ online communication in discussion boards.
- Games (24, 25): Ringland and colleagues used open-source games to enhance learners’ socialization and sensory development through 3D artifact designs (Ringland et al., 2016; Ringland et al., 2017). In these studies, the researchers demonstrated the effect of Autcraft, a modified platform of the 3D game Minecraft designed for learners with autism spectrum disorder. The game platform facilitated learners’ social interactions, allowing them to practice interpersonal communication skills safely with collaborative designs. Learners with autism spectrum disorder could share their artifacts and discuss design ideas with their peers through synchronous communications on the Minecraft server.

Learner–Instructor Interactions

Five studies (1, 7, 24, 25, 28) show how learner–instructor interactions emerge when using OER. Learner–instructor interactions in OER appear vital to managing learners’ attention because OER encourage learners to seek, identify, and apply knowledge mindfully in problem-solving. Since the benefits of OER depend on learners’ self-regulated attitudes (Gil-Jaurena, 2014), fostering learner engagement is essential. Different types of learner–instructor interactions emerged across the various OER platforms discussed in these studies.

- Makerspaces (1): Buehler et al. (2016) suggest several guidelines to promote engaging experiences for learners with disabilities when using 3D printers. The researchers collected suggestions for device management (i.e., budgeting time for training, ensuring printer reliability and maintenance, and developing a plan to share resources equally) in learning activities in a makerspace.
- Programming toolkits (7, 29): Two studies observed instructors’ learning supports for learners with disabilities in programming toolkits (e.g., Scratch and Alice). Since computer programming exercises appeared challenging to novice learners, specific and adaptive learning supports were emphasized.
 - Israel et al. (2015, [7]) demonstrate a contextualized UDL framework for teaching computational thinking through programming toolkits (e.g., Scratch and Alice). The researchers suggest strategies to promote learners’ attention (e.g., presenting multiple means of representations/action and expression/engagement). This study indicates the

necessity to consider instructional sequences and flow that allow learners to practice their skills and then recognize underlying concepts from explicit instruction.

- Snodgrass et al. (2016, [28]) investigated various instructional supports for implementing Scratch in Code.org. Code.org is a web platform that encourages both teachers and students to learn the fundamental concepts of computer science. This web environment provides learners with free coding tutorials and hands-on exercises. The teacher in this study provided several types of individualized instructional supports to each participant with disabilities (e.g., access to materials, verbal directions, problem-solving techniques, and task-specific guidance) and incorporated computational thinking pedagogy.
- Games (24, 25): Ringland and colleagues used the sandbox 3D video game Minecraft to implement social-skills' training for learners with autism spectrum disorder. Since the studies focused on learners' social-interaction practices and collaborations during the interventions, the role of the instructor was limited to providing minimal guidance and virtual community rules (e.g., avoiding abusive behavior, building a social relationship).

Learner–Interface Interaction

Most of the selected studies demonstrate learner–interface interactions, which are related to learners' hands-on practices and self-regulated learning through OER (1-3, 5-9, 11-13, 16-23, 26, 27, 29, 30). We categorized these studies based on their specific emphasis on learner–interface interactions across various OER platforms: 1. pedagogical approach (e.g., open educational practices); 2. design and development of accessible OER; and 3. quality assurance of OER.

- Pedagogical approach (1, 2, 5, 9, 11, 12, 22, 23, 27, 29): A group of studies emphasized the pedagogical approach of OER for learners with disabilities. These studies primarily observed learners' learning processes and evaluated the user interface designs of OER.
 - Observations (1, 5, 9, 12, 22, 23, 29): Research using open-license programming toolkits (e.g., Scratch, Logo, Blockly) and makerspaces tended to observe learners' behavior patterns (Buehler et al., 2016; Hansen et al., 2016; Koushik & Kane, 2019; Lin & Chang, 2015; Paramasivam et al., 2017; Ratcliff & Anderson, 2011; Taylor, 2018).
 - User-testing in OER (11, 27): Two studies focused on user-testing of OER Websites that serve as Web-based information repositories for instructional practices. They primarily addressed possible navigation issues and requirements of adaptive interface design that could enhance ease of use in OER (Sevilla et al., 2007).
 - Accessibility training: One study (2) implemented a training program to teach engineering educators how to apply the Web content accessibility guidelines (WCAG 2.0; W3C, 2020) when designing accessible online courses (Bustamante et al., 2018).
- Design and development of accessible OER (6, 7, 8, 13, 19–21, 26, 30): Nine studies on learner–interface interactions emphasized the design and development of accessible OER for learners with

