Humanities & Social Sciences Communications

REVIEW ARTICLE

https://doi.org/10.1057/s41599-025-04644-y OPEN

Uncovering the black box effect of Open Educational Resources (OER) and practices (OEP): a meta-analysis and meta-synthesis from the perspective of activity theory

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Conflicting results exist in the literature on whether Open Educational Resources (OER) and Open Educational Practices (OEP) can improve learning performance. Additionally, limited studies, in this context, have attempted to systematically measure and understand this phenomenon. To address this research gap, this study conducts a two-level analysis based on a systematic review of the OER and OEP literature. It first conducts a meta-analysis to measure the effect of OER and OEP on learning performance. It then conducts a meta-synthesis based on the activity theory to understand what led to this effect (measured in the first phase). Specifically, 32 studies ($N = 134905$ participants) were quantitatively and qualitatively analyzed. The obtained results revealed that OER and OEP have significant negligible effect ($g = 0.10$; $p < 0.05$), which indicates that learners are mostly consumers of knowledge in a very traditional way. Additionally, it is found that the learning process was mainly in formal settings in classrooms using traditional technologies like websites and learning management systems. The findings of this study can help to enhance the effective adoption of OER and OEP by highlighting the confounding variables that should be considered when developing their open education initiatives.

Introduction

The term Open Educational Resources (OER) was first coined at UNESCO's (2002) Forum on Open Courseware. Since then, several discussions were initiated about its definition and adoption. It was then defined in the recent UNESCO Recommendation on OER as "learning, teaching, and research materials in any format and medium that reside in the public

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domain or are under copyright that have been released under an open license that permit no-cost access, reuse, repurpose, adaptation, and redistribution by others" (UNESCO, 2019). Alongside OER, several organizations, such as the Open e-Learning Content Observatory Services (OLCOS), have further highlighted the need for innovative teaching practices that work with OER instead of the traditional instructions to enhance learning performance (OLCOS, 2007). This notion catalyzed the debate that open education should shift from mainly content-based (i.e., OER) to also cover practice-based initiatives, which is also known as Open Educational Practices (OEP). OEP is, therefore, defined as the "practices which support the (re)use and production of Open Educational Resources through institutional policies, promote innovative pedagogical models, and respect and empower learners as co-producers on their lifelong learning paths" (Ehlers, 2011, p. 4). In this context, several studies highlighted that OER improve the associated educational practices and allow innovative instructions (Degen et al., 2024; LeMire, 2024; Milošević et al., 2024) pointed to OER as a medium for developing teaching materials and creative educational methodologies. Cronin and MacLaren (2018) mentioned that the wide variation of OEP concept, which is ranging from those centered primarily on the creation and use of open educational resources (OER) to broader definitions of OEP, inclusive of but not necessarily focused on OER. Recently Arispe and Hoye (2023) summarized the definition of OEP in using OER to support learning and teaching practices with a goal of improving education and training at the institutional, professional, and individual levels.

Despite the fact that OER and OEP have proven to be efficient in reducing educational cost and providing inclusive educational approaches (Allman et al., 2024), conflicting results are found about whether they are effective in enhancing students' learning performance in a given subject (Fortney, 2021; Grissett and Huffman, 2019). For instance, while some studies reported positive effects of using OER and OEP (e.g., Colvard et al., 2018), no effects (e.g., Fortney, 2021; Grissett and Huffman, 2019) or even negative effects (e.g., Gurung, 2017) were found. This implies that some students who used OER and OER had lower learning performance and score compared to those who used traditionally copyrighted materials.

The question of whether OER and OEP can enhance learning performance has persisted for a long while. This ongoing inquiry has prompted numerous studies aimed at comprehensively analyzing the related literature to provide a definitive answer. Despite the wealth of research, the question still remains a topic of active investigation, reflecting the complexity and multidimensional nature of OER and OEP.

Previous reviews on OER and OEP effect on learning performance. While several studies have conducted reviews on OER and OEP from various perspectives (e.g., Hylén, 2020; Otto et al., 2021; Tlili et al., 2023), only a limited number of them tackled the effect of OER and OEP on learning performance. For example, Hilton (2016) systematically reviewed studies published between 2002 and August of 2015 that focused on OER issues and learning achievement. He identified that only nine of sixteen studies focused on learning performance, where the results were mixed (i.e., the students sometimes had better learning performance with OER and other times, they did not). In 2020, Hilton (2020) found only nine additional studies discussing OER and learning performance.

On the other hand, two studies have quantitatively reviewed the effect of OER on learning performance. Clinton and Khan (2019) conducted a meta-analysis of 22 studies, focusing on the effect of open textbooks on post-secondary students' learning performance in the USA and Canada. The study revealed that there is no difference in learning performance between open and commercial textbooks ($g = 0.01$, $p = 0.87$). Tlili et al. (2023) took a more comprehensive approach and conducted a meta-analysis to investigate the effect of OER and OEP on learning performance without being limited to a specific OER type or geographic location. Specifically, 25 studies were meta-analyzed and the results revealed that OER and OEP have a significant yet negligible effect ($g = 0.07$, $p < 0.001$). Similarly, Cho and Permzadian (2024) conducted a meta-analysis of 26 studies to investigate the effect of OER on academic performance and course completion rate. They found that OER has a small significant effect ($d = 0.17$; $p = 0.003$) on learning performance.

Research gap and study objectives. While some research studies have systematically investigated the effect of OER and OEP on learning performance, most of these studies are qualitative and did not measure and reveal the true impact of OER and OEP (Hilton, 2016; 2020). Other studies (e.g., Cho and Permzadian, 2024; Tlili et al., 2023), on the other hand, have mainly conducted meta-analyses to measure the effect of OER and OEP, and did not go beyond numbers (i.e., the quantitative analysis) to understand what caused the explored outcomes reported in the related literature. For instance, Tlili et al. (2023) have reported after a meta-analysis of OER and OEP that there is a variation in learning performance after using OER and OEP in the different analyzed studies, and also across educational levels or subjects. But, how each study has implemented OER and OEP and what might have caused this variation was not analyzed. In fact, OER and OEP have been treated a black box, where limited information exists in the literature on how they were adopted (i.e., design, teaching and learning practices, interaction, etc.) and how this adoption might affect learning performance. This might hinder successfully using OER and OEP. To expose and explore this black box effect, the present study conducts a two-stage analysis, where a meta-analysis was first conducted to measure the effect of OER and OEP on learning performance. Then, to understand what led to this effect, the study takes a forward step by analyzing each of the studies according to the Activity Theory framework (Engeström, 2001). O'Cathain et al. (2007) highlighted the importance of conducting mixed methods to overcome the pitfall of quantitative methods. The Activity Theory covers seven dimensions, namely *subject*, *object*, *tool*, *rules*, *community*, *division of labor*, and *outcomes* (Engeström, 2001). Several recent studies in the literature have focused on exploring the black box effect of various technologies, including gamification (Denden et al., 2023) or artificial intelligence (AI) (Carabantes, 2020; Wang et al., 2023), but no study, to the best of our knowledge, has attempted to do so in OER and OEP. Based on this background, this present study addresses the following research questions:

RQ1. What is the effect of OER and OEP on students' learning performance, and what might moderate this effect?

RQ2. What relevant features concerning the design, implementation, and performance of OER and OEP can be identified through the lens of activity theory?

To address the first research question (RQ 1), a meta-analysis was conducted to draw quantitative evidence on the effect size of OER and OEP on students' learning performance. To address the second research question (RQ 2), a qualitative analysis was conducted, where the OER and OEP studies were analyzed through the seven dimensions of the activity theory to reveal insights on how they were implemented and what led to the effect size identified in RQ 1.

