Chapter 6

Effectiveness of OER use in first-year higher education students' mathematical course performance: A case study

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Summary

This chapter aims to understand the impact of Open Educational Resources (OER) on first-year mathematics students at the Instituto Profesional Providencia (IPP) in Santiago, Chile, where more than half (52%) of first-year students typically drop out of their studies. In order to address this, the institution established an innovation fund and a project to profile, assess and monitor student performance through an early warning system. IPP stakeholders envisioned that a strategy to promote OER uptake could complement these efforts. By looking at an OER intervention amongst first-year students, this study seeks to identify ways in which OER can provide new tools, opportunities, and contexts to improve student performance and lower dropout rates by answering the following research questions: What is the effect of OER use on first-year students' mathematics course performance? In face-to-face instruction, what is the effect of OER use on first-year students' class attendance? What are teachers' and students' perceptions of the OER adoption process?

To answer questions one and two, this study used a quantitative method to estimate the effect of OER use on students' mathematical course performance and class attendance. Five groups of first-year students were compared based on the analysis of two scenarios. In Scenario 1, a control group and two treatment groups were in a traditional face-to-face classroom setting. The control group relied on a proprietary textbook; the first treatment group was taught with the help of a Khan Academy OER collection; and the second treatment group was taught by means of a custom-designed Open Textbook. Scenario 2 compared two classes in blended-mode Algebra and Calculus courses. The control group relied on a proprietary resource, ▶

and the treatment group used a Khan Academy collection of OER in addition to the proprietary resource. In order to estimate the effectiveness of OER use on students' mathematical performance, the impact analysis focused on three result variables: (1) students' marks before the final exam, (2) students' final exam marks, and (3) students' final course marks after the exam.

To answer research question three, a mixed-methods approach was applied in the form of a series of semi-structured interviews, a focus group discussion and a student survey. The students who used the Khan Academy OER collections or the Open Textbook were asked to participate in this study in order to better comprehend learners' and teachers' perceptions of OER.

Students in Scenario 1 who used Khan Academy resources obtained statistically significantly better exam grades than those who used the proprietary resource or the Open Textbook, suggesting that not all kinds of OER have the same effect on student performance. In Scenario 2, there was no improvement in mathematical course performance amongst students using OER. In terms of student attendance, face-to-face mode students who used Khan Academy OER had significantly lower attendance levels than those who relied on the proprietary textbook, which may be due to the fact that when students have access to the infrastructure required to access OER remotely they tend to work more from home.

With regard to student and teacher perceptions of the OER adoption process, the qualitative and quantitative data confirmed the assumption that OER can be relevant and useful to Chilean students.

The chapter concludes with the insight that "openness" does not necessarily produce an impact in and of itself, but is instead part of a greater set of tools and practices in which many variables exert an influence. Neither the intrinsic nature of information and communication technologies nor openness are tools or instruments that can be said to result in a specific outcome.

The dataset arising from this study can be accessed at:
https://www.datafirst.uct.ac.za/dataportal/index.php/catalog/577

Acronyms and abbreviations

ESD	Education for Sustainable Development
ICT	information and communication technologies
IPP	Instituto Profesional Providencia
LMS	learning management system
OER	Open Educational Resources
PSM	Propensity Score Matching
US	United States

Introduction

Education is a pivotal means of promoting development in every developing country. As countries seek to develop their human capital to participate in the global knowledge society and address the challenges of the new global economy, there is increasing pressure on educational systems, particularly those in higher education, to meet the increasing demand for equal educational opportunities and supply high-quality, relevant and efficient formal and informal educational processes.

Both equity and quality are major challenges for national educational systems in terms of the level of innovation and transformation required. The United Nations Educational, Scientific and Cultural Organization coined the phrase "Education for Sustainable Development" (ESD)[1] as an umbrella term for the many forms of educational practice that promote efforts to rethink educational systems (both in terms of curriculum and pedagogy) in countries facing extreme educational challenges. ESD requires participatory teaching and learning approaches in order to motivate teachers and empower learners to change their behaviour and take action to achieve sustainable development. It promotes competencies such as critical thinking, imagining future scenarios, making decisions and solving problems in a collaborative way.