disabilities. For example, five studies suggest design strategies or standards to enhance the OER Website interface to support learners' needs and preferences based on their ability levels (Navarrete & Luján-Mora, 2016, 2018; Nganji & Brayshaw, 2014; Rodrigo, 2014). In addition, a group of studies explored learners' interactions with programming toolkits. They observed the types of interactions that appeared when learners manipulated the toolkits (Israel et al., 2015; Kane et al., 2018; Ludi & Spencer, 2017; Worsley et al., 2018). Only one study discussed general strategies to improve MOOC accessibility (Iniesto et al., 2014).

- Quality assurance of OER (3, 16–18): Four studies focused on the quality assurance of OER in terms of learner–interface interactions. These studies assessed the quality of the accessibility of OER Websites (e.g., OER Commons, MERLOT, and MOOC), using either WCAG 2.0 (W3C, 2020) or automated accessibility test tools (Calle-Jimenez et al., 2014; Moolo et al., 2018; Navarrete & Lujan-Mora, 2015a, 2015b).

Learner–Content Interaction

Five studies demonstrate learner–content interactions, mainly when learners experienced problem-solving across different subject matter, and identify strategies to promote such interactions (2, 8, 9, 16, 26):

- Using code templates for programming exercises (8, 9): Two studies identified youth learners' behavior patterns while using interactive whiteboards and videos, reviewing content, and activating prerequisite knowledge through templates to complete exercises in computer programming toolkits. Kane et al. (2018) observed learners while they used an online repository that allowed them to explore template codes shared by open-source projects and then create new ideas based on a code structure.
- Using guideline design and implementation (2, 16, 26): Three studies demonstrate strategies to promote learner–content interactions in OER. Rodrigo (2014) proposes the access-for-all meta-data guideline for accessibility in OER. This guideline considers the available use of learning objects, learner preferences, and environmental resources. Mooloo et al. (2018) identified several components of facilitating learner–content interactions in MOOCs, including ease of understanding, interactivity, personalization, and audio pedagogy in audio learning MOOCs. Bustamante et al. (2018) implemented teacher training, aligned with accessibility guidelines, on organizing course materials, so that learners can select materials based on their needs.

Research Question 2: What Are the Major Challenges of Supporting Interactions in OER for Learners With Disabilities?

Learner–Learner Interactions

Learner–learner interactions present a number of challenges in the selected literature. First, Ringland et al. (2016) confirm that the transferability of social skills acquired in games for social-skills' training may be limited. Relying on a single channel of communication could negatively affect the transfer of social skills; hence, they recommend that interventions incorporate varied and interchangeable means and modes of training. This finding raises concerns about dependence on a single game mode without variations, which

may hinder the transfer of learners' social skills. Second, the challenge of assistive technologies also impacts learner–learner interactions through OER. Research has found that learners experienced technical issues when communicating with peers and that inadequate communication tools interrupted seamless discussions during learner collaborations (Kane et al., 2018; Koushik & Kane, 2019). In addition to technical problems, instructors' limited familiarity with assistive technologies is a critical issue, because learners may struggle to maintain conversations when facilitators fail to provide them timely help to cope with technical issues.

Learner–Instructor Interactions

Some of the studies found that teachers were not familiar with contextual- and subject-oriented teaching supports (e.g., computational thinking) and consequently struggled to guide learners' hands-on exercises (Israel et al., 2015; Ludi & Spencer, 2017). Since OER and OER-enabled pedagogy assume that learners engage in open-ended explorations, content-related and timely guidance to facilitate learners' mindful exercises is essential. Teachers' limited familiarity with teaching supports could delay feedback, resulting in learners' disorientation. For the most part, these instructional challenges appeared in classroom settings. In addition, some of the studies show that learners' developmental disabilities may affect the learning process; specifically, the following challenges commonly appear among novice learners when presented with highly complex tasks, cognitive distraction, difficulties understanding task circumstances, and difficulties in manipulating figures (Guimaraes & Mattos, 2015; Israel et al., 2015; Lin & Chang, 2015; Ratcliff & Anderson, 2011; Taylor, 2018).