Method

Study design. This study follows a mixed methods approach and adapts an explanatory mixed methods design (Creswell, 2004),

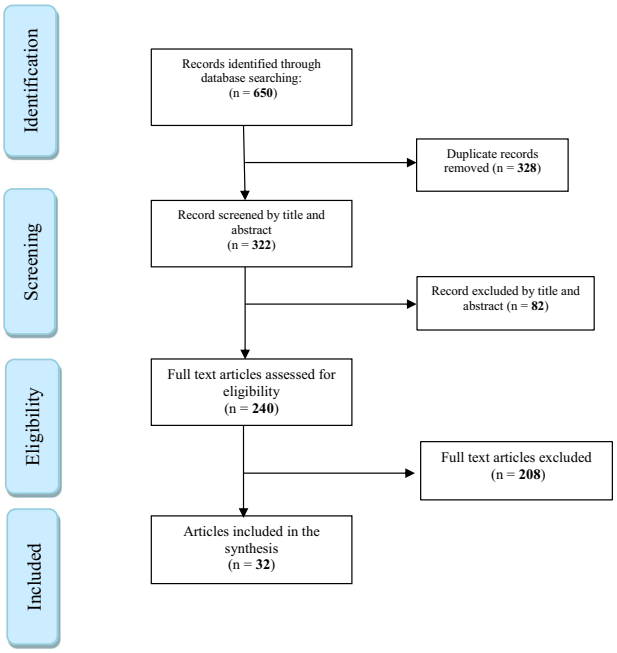

Fig. 1 PRISMA flowchart of study selection process.

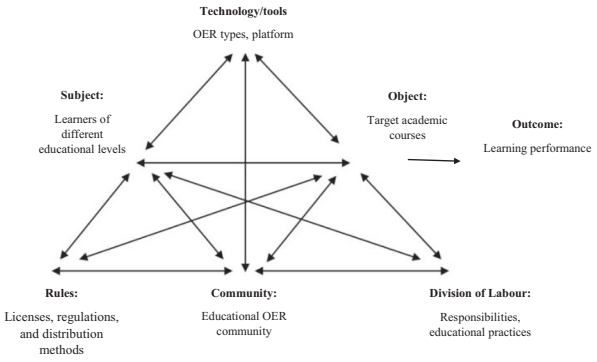

Fig. 2 Using activity theory to analyze OER and OEP in learning.

where qualitative phase is informed by quantitative phase. Compared to other approaches (like solely relying on qualitative or quantitative analysis, as most of the OER and OEP literature is doing), relying on this approach can: (1) provide an in-depth and broader understanding of a phenomenon (e.g., Hurmerinta-Peltomaki and Nummela, 2006); (2) put more confidence and reliability into the obtained results and interpretations (e.g., Coyle and Williams, 2000; Sieber, 1973); (3) cultivate ideas for future research (e.g., O'Cathain et al., 2010); and, (4) be more valuable and attract readers (e.g., Molina-Azorin, 2011). To do so, this study first conducts a meta-analysis of the OER and OEP literature to quantitatively measure the effect of OER and OEP on learning performance (see Section 2.3.). It then qualitatively analyzes the literature based on the activity theory to understand what led to these numbers (i.e., effects) (see Section 2.4). To identify the relevant OER and OEP literature for this present study to be analyzed, the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (Page et al., 2021).

Data selection. "Open educational resources" and "open educational practices" were used as search keywords. The search process included the following databases: Web of Science, Scopus, Taylor and Francis, and ERIC. The publication time frame was set from 2012 because this year marked the release of the "UNESCO Paris OER Declaration", which encouraged governments to enhance the use of OER. The search was conducted on December 20, 2023, at which date, researchers were able to identify 650 studies (Web of Science: 119, Scopus: 41, Taylor and Francis: 263, and ERIC: 227). After removing duplicates, the remaining 104 studies were filtered based on the following inclusion criteria: (1) empirical studies, (2) studies that specifically used OER or OEP, (3) studies that provided sufficient information (i.e., mean, median, standard deviation) to calculate the effect size. Therefore, a study was excluded if (1) it was not empirical research, (2) it did not focus on using OER or OEP, (3) it was qualitative or review research, (4) it did not provide sufficient information to calculate the effect size, or (5) it was not written in English. This process limited the corpus for investigation to 32 studies (1 PhD dissertation, 30 journal papers, and conference paper). At the end of this process, the reference section of each paper was then reviewed. However, this process did not provide additional studies. The inter-rater reliability in each phase was above 0.7, which is considered very good (Cohen, 1960). Figure 1 presents the data selection process. Appendix A presents the included 32 studies in the present meta-analysis and meta-synthesis.

Meta-analysis (quantitative analysis). Comprehensive Meta-Analysis V.4 (Borenstein, 2022) software was used to conduct the current meta-analysis. In addition, Hedges' g was used to calculate the effect sizes (Hedges, 1981).

Three methods were used to assess publication bias. Firstly, the trim-and-fill method with the intention of identifying publication bias by means of a funnel plot wherein the studies are represented by dots. If the dots are distributed on both sides of a vertical line representing the average effect size, it is assumed that there is no publication bias (Borenstein et al., 2010). Secondly, Rosenthal's (1979) fail-safe number aims to determine the number of studies with nonsignificant results of unpublished data needed to nullify the mean effect size. A fail-safe number larger than $5k + 10$ (where k is the original number of studies included in the meta-analysis) is robust. This means that the effect size of unpublished studies is not likely to affect the average effect size of the meta-analysis. However, this method assumes that the mean effect size in the missing studies is zero (Borenstein, 2022). The third method was Egger's regression test where a significant intercept suggests publication bias (Lin et al., 2018).

Meta-synthesis (qualitative analysis). The current research adopted the Activity Theory to conduct content analysis on the interplay of various components and actors in OER and OEP in education research (Tlilli et al., 2022). Kim (2010) defined the activity as a system of purposeful behaviors leading to recognizable changes in human practices. Therefore, the researchers investigated how OER and OEP could lead to evolving behaviors and practices (learning performance) among the participants. Figure 2 presents how OER and OEP were used for learning and how they mediated to learning performance.

Several studies have used the Activity Theory as a framework to analyze the integration and use of OER (Cox, 2013; Godwin et al., 2008; Panke and Seufert, 2013). Based on these studies and following the specifications and definitions of Engeström (Engeström, 1999; Engeström, 2015), the seven Activity Theory elements were defined and coded below. During the coding process, weekly meetings were organized, where consensus was reached through discussions for any coding differences

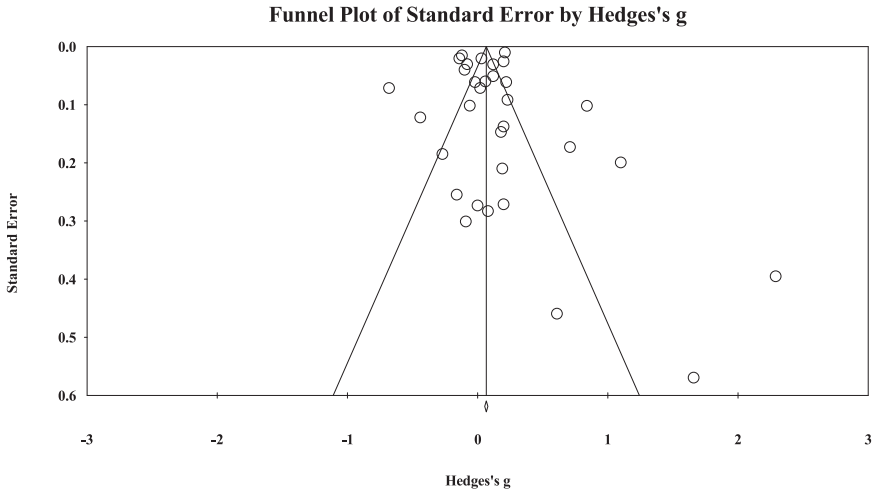

Fig. 3 Funnel plot of standard error by Hedges' *g*.