Learner–Interface Interactions

Some challenges emerged in learner–interface interactions through OER in the selected literature. First, research shows that the complicated interfaces of OER failed to consider learners' physical difficulties and the unique circumstances they create (Navarrete & Luján-Mora, 2016). Most studies report that both complicated interfaces and learners' motor-skill limitations negatively impacted their ability to navigate OER and identify personalized supports. Some studies argue that existing Web-based OER appear complex and inconsistent (Navarrete & Luján-Mora, 2016; Rodrigo, 2014). Specifically, learners with disabilities faced challenges when manipulating OER interfaces in inapplicable formats, such as font sizes or media types, which require adaptive changes (Kane et al., 2018; Navarrete & Luján-Mora, 2018). Learners were unable to adapt the information format to their various needs when navigating interfaces, which likely hindered information retrieval (Buehler et al., 2016; Hansen et al., 2016; Sevilla et al., 2007). Second, the selected studies demonstrate the need for adaptive designs that foster learners' access to OER. Adaptivity indicates interface changes in computing systems that can be automatically tailored to learners' needs (Sanchez-Gordon & Luján-Mora, 2020). Three studies specifically identify weaknesses in OER design, which demonstrate the need for adaptive designs to support learner–interface interactions: lack of personalized learning (Moloo et al., 2018), inadaptible interfaces (Navarrete & Luján-Mora, 2015a), and limited representation of accessible interfaces (Calle-Jimenez et al., 2014).

Learner–Content Interactions

Research demonstrates that OER implemented by educators did not particularly contribute to improving the memory and problem-solving skills of learners with disabilities due to inappropriate formats or presentation methods (Israel et al., 2015). Learner–content interaction assumes learners' internal and

mental processes when interacting with OER, which excludes many variables among individual learners. To address this issue, Israel et al (2015) recommend incorporating diverse sequencing of visual representations and activities in interventions. Another challenge in supporting learner–content interactions is a lack of multimedia stimuli adapted to learners with various disabilities. Bustamante et al. (2018), Moloo et al. (2018), and Rodrigo (2014) suggest that a one-size-fits-all approach fails to consider the most appropriate and accessible stimuli for learners with different disabilities in OER and OER-enabled pedagogical environments.

Discussions and Conclusion

This study identified the ways in which OER have supported different types of learner interactions (i.e., learner–learner, learner–instructor, learner–interface, and learner–content interactions) and the challenges that emerge when learners with disabilities use existing OER. Based on our study findings, we suggest both research and practical implications in terms of future OER research and design practices.

Research Implications

The study findings expand upon the research trend of accessibility and universal design for learning in OER. The findings demonstrate that existing research has adopted the concept of accessibility or UDL across various OER platforms in different ways. While research on Web-based information repositories or MOOCs primarily considers accessibility design for learners with disabilities (Iniesto et al., 2014; Laiola Guimarães et al., 2015), research on computing education (e.g., programming toolkits) mainly addresses the integration of UDL instructional practice principles with OER (Israel et al., 2015). A major reason for the different foci is the variety of OER platform characteristics. Both Web-based information repositories and MOOC environments consider better navigation paths and alternative interaction features for learners' information retrieval. However, a group of studies on UDL principles focus on exploring how to foster learners' participation through various representations (Hansen et al., 2016; Snodgrass et al., 2016). OER studies embracing UDL tend to highlight the design of instructional practices because they aim to promote learners' problem-solving skills via hands-on and self-regulated interactions with programming toolkits. This finding implies that OER implemented according to UDL principles consider learner engagement, whereas OER with accessibility address the usability of interaction options.

Furthermore, our synthesis results reveal the need for future research on OER-enabled pedagogy. OER-enabled pedagogy assumes that learners evaluate, modify, and create artifacts to deepen their learning experiences (Wiley & Hilton III, 2018). However, the sampled literature rarely discussed instructional practices related to OER-enabled pedagogy and, instead, focused on learners' re-creations and distributions through OER. Existing OER research emphasizes designing better accessibility for online information retrieval more than pedagogy. This finding suggests a discrepancy between increasing interest in OER-enabled pedagogy and current OER designs for learners with disabilities. Moreover, while existing OER research tends to focus on the evaluation of OER accessibility and usability, supporting the engagement of learners with disabilities in OER and OER-enabled pedagogy has received little attention.

A few of the studies in this review examined learners' manipulations in programming toolkits (Snodgrass et al., 2016; Koushik & Kane, 2019); however, most of the studies could not bridge the concept of constructionism through OER and open educational practices. Thus, further studies are essential to implement OER-enabled pedagogy for learners with disabilities. In particular, as OER-enabled pedagogy requires learners to attain high-order thinking and creative skills, additional supports, including scaffolding, should be considered. Future studies could design instructional supports for OER-enabled pedagogy that address the needs of learners with disabilities.

Design Implications

This literature synthesis demonstrates a number of design implications. First, our study reveals the importance of designing legitimized and collaborative activities for OER. We found that learners with disabilities tended to experience technical problems in managing their assistive technologies and significant difficulties when attempting highly complex learning tasks (e.g., programming). Such situations require more learning supports to provide scaffolding for learners with disabilities. A few studies in our review highlight examples of designing legitimized and collaborative activities that help learners with disabilities by facilitating learner–learner and learner–instructor interactions (Kane et al., 2018; Koushik & Kane, 2019). Informal small group activities in schools managed by teachers and peer tutors can effectively manage collaborative activities using OER.

Second, we conclude that it is necessary to train teachers in technology-integration skills to support learners with disabilities when using OER. Our study suggests that learner–instructor interactions were hindered due to instructors' unfamiliarity with the technology used. Teachers' difficulties in supporting learners with assistive technologies interrupted communications during exercises. Therefore, it is essential to consider teacher training that provides a skill set to handle assistive technologies for OER effectively.

Third, we found that OER research tends to consider personalized supports that enhance learners' ease with web navigation paths and consider individual special needs. However, such research rarely demonstrates whether and how OER-driven interventions that support learner interactions enhance learner outcomes. In other words, scholarly work on how OER help learners with disabilities experience deep learning by supporting different types of interactions are needed. In response to this need, further research should integrate various instructional design practices (e.g., knowledge type, sequencing, and content scoping) into learning supports for learners with disabilities across various OER cases.

Study Limitations

This study has a number of limitations. First, the literature synthesis did not include many experimental studies that investigate the effect of OER-driven interventions on key learning outcomes (e.g., learning achievement, problem-solving skills, and motivation). Thus, this scoping review could not extend the discussion on how different types of learner interactions across OER platforms boost learning outcomes. Future research is necessary to identify how specific interactions in OER can improve the achievement of learners with disabilities. Second, of the 30 articles included in our literature synthesis, 12 were from conference papers, and 13 researchers co-authored 11 of the selected articles. This indicates that OER research on learners with disabilities is still limited and less generalizable; as such, further research is necessary in this area. Third, due to the lack of relevant studies that corresponded to our scope, we could

not explore and compare target learners' characteristics in each study. This limitation indicates that future qualitative studies should be considered to deeply explore how OER and their practices provide scaffolding for learners with specific types of disabilities.