Table 1 Effect of OER on students' learning performance.

Analysis	*N*	*g*	95% CI	*Z*	*p*	I^2	τ^2	Effect size interpretation
Overall	32	0.10	[0.02, 0.18]	2.44	0.015*	96.17	0.04	Negligible
Document	1	−0.02	[−0.14, 0.10]	−0.33	0.744	0	0	Negligible
Interactive (text) book	25	0.05	[−0.04, 0.14]	1.12	0.262	96.59	0.04	Negligible
Interactive materials	5	0.66	[0.06, 1.26]	2.14	0.032*	96.05	0.39	Moderate
Video	1	0.20	[−0.33, 0.73]	0.74	0.461	0	0	Small

N number of studies, *g* Hedges' *g effect size*, *CI* confidence interval, *Z Z* value for Hedges' g, *p* = *p values of* Hedges' g, I^2 and τ^2 are measures of effect size variability.
*$p < .05$.

- *Tools/Instruments*: Refer to specific technologies, resources, and platforms used.
- *Subject*: Refers to the characteristics of the target group which the OER are aimed at and who are actively engaged with the material.
- *Object*: Refers to the characteristics and aims of the OER developed and/or used for a specific taught subject.
- *Rules*: Refer to the specifications about licenses, regulations, and distribution methods as well as to the characteristics of openness based on "retain, reuse, revise, remix, and redistribute".
- *Community*: Refers to the educational community and its subset communities which the specific OER are targeting at.
- *Division of Labour*: Refers to the characteristics of the roles of all individuals associated with the specific OER and their potential contribution as well as the design of the learning process following open educational practices and the individuals' role within it.
- *Outcomes*: Refers to the learning performance achieved when using OER and OEP.

Results

The results are presented according to each of the aforementioned research questions.

Effect of OER and OEP on students' learning performance, and what might moderate this effect. Prior to investigating the effect of OER and OEP on learning performance, the publication bias was first assessed using the trim-and-fill method. It allows estimating the number of unpublished studies and it assumes publication bias as the only reason for funnel plot asymmetry which is an unrealistic assumption (Mavridis and Salanti, 2014). The idea of the trim-and-fill method is to first trim the studies that cause a funnel plot's asymmetry so that the overall effect estimate produced by the remaining studies can be considered minimally impacted by publication bias, and then to fill imputed missing studies in the funnel plot based on the bias-corrected overall estimate. Borenstein et al. (2010) stated that a symmetric funnel plot—when the dots (studies) are distributed on both sides of the vertical line (combined effect size)—implies that there is no publication bias. However, if most of the dots are situated at the bottom of the funnel or on one side of the vertical line, there is publication bias. Figure 3 shows that the dots in this study are distributed symmetrically around the vertical line. Additionally, although some dots are outside the triangle of the funnel plot, most of them are in the upper part of Fig. 3 and not at the bottom. Therefore, it can be argued that the reliability of the present meta-analysis is not affected by publication bias. Additionally, publication bias of the funnel plot asymmetry was examined by a regression test ($Z = 7.03$, $\alpha < 0.05$), which reveals the absence of publication bias (see Fig. 3). Additionally, Rosenthal's fail-safe number method was used. It calculates the significance of multiple studies by calculating the significance of the mean Z-score (Rosenberg, 2005). The fail-safe number represents the number of studies required to refute significant meta-analytic means (Fragkos et al., 2014). Rosenthal's fail-safe N was 380, which is larger than ($5*32 + 10 = 170$), and this supports the symmetry of the funnel plot (Rosenthal, 1979).

The meta-analysis was then conducted and yielded an overall effect size of $g = 0.10$, $p < 0.05$, indicating that OER and OEP had a negligible effect on students' learning achievement (see Table 1). Specifically, Document ($g = -0.20$; *95% CI* = −0.14 to 0.10; $n = 1$), Interactive (text) book ($g = 0.05$; *95% CI* = −0.04 to 0.14; $n = 25$) and Interactive materials ($g = -0.66$; *95% CI* = −0.06 to

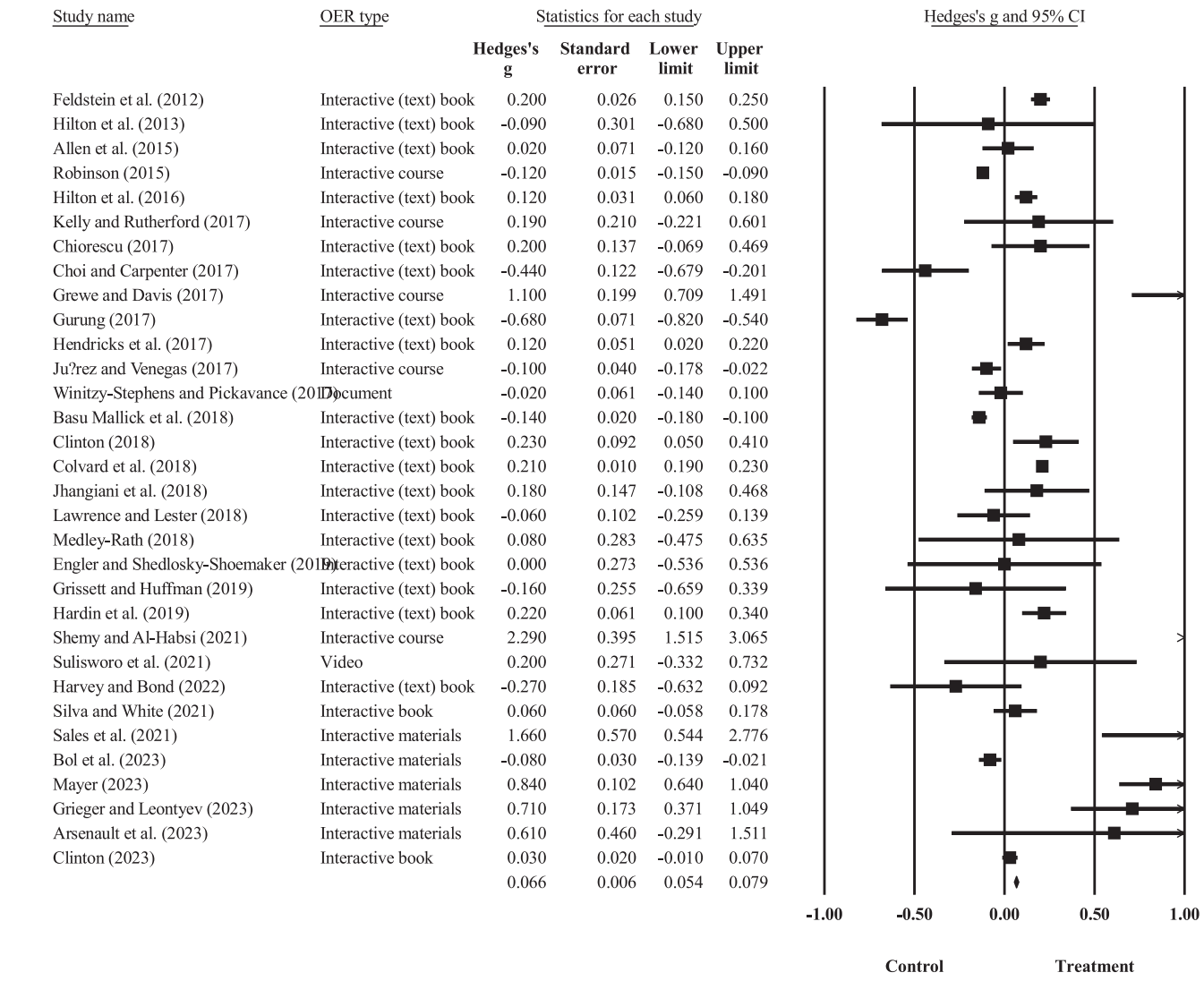

Fig. 4 A forest plot of the Hedge's g estimates and the confidence intervals of the included studies.

1.26; $n = 5$) had a moderate effect on students' learning achievement. Video ($g = 0.20$; *95% CI* = − 0.0.33 to 0.73; $n = 1$) had a small effect on students' learning achievement. The I^2 statistic showed that 96.17% of variance resulted from between-study factors, implying that other variables might moderate the effect size of OER (as pointed out in the background of this study). The forest plot presents the variation of effect size across the 32 included studies (see Fig. 4). The overall mean effect size ($g = 0.10$) is presented at the last row of the forest plot. Interestingly, it is seen that almost half of the studies had a negative effect size, implying that the use of traditionally copyrighted materials had a better impact on learning achievement compared to the use of OER and OEP. This further explains the obtained negligible effect of OER and OEP on students' learning performance (see Table 1).

The effect of various potential moderating variables (identified from the activity theory analysis, see Section 3.2) were then analyzed (see Table 2). In terms of the taught subject, science and business had a small effect size ($g = 0.23$, $g = 0.20$). On the other hand, in terms of educational level, professional development was the only educational level with a significant positive effect ($g = 2.29$, huge effect).

In terms of the experiment design, the meta-analysis further indicated that the intervention durations of trimester and one year had a significant positive effect. The trimester duration had a negligible effect size ($g = 0.09$) while the year duration had a small effect size ($g = 0.20$). The effect of sample size on students' learning achievement, on the other hand, was significant and positive when it is small ($g = 0.26$). Finally, the research design did not have any significant effect on learning performance.

Finally, to further investigate possible covariance between the moderators, a meta-regression that includes all of them was conducted. Table 3 reveals that educational level ($p = 0.001$) moderate the relation between OER and students' achievement.

Relevant features concerning the design, implementation, and outcome of OER and OEP that can be identified through the lens of activity theory. The 32 included studies are analyzed and the results are presented according to the seven dimensions of the activity theory.

Subject. OER have the potential to be applied in and enrich all educational levels. Nonetheless, as it is presented in Fig. 5, the overwhelming majority of studies explored the use of OER at Bachelor level (freq: 25, perc.: 78.1%) (Allen et al., 2015; Arsenault et al., 2023; Basu Mallick et al., 2018; Bol et al., 2022; Chiorescu, 2017; Choi and Carpenter, 2017; Clinton, 2018; Clinton-Lisell, 2023; Colvard et al., 2018; Engler and Shedlosky-Shoemaker,

Table 2 Effect of subject, educational level, intervention duration, sample size, geographical distribution and research design on students' learning performance.

Moderator	Analysis	N	g	95% CI	Z	p	I^2	τ^2	Effect size interpretation
Subject	Mathematics	5	−0.02	[−0.19, 0.14]	−0.28	0.78	43.66	0.02	Negligible
	Science	5	0.23	[0.02, 0.45]	2.15	0.03*	73.00	0.03	Small
	Psychology	7	−0.02	[−0.33, 0.29]	−0.13	0.90	94.65	0.15	Negligible
	Computer science	1	−0.44	[−0.68, −0.20]	−3.61	0.001***	0	0	Negligible
	Business	1	0.20	[0.15, 0.25]	7.84	0.001***	0	0	Small
	History and politics	2	0.51	[−0.63, 1.64]	0.88	0.38	96.28	0.65	Moderate
	Literature and sociology	2	0.80	[−0.75, 2.33]	1.01	0.31	83.80	1.05	Large
	Varied	9	0.14	[0.01, 0.27]	2.04	0.041*	98.60	0.04	Negligible
Educational level	Secondary	4	0.25	[−0.27, 0.76]	0.95	0.35	74.42	0.19	Small
	Post-secondary	2	0.01	[−0.29, 0.28]	−0.04	0.97	75.75	0.03	Negligible
	Bachelor	25	0.09	[−0.01, 0.17]	1.92	0.06	95.92	0.04	Negligible
	PD	1	2.29	[1.52, 3.07]	5.80	0.001***	0	0	Huge
Intervention duration	One week and less	6	0.23	[−0.21, 0.65]	1.03	0.31	96.24	0.24	Small
	One month	1	0.19	[−0.22, 0.60]	0.91	0.37	0	0	Small
	Trimester	2	0.09	[0.01, 0.18]	1.99	0.046*	39.78	0.01	Negligible
	One semester	17	0.04	[−0.04, 0.12]	1.01	0.317	87.52	0.02	Negligible
	One year	2	0.20	[0.15, 0.25]	7.90	0.001***	0	0	Small
	Two years	2	0.43	[−0.36, 1.22]	1.06	0.290	98.35	0.32	Moderate
	Not mentioned	2	0.01	[−0.46, 0.47]	0.02	0.982	85.12	0.10	Negligible
Sample size	Small	15	0.26	[0.09, 0.43]	2.99	0.003**	87.22	0.07	Small
	Large	17	0.04	[−0.06, 0.14]	0.81	0.42	97.65	0.04	Negligible
Geographical distribution	Asia	3	1.35	[−0.09, 2.80]	1.84	0.07	90.33	1.45	Very large
	Latin America	1	−0.10	[−0.18, −0.02]	−2.51	0.012*	0	0	Negligible
	North America	28	0.08	[−0.01, 0.16]	1.87	0.06	96.41	0.04	Negligible
Research design	POWC	17	0.13	[−0.02, 0.27]	1.73	0.08	96.91	0.07	Negligible
	PPC	15	0.08	[−0.01, 0.17]	1.84	0.07	92.07	0.02	Negligible

*$p < .05$, **$p < .01$, ***$p < .001$.

Table 3 Meta-regression results for the learning achievement of response from subject, educational level, intervention duration, sample size, geographical distribution and research design.

Model		Coefficient	Standard Error	95% lower	95% upper	Z-value	2-sided p value	
Intercept		−0.04	0.15	−0.33	0.24	−0.30	0.77	
Subject	1=Mathematics	0.17	0.26	−0.33	0.68	0.67	0.50	$Q^* = 8.23$, $df = 7$, $p = 0.31$
	2=Science	0.20	0.19	−0.17	0.57	1.05	0.30	
	3=Psychology	0.20	0.15	−0.28	0.32	0.12	0.91	
	4=Computer science	−0.40	0.29	−0.97	0.18	−1.36	0.17	
	5=Business	−0.02	0.60	−1.20	1.16	−0.04	0.97	
	6=History and politics	0.37	0.23	−0.08	0.82	1.63	0.10	
	7=Literature and sociology	0.43	0.38	−0.31	1.17	1.13	0.26	
Educational level	1=Secondary	−0.84	0.49	−1.79	0.11	−1.73	0.08	$Q^* = 15.07$, $df = 3$, $p = 0.001$*
	2=Post-secondary	0.00	0.22	−0.42	0.42	−0.01	0.99	
	3 = PD	1.15	0.76	−0.33	2.64	1.52	0.13	
Intervention duration	1=One week and less	−0.19	0.17	−0.52	0.15	−1.08	0.28	$Q^* = 9.81$, $df = 6$, $p = 0.13$
	2=One month	0.71	0.50	−0.26	1.69	1.44	0.15	
	3=Trimester	0.04	0.20	−0.36	0.44	0.18	0.86	
	4= One year	0.30	0.54	−0.76	1.36	0.56	0.58	
	5= Two years	0.46	0.22	0.04	0.88	2.13	0.03*	
	6= Not mentioned	0.25	0.27	−0.27	0.77	0.96	0.34	
Sample size	1=Small	0.19	0.15	−0.10	0.48	1.26	0.21	
Geographical distribution	1=Asia	1.18	0.57	0.06	2.29	2.07	0.04*	$Q^* = 4.56$, $df = 2$, $p = 0.10$
	2= Latin America	−0.38	0.35	−1.07	0.31	−1.09	0.28	
Research design	1 = PPC	−0.04	0.13	−0.29	0.22	−0.27	0.78	

*Q statistics are the sets of the moderators (subject, educational level, intervention duration, sample size, geographical distribution and research design).
*$p < .05$.