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Appendix A

Coding Results

Number	Article	Research type	OER platform types	Interaction types	Description
1	Buehler et al. (2016)	Empirical	Makerspace	LI, LF	Study of the challenges of implementing makerspace activities for learners with disabilities. Qualitative notes included.
2	Bustamante et al. (2018)	Empirical	MOOC	LF	Implementation of teacher training on how to design accessible virtual courses in MOOC.
3	Calle-Jimenez et al. (2014)	Design and development	MOOC	LF, LC	Development and evaluation of a GeoMOOC with focus on accessibility.
4	Drake et al. (2015)	Empirical	MOOC	LL	Literature review on MOOC design decisions.
5	Hansen et al. (2016)	Empirical	Programming toolkit	LF	Experimental study to examine the results of differentiated instruction and UDL.
6	Iniesto et al. (2014)	Design and development	MOOC	LF	Discussion of strategies for improving accessibility in MOOCs.
7	Israel et al. (2015)	Empirical	Programming toolkit	LL, LI, LF, LC	Examination of the implementation of a UDL framework for learners with disabilities in computing education.
8	Kane et al. (2018)	Empirical	Programming toolkit	LL, LF	Development of an audio-programming game for blind and visually impaired learners.
9	Koushik and Kane (2019)	Empirical	Programming toolkit	LL, LF, LC	Qualitative study to explore the learning of learners with cognitive disabilities in computing education.
10	Laiola Guimarães and Britto Mattos (2015)	Empirical	MOOC	LL	Examination of how learners with intellectual disabilities learn through MOOCs.
11	Lee and Lee (2019)	Empirical	MOOC	LF	Development of a checklist for assessing the usability of educational applications for blind users.

12	Lin and Chang (2015)	Empirical	Programming toolkit	LF	Use of technology from a real-time feedback concept through external Webcam and Scratch 2.0 and investigation of results for learners with developmental disabilities.
13	Ludi and Spencer (2017)	Empirical	Programming toolkit	LI	Development of accessible block-based programming for blind learners and suggestions for consideration.
14	Meyer and Fourie (2016)	Conceptual	Makerspace	LF	Practical guidelines to establish a blend-able makerspace environment using UDL and ergonomics for learners with physical disabilities.
15	Moeller et al. (2015)	Conceptual	Makerspace	LF	Qualitative study to explore design features that makerspace facilities should address for learners with disabilities.
16	Moloo et al. (2018)	Empirical	MOOC	LL, LF, LC	Development and assessment of a new audio learning system in MOOCs.
17	Navarrete and Luján-Mora (2015a)	Design and development	Information repository	LF	Evaluation of the findability of resources in some important OER Websites.
18	Navarrete and Luján-Mora (2015b)	Design and development	Information repository	LF	Guidelines for the creation and release of accessible educational resources and applications.
19	Navarrete and Luján-Mora (2018)	Design and development	Information repository	LF	Development and implementation of an OER Website named OERfall.
20	Navarrete and Luján-Mora (2016)	Design and development	Information repository	LF	Presentation of an OER Website designed for enhancing the user experience (UX) of learners with disabilities.

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21	Nganji and Brayshaw (2014)	Design and development	MOOC	LF	Development of the ontology-driven disability-aware personalized e-learning system (ONTODAPS), which personalizes e-learning resources for disabled learners.
22	Paramasivam et al. (2017)	Empirical	Programming toolkit	LF	Demonstration of the effect of an end-user-programming tool.
23	Ratcliff and Anderson (2011)	Empirical	Programming toolkit	LF	Qualitative study on the implementation of a programming tool.
24	Ringland et al. (2016)	Empirical	Game	LL, LI, LF	Examination of how learners with autism spectrum disorder search for Minecraft community and practice sociality.
25	Ringland et al. (2017)	Empirical	Game	LL, LI, LF	Exploration of how designers and researchers learn by observing the youngest users' augmentation and mainstream of assistive technology.
26	Rodrigo (2014)	Conceptual	MOOC	LL, LF, LC	Discussion of specific strategies for accessible MOOCs for all learners.
27	Sevilla et al. (2007)	Empirical	Information repository	LF	Comparison between adapted and conventional MOOC Websites for learners with cognitive deficits.
28	Snodgrass et al. (2016)	Empirical	Programming toolkit	LL, LI, LF	Exploration of the development of critical thinking skills for learners with disabilities and instructional support by teachers.
29	Taylor (2018)	Empirical	Programming toolkit	LF	A case study to examine the potential for pre-kindergarten through 1st grade learners with intellectual disabilities learning programming skills.
30	Worsley et al. (2018)	Conceptual	Assistive technology	LF	Presentation of an exemplar of multimodal interfaces as tools for inclusive learning.

Note. LL = learner-learner interactions, LI = learner-instructor interactions, LF = learner-interface interactions, and LC = learner-content interactions.