2019; Feldstein et al., 2012; Grewe and Davis, 2017; Grieger and Leontyev, 2023; Grissett and Huffman, 2019; Gurung, 2017; Hardin et al., 2019; Hendricks et al., 2017; Hilton III et al., 2013, 2016; Juárez, Muggli (2019); Lawrence and Lester, 2018; Mayer, 2023; Medley-Rath, 2018; da Silva and White, 2021; Winitzy-Stephens and Pickavance, 2017). Only four studies

(12.5%) looked into the integration of OER in secondary education (Harvey and Bond, 2022; Kelly and Rutherford, 2017; Sales et al., 2021; Sulisworo et al., 2021). Moreover, out of the 32 studies examined, two (6.3%) of them examined OER at post-secondary education (Jhangiani et al., 2018; Robinson, 2015) and only a single study (3.11%) focused on the adoption and use of OER in professional development (Shemy and Al-Habsi, 2021).

Object. When looking into the subjects in which OER were mostly examined (Fig. 6), the most popular topic was Psychology (freq: 7, perc.: 21.9%) (Gurung, 2017; Clinton, 2018; Engler and Shedlosky-Shoemaker, 2019; Grissett and Huffman, 2019; Hardin et al., 2019; Jhangiani et al., 2018; da Silva and White, 2021), followed by Mathematics (freq: 5, perc.: 15.6%) (Chiorescu, 2017; Harvey and Bond, 2022; Hilton III et al., 2013; Juárez, Muggli (2019); Kelly and Rutherford, 2017) and Sciences (freq: 5, perc.: 15.6%) (Allen et al., 2015; Arsenault et al., 2023; Grieger and Leontyev, 2023; Hendricks et al., 2017; Sulisworo et al., 2021). A few studies have also examined the use of OER in History and Politics (freq: 2, perc.: 6.3%) (Grewe and Davis, 2017; Lawrence and Lester, 2018) and in Literature and Sociology (freq: 2, perc.: 6.3%) (Medley-Rath, 2018; Sales et al., 2021). However, only a single study (3.1%) has explored how OER can influence Business (Feldstein et al., 2012) and Computer Science (Choi and Carpenter, 2017). However, it is worth noting that a total of 9 studies (28.1%) examined and compared a variety of subjects (Basu Mallick et al., 2018; Bol et al., 2022; Clinton-Lisell, 2023; Colvard et al., 2018; Hilton III et al., 2016; Mayer, 2023; Robinson, 2015; Shemy and Al-Habsi, 2021; Winitzy-Stephens and Pickavance, 2017).

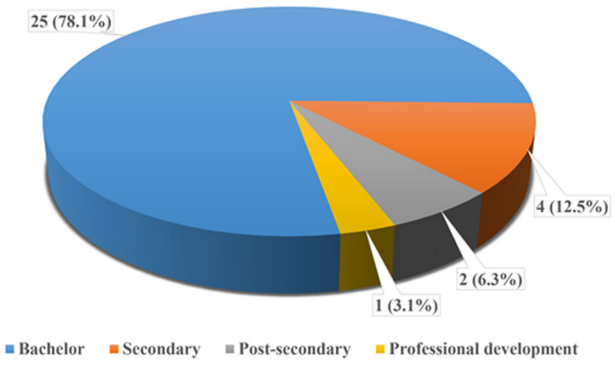

Fig. 5 Distribution of OER and OEP studies by educational level.

Tool/Instrument. Figure 7 shows that the vast majority of studies adopted OER interactive textbooks (freq: 25, perc.: 78.2%) (Allen et al., 2015; Arsenault et al., 2023; Basu Mallick et al., 2018; Bol et al., 2022; Chiorescu, 2017; Choi and Carpenter, 2017; Clinton, 2018, 2023; Colvard et al., 2018; da Silva and White, 2021; Engler and Shedlosky-Shoemaker, 2019; Feldstein et al., 2012; Grieger and Leontyev, 2023; Grissett and Huffman, 2019; Gurung, 2017; Hardin et al., 2019; Harvey and Bond, 2022; Hendricks et al., 2017; Hilton III et al., 2013, 2016; Jhangiani et al., 2018; Lawrence and Lester, 2018; Mayer 2023; Medley-Rath, 2018; Sales et al., 2021), followed by OER interactive material (freq: 5, perc.: 15.6%) (Grewe and Davis, 2017; Kelly and Rutherford, 2017; Robinson 2015; Juárez, Muggli (2019); Shemy and Al-Habsi, 2021). Only a single study (3.1%) used OER documents (Winitzy-Stephens and Pickavance, 2017) and another one (3.1%) adopted OER videos (Sulisworo et al., 2021). These materials were made available to students through different means such as online platforms, websites, learning management systems, institutional subject guides, course management platforms, and online links. Specifically, learning management systems such as edX (Hendricks et al., 2017), Moodle (Engler and Shedlosky-Shoemaker, 2019), Blackboard Learn (Clinton, 2018), and Desire2Learn (Grissett and Huffman, 2019), were used to manage and distribute OER among educational stakeholders. Access to OER was also offered to students through the use of non-profit organization websites, such as Khan Academy (Juárez, Muggli (2019); Kelly and Rutherford, 2017) and Saylor Academy (Grissett and Huffman, 2019). In contrast to learning management systems, websites were mostly used as a common point for students to access educational materials.

Rules. Although all studies commented upon the openness of OER licenses, only 5 studies (15.6%) specifically mentioned their license, which was Creative Commons license, (Bol et al., 2022; Feldstein et al., 2012; Hilton III et al., 2013; Lawrence and Lester, 2018; Shemy and Al-Habsi, 2021) and one study (3.1%) reported their material being under the Creative Commons Attribution 4.0 International license (Juárez, Muggli (2019)).

As far as the modalities are concerned (Fig. 8), 23 studies (65.6%) explored the impact of OER on students' performance in face-to-face learning (Allen et al., 2015; Arsenault et al., 2023; Basu Mallick et al., 2018; Chiorescu, 2017; Choi and Carpenter,

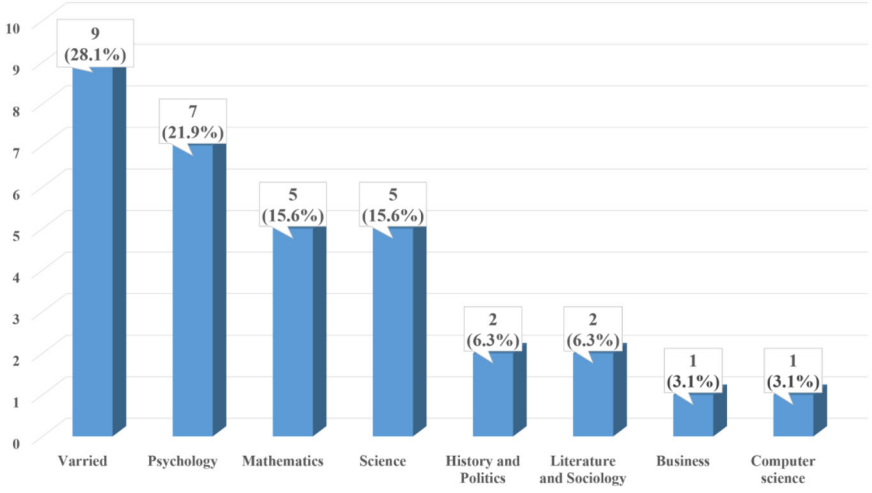

Fig. 6 Distribution of OER and OEP studies by educational subject.

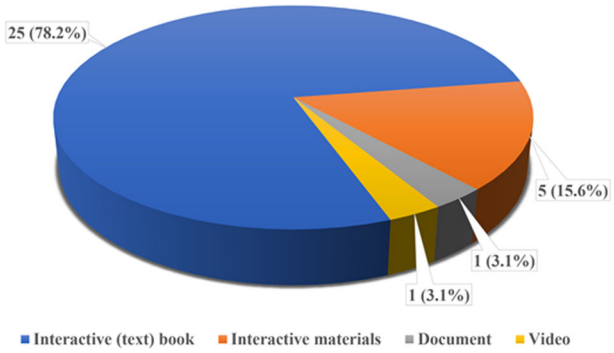

Fig. 7 Distribution of OER by resource type.

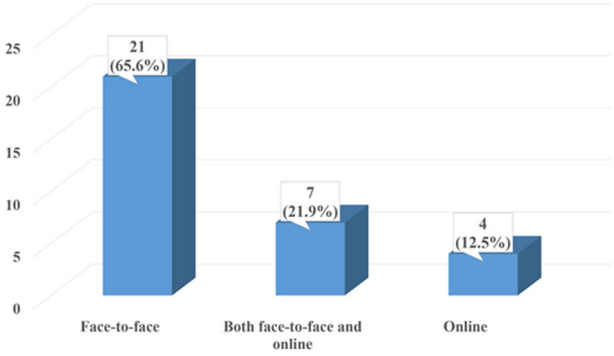

Fig. 8 Distribution of course delivery modalities using OER and OEP.

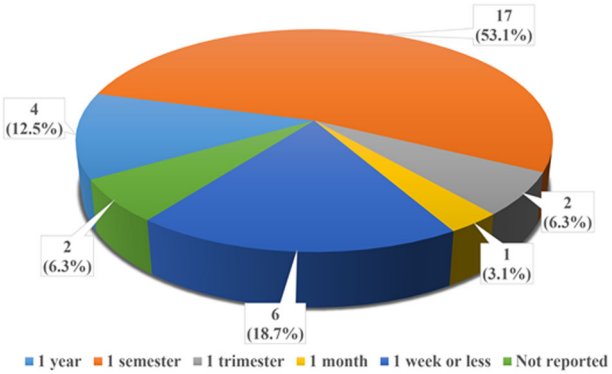

Fig. 9 Distribution of intervention duration.

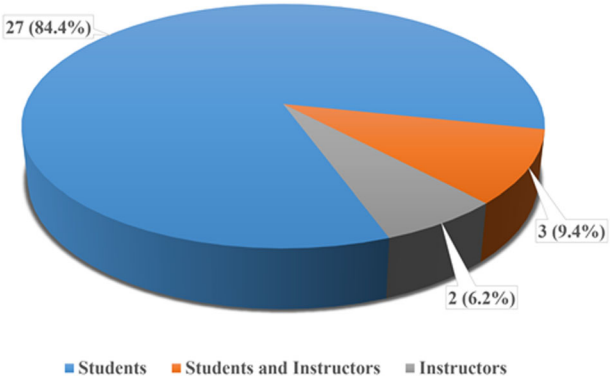

Fig. 10 Distribution of OER and OEP studies by the involved stakeholders.

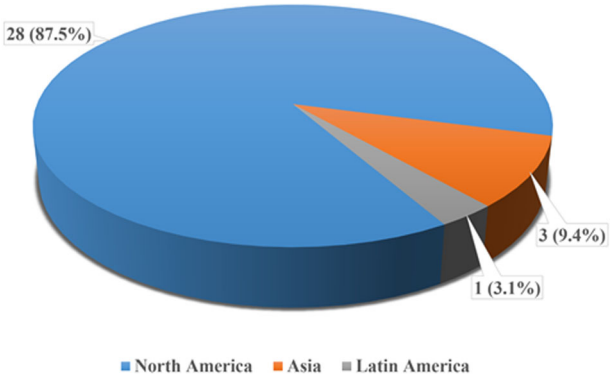

Fig. 11 Geographic distribution of OER and OEP studies.

2017; Clinton, 2018; Colvard et al., 2018; Engler and Shedlosky-Shoemaker, 2019; Feldstein et al., 2012; Grieger and Leontyev, 2023; Grissett and Huffman, 2019; Gurung, 2017; Harvey and Bond, 2022; Hilton III et al., 2013; Jhangiani et al., 2018; Juárez, Muggli (2019); Kelly and Rutherford, 2017; Robinson, 2015; Sales et al., 2021; da Silva and White, 2021; Winitzy-Stephens and Pickavance, 2017). Only 4 studies (12.5%) looked into online learning (Bol et al., 2022; Grewe and Davis, 2017; Mayer, 2023; Shemy and Al-Habsi, 2021), while 7 studies (21.8%) explored the influence of OER in both face-to-face and online learning (Clinton-Lisell, 2023; Hardin et al., 2019; Hendricks et al., 2017; Hilton III et al., 2016; Lawrence and Lester, 2018; Medley-Rath, 2018; Sulisworo et al., 2021).

All studies followed an experimental approach using treatment and control groups. However, two patterns were observed. On the one hand, 16 studies (50.0%) examined how the integration of OER affected students' learning performance by integrating OER-based learning during their intervention to all participants and comparing their results with those who used traditional textbooks in previous semesters. On the other hand, 16 studies (50.0%) explored the influence of OER on students' learning performance by separating the participants into the ones using OER and the others using traditional textbooks in the same course.

Furthermore, Fig. 9 shows that the interventions of the studies differed. In total, 17 studies (53.1%) had a one semester intervention duration (Basu Mallick et al., 2018; Bol et al., 2022; Chiorescu, 2017; Choi and Carpenter, 2017; Clinton, 2018; Engler and Shedlosky-Shoemaker, 2019; Grewe and Davis, 2017; Grieger and Leontyev, 2023; Grissett and Huffman, 2019; Hendricks et al., 2017; Hilton III et al., 2013; Jhangiani et al., 2018; Juárez, Muggli (2019); Lawrence and Lester, 2018; Robinson, 2015; Sales et al., 2021; da Silva and White, 2021), followed by 6 studies (18.7%) whose intervention lasted for a week or less (Gurung, 2017; Hardin et al., 2019; Medley-Rath, 2018; Shemy and Al-Habsi, 2021; Sulisworo et al., 2021; Winitzy-Stephens and Pickavance, 2017) and 4 studies (12.5%) with a one-year intervention duration (Arsenault et al., 2023; Clinton-Lisell, 2023; Feldstein et al., 2012; Mayer, 2023). Only 2 studies (6.3%) had a one trimester intervention duration (Allen et al., 2015; Hilton et al., 2016) and a single study (3.1%) had a one-month intervention (Kelly and Rutherford, 2017). Finally, two studies (6.3%) did not report a specific duration for their intervention (Colvard et al., 2018; Harvey and Bond, 2022).

Community. All of the 32 studies examined looked into the integration of OER in formal settings. Additionally, Fig. 10 reveals that the main educational stakeholders whose perspectives and performance were evaluated by 27 studies (84.4%) were students (Allen et al. 2015; Arsenault et al. 2023; Basu Mallick et al. 2018; Bol et al., 2022; Choi and Carpenter 2017; Clinton 2018, 2023; Colvard et al. 2018; Engler and Shedlosky-Shoemaker 2019;

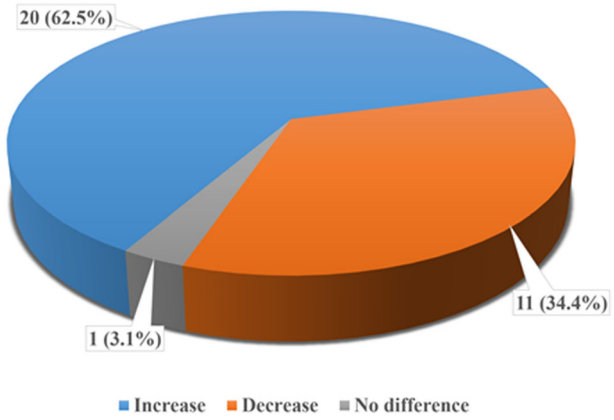

Fig. 12 Distribution of OER and OEP studies based on learning performance.

Feldstein et al. 2012; Grewe and Davis 2017; Grieger and Leontyev 2023; Grissett and Huffman 2019; Gurung 2017; Harvey and Bond 2022; Hendricks et al. 2017; Hilton III et al., 2013, 2016; Jhangiani et al. 2018; Kelly and Rutherford 2017; Lawrence and Lester 2018; Mayer 2023; Medley-Rath 2018; Robinson 2015; Silva and White, 2021; Sulisworo et al. 2021; Winitzy-Stephens and Pickavance, 2017). Three studies (9.4%) examined both students' performance and instructors' perspectives (Chiorescu, 2017; Hardin et al., 2019; Juárez, Muggli (2019)). A total of two studies (6.2%) looked into how OER can affect instructors' delivering their course (Sales et al., 2021; Shemy and Al-Habsi, 2021).

Regarding the geographic location (see Fig. 11), the vast majority of studies (freq: 28, perc.: 87.5%) took place in North America (Allen et al., 2015; Arsenault et al., 2023; Basu Mallick et al., 2018; Bol et al., 2022; Chiorescu, 2017; Choi and Carpenter, 2017; Clinton, 2018, 2023; Colvard et al., 2018; Engler and Shedlosky-Shoemaker, 2019; Feldstein et al., 2012; Grewe and Davis, 2017; Grieger and Leontyev, 2023; Grissett and Huffman, 2019; Gurung, 2017; Hardin et al., 2019; Harvey and Bond, 2022; Hendricks et al., 2017; Hilton III et al., 2013, 2016; Jhangiani et al., 2018; Kelly and Rutherford, 2017; Lawrence and Lester, 2018; Mayer, 2023; Medley-Rath, 2018; Robinson, 2015; da Silva and White, 2021; Winitzy-Stephens and Pickavance, 2017). Only 3 of the studies (9.4%) examined the integration of OER in Asia (3.1%) and a single study (Sales et al., 2021; Shemy and Al-Habsi, 2021; Sulisworo et al., 2021) focused on Latin America (Juárez, Muggli (2019)).

Division of labour. From the studies examined, 31 (96.9%) referred to instructors solely being in charge of the selection or creation of the OER used and acting as facilitators to distribute the material. Hence, instructors were mostly associated with the distribution of OER while students were mere recipients and consumed the material. As a result, students' role was not predominant in the selection, shaping, and distribution of the OER. However, in the context of OER, students should partake and play an active role in shaping the educational material. Only a single (3.1%) study (Grieger and Leontyev, 2023) looked into how students' involvement in the creation of OER influenced their engagement, motivation, and learning performance. Additionally, OER were mostly used as a one-to-one replacement of traditional textbooks which indicates that there is a need for a sustainable business model in the OER landscape. This fact reveals that appropriate design principles and processes were not always adopted or followed. However, OER still emerged as valuable educational tools that can enrich education and improve students' performance and knowledge while also yielding other benefits, such as increased accessibility and reduced costs.

Outcomes. Based on the findings of the 32 analyzed studies, there are several conclusions that can be drawn. Based on Fig. 12, it became evident that the significant majority of studies reported that students' learning performance, motivation, and knowledge acquisition were similar when using OER and when using traditional/commercial textbooks. Out of the 32 studies examined, a total of 20 studies (62.5%) reported that the use of OER yielded similar or even slightly better student learning performance while also improving their subject knowledge (Allen et al., 2015; Arsenault et al., 2023; Chiorescu, 2017; Clinton, 2018, 2023; Colvard et al., 2018; Feldstein et al., 2012; Grewe and Davis, 2017; Grieger and Leontyev, 2023; Hardin et al., 2019; Hendricks et al., 2017; Hilton III et al., 2016; Jhangiani et al., 2018; Kelly and Rutherford, 2017; Mayer, 2023; Medley-Rath, 2018; Sales et al., 2021; Shemy and Al-Habsi, 2021; da Silva and White, 2021; Sulisworo et al., 2021). It is important to note that the increase in academic performance was evident in both low and high performing students. Nonetheless, one study (3.1%) revealed no differences (Engler and Shedlosky-Shoemaker, 2019) while 11 studies (34.4%) reported a slight decrease in performance (Basu Mallick et al., 2018; Bol et al., 2022; Choi and Carpenter, 2017; Grissett and Huffman, 2019; Gurung, 2017; Harvey and Bond, 2022; Hilton III et al., 2013; Juárez, Muggli (2019); Lawrence and Lester, 2018; Robinson, 2015; Winitzy-Stephens and Pickavance, 2017). This fact highlights that there are several factors that can influence the effective adoption and integration of OER, including the nature of the course in itself, and the results may differ between courses. To combat this issue, instructors are encouraged to customize and tailor the OER to the specific needs of their courses.

Discussions

This study conducted a two-phase analysis to measure and understand the effect of OER and OEP on learning performance. The first-phase results revealed that OER and OEP have a significant but negligible ($g = 0.10$) effect on students' learning performance. To understand what led to these results, a second-phase analysis, based on the Activity Theory framework, was conducted. Our findings are discussed from various perspectives in the following sections.

A change in instruction is a must. To understand what led to this effect, the ways of using OER and OEP in education were investigated. This was through analyzing the *division of labour* dimension within the activity theory framework (the second phase analysis). The results highlighted that in almost 97% of the studies, the creation and distribution of OER was solely by the teacher. Although several studies highlighted that OER and OEP can foster innovative teaching and learning practices (Degen et al., 2024; LeMire, 2024; Milošević et al., 2024), our results revealed that most of the analyzed studies simply changed the content license to open and continued to rely on traditional teaching practices, wherein students primarily act as consumers of knowledge. Indeed, such an approach does not fully leverage the potential of OER and OEP to transform educational experiences. Instead of fostering active learning and engagement, these studies maintained conventional pedagogical methods, thus limiting the potential benefits that open resources and practices could offer. This explains the low effect on students' learning performance since simply changing a content license from commercial to open does not imply a change in performance (Dotson and Foley, 2017; Harvey and Bond, 2022). In the same vein, Salomon and Clark (1977, p. 102) concluded that "when only the least significant aspects of instruction are allowed to vary, nothing of interest could, and did, result." Therefore, future studies should harness

the power of OER and OEP to provide more innovative learning environments that could enhance learning experiences, hence achieving better performance. For instance, Zhang et al. (2020) relied on open pedagogy to teach family education, where the learners participated in the co-creation of the teaching content and process, and the teacher became more of a facilitator. The final produced content at the end of the semester was organized in an open textbook that others could make use of and enrich in their contexts.

To brief, in the existing literature, there is a clear gap on how students and instructors communicate and collaborate when creating, shaping, and using OER and adapting OEP. The role of students in co-creating, co-editing, and co-distributing the educational material needs to be further examined. It is also important to understand the perspectives of instructors on students themselves playing an active role in shaping the course. By achieving a balance between instructors' and students' contribution, versatile and customized OER can be created, which express the perspectives of various contributors and derive from diverse sources, thus, potentially leading to better outcomes. However, the instructors' role and responsibilities to supervise the OER as it develops need to be looked into. In this context, the importance of cultivating educational stakeholders' critical thinking, reasoning, argumentation, and information literacy becomes evident.

Harnessing the power of technology for new learning opportunities. The analysis of *community* and *tools* dimensions revealed that all the reviewed studies used OER and OEP in formal settings by relying on traditional technologies, such as websites and learning management systems. This might explain the limited effect obtained on learning performance. Based on a comprehensive review of the literature, Huang et al. (2020) developed an OEP framework, where they emphasized the importance of technology in facilitating various OEP dimensions, including open teaching, open collaboration, and open assessment. It is, therefore, crucial to go with the broader definition of "openness" to provide learning experiences, beyond classrooms, in informal settings through harnessing the power of various technologies, including mobile technology, virtual reality (VR), augmented reality (AR), among others.

OER should go beyond textbooks and have a clear indication of the open license. The analysis of *tools* and *rules* dimensions revealed that most of the studies relied on open textbooks, as OER, in addition to that only five studies explicitly stated the used open license. Open textbooks have been shown to reduce educational cost and ensure more educational inclusiveness (Bozkurt et al., 2023) without any impact on learning achievement (Clinton and Khan, 2019). This might explain the overall negligible effect on learning performance obtained in this study. It is therefore important that future studies try to rely on more open types of resources, such as multimedia resources, games, simulation resources to make the learning process more immersive, and also to give more freedom to students to experience the power of openness where they can adjust and revise these materials accordingly. It is encouraged that future studies explore how different types of OER can influence students' learning performance to identify which form of OER or which combination of OER is the most effective.

A renewable assignments approach can also be used to engage students and take OER/OEP practices beyond textbooks (Simon et al., 2024; Van Allen and Katz, 2019, 2022). In this way, it is possible to actively involve teachers and students in the OER/OEP ecosystem and enable students to adopt the philosophy of openness in education through OER/ OEP practices and create a culture of openness. Supporting these notions, Tlili et al. (2022) emphasized the need, within this ecosystem, for developing open educators by also covering personal characteristics (e.g., personality) that are seen as complementary to the needed competences to adopt and work with OEP.

Besides, despite that open license defines the mechanism of OER (e.g., how a given OER should be revised, remixed, redistributed, etc.), thereby highlighting the potential involvement of students while using OER, only 5 studies mentioned their open license. This highlights that most of the reviewed studies who used OER did not, at least, explicitly think and report of what students can or cannot do when learning using OER within the boundaries of the open license. Such deficiency in the learning design might hinder the effect on learning performance. Therefore, to increase the effectiveness of OER on learning performance, future research should carefully think of how the learning process will be designed (including activities, interaction, final outcomes, etc.) within the boundaries of the open license to be used.

OER and OEP adoption and implementation should be in and for all. Our results revealed that educational level moderates the effect of OER and OEP and learning performance. To further understand this moderation effect, the *subject* and *object* dimensions (within the activity theory framework) were analyzed. The results revealed that 78.1% of the studies adopted OER and OEP at bachelor level, and mostly in psychology. Therefore, this moderation effect cannot be generalized and there is a clear need for future studies to examine all educational levels while also focusing on primary and secondary education. Additionally, comparing the performance and preferences at different educational levels could help identify the most optimal OER as well as the adequate OEP to use in each case and create appropriate approaches for each target group. It is also evident that the nature of the subject can influence the outcomes of an OER intervention. Therefore, it is important for more comparative studies that look into different subjects while using similar settings and OER and OEP to be conducted so that a better understanding of the specifications and characteristics that influence learning performance can be identified. Additionally, there is a clear need to examine how OER and OEP impact more types of courses and particularly the ones that have both theoretical and applied parts.

Looking into the *outcomes* dimension, more studies that focus on analyzing the viewpoints and experiences of more educational stakeholders besides students should be carried out. Additionally, more studies from different areas need to be conducted to comprehend how factors, such as culture, educational settings, socio-economic backgrounds, might influence the impact of OER and OEP. It is also important to examine how similar OER and OEP influence students of different countries and backgrounds.

Conclusions, implications and limitations

This study conducted a two-level analysis to measure the effect of OER and OEP on learning performance, as well as to understand what led to this effect. To do so, a meta-analysis and a meta-synthesis based on the activity theory were conducted. The obtained results revealed that OER and OEP have a significant negligible effect, where this low obtained effect might be due to various confounding variables, including instructions, resources, learning settings, etc. Based on these findings several findings are obtained.

From a theoretical perspective, this study enriches the ongoing debate about what variables might influence the effective adoption of OER and OEP. Highlighting such variables can help

develop frameworks and policies that account for them. The findings also highlight the need for various potential cross-collaborations that should be considered between different stakeholders (i.e., instructional designers, educators, technologists, license organizations) to provide an innovative OER- and OEP-based learning and teaching process, allowing students to be more active and co-creators of their learning experiences rather than simply being consumers.

From a practical perspective, this study highlights that a holistic approach is needed to enhance learning performance that goes beyond simply changing the content license and involves innovative instructional strategies, resources, and learning settings. It is also important to harness the power of emerging technologies, including AR, VR, AI to provide open learning experiences beyond the formal environments (e.g., classrooms) such as situated learning settings. For instance, learners can learn history or science while being in museums or parks, where they interact with the OER and revise it accordingly (related to history or science) based on their knowledge gained from the physical environment. The findings also revealed the importance and need of designing learning experiences within the boundaries of the open license, allowing learning interactions and activities to be clearly thought of based on the ultimate educational objective to be taught, thereby achieving better learning performance. This also ensures the safe and responsible use of OER and OEP without going beyond the legal boundaries (e.g., violating copyright laws) which is a major concern in any educational setting, including open education. Furthermore, future studies should explore the power of various open-source software, such as MIT License or GNU General Public License (GNU GPL), to foster innovation and creativity of students in certain educational subjects.

The combined findings of this study also point to the need to implement OER/OEP applications within an ecosystem centered on the philosophy of openness in a way that creates a culture of openness, especially in education. Otherwise, a future is envisaged in which only textbooks are adapted to open licenses, mostly educators are the critical stakeholders, and OER/OEP adaptations do not go beyond traditional educational settings. Such a speculative future justifies the importance of a learning ecosystem that truly embraces OER/OEP applications and a culture of openness that will grow within this ecosystem.

While the reliability of this study has been validated through the bias assessment, this study still has some limitations that should be acknowledged and further researched. For instance, the obtained results are limited by the search keywords and databases used. Therefore, future research studies are encouraged to complement this study by covering more databases and also including studies written in languages other than English. Despite these limitations, this study provided solid foundations, relying on mixed methods, to enhance the effective adoption of OER and OEP in the future.

Data availability

The datasets generated and/or analyzed during the current study are presented within this study.

Received: 2 June 2024; Accepted: 21 February 2025;
Published online: 10 April 2025

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Author contributions

Ahmed Tlili, Soheil Salha, and Georgios Lampropoulos analyzed and interpreted the data. All authors contributed to writing the original draft as well as in revising and editing it. All authors have read and approved the final version of the manuscript.

Funding

This work was supported by Beijing Digital Education Center (Research on Experimental Teaching of Physics, Chemistry and Biology in Middle Schools based on Digital Education Resources). Grant number is: BDEC2023619102.

Competing interests

The authors declare no competing interests.

Ethical approval

Not applicable.

Informed consent

Not applicable.

Additional information

Supplementary information The online version contains supplementary material available at https://doi.org/10.1057/s41599-025-04644-y.

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