As a reimagined education system is required to create a new set of skills and competencies for the burgeoning number of new learners, there appears to be widespread consensus that new forms of educational provision need to be online and free of cost to the learner. The European Commission (2012, p.9) states that digital technology "offers unprecedented opportunities to improve quality, access and equity in education and training", and that it is a "key lever for more effective learning and for reducing barriers to education, in particular social barriers". It recognises, however, that technology on its own does not assure innovation; it is instead the level of openness in the use of technology, in the context of an open learning environment (European Commission, 2013), that enables capacity development in order to stay current, promote innovation and exploit the potential of new learning technologies and digital content.

Recent trends in the use of Open Educational Resources (OER), also referred to as "open content"[2] or "*Recursos Educativos Abiertos*" in Spanish (Betancourt, Celaya & Ramírez, 2014), are enabling fundamental changes and innovation in educational provision. New ways of learning, characterised by personalisation, engagement, use of digital media, collaboration, bottom-up practices and an approach where the learner or teacher is a creator as well as consumer of learning content, have been facilitated by the exponential growth of OER in recent years. OER are important for stimulating innovative learning environments where content can be adapted by users according to their needs (Keegan & Bell, 2011). The European Commission has asserted that "stimulating supply and demand for high-quality OERs is essential for modernizing education" (European Commission, 2013, p.8). In the current global educational environment, OER are recognised as having the potential to make an impact in the following areas (Orr, Rimini & Van Damme, 2015):

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1   http://en.unesco.org/themes/education-sustainable-development
2   https://web.archive.org/web/19990128224600/http://www.opencontent.org/home.shtml

- Harnessing the possibilities afforded by digital technology in order to address common educational challenges.
- Acting as a catalyst for social innovation and new forms of interaction between teachers and learners in the knowledge-generation process.
- Promoting the idea of an extended lifecycle beyond original design and purpose, where the process of distribution, adaptation and iteration can improve access to high-quality, context-appropriate educational materials for all.

In the case of Chile, the educational system has been challenged by the demands of civil society to access quality education. Following a series of ongoing student-led protests across the country that set the foundation for a national social reform movement, the second presidential term of Michelle Bachelet's government (2014–2018) has embraced the challenge through complex and structural educational reform.[3] An ambitious legislative agenda seeks equal accessibility to quality education as a civil right, more direct state participation in primary and secondary education, the end of for-profit education, an increase in state support for public universities, the creation of a government agency to apply the law against for-profit activities in higher education, and an improvement in quality accreditation processes (Brunner, 2008). In short, it is a system of reform based on strengthening the public supply of education.

Although educational resources are considered in the various strategies of multi-dimensional educational reform in Chile, there is no reference to openly licensed resources as part of a strategy for equitable access to quality educational services and increasing the affordability of education to address wider and constantly growing demand. The issue of how to leverage legal and technical openness to improve the quality of education therefore remains a central challenge.

Professional institutes (*Institutos profesionales*), which address around 60% of national, post-secondary education supply, typically accommodate many underprivileged and disadvantaged students with low levels of basic knowledge and cognitive skills. However, a recent study stated that nearly three out of four professional institute graduates lacked basic reading comprehension skills (Fundación La Fuente/Adimark GFK, 2011). Conducting research on how innovative open approaches to learning can impact upon and improve student performance is particularly important in the context of first- and second-year students with deficits in knowledge and skills who enrol in higher education courses. Along with the need to improve student performance, retention rates in first- and second-year students, alongside poor throughput (graduation) rates, are the main problems in higher education (MINEDC, 2012). When considering the tertiary education sector in Chile,[4] the dropout rate is a substantial challenge, as many institutions have retention rates of less than 40%. This places a heavy burden on institutions and on society, particularly as relates to the loss of tuition revenue from the students who drop out or transfer to other institutions (MINEDC, 2012).

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3   http://www.gob.cl/la-reforma-educacional-esta-marcha/
4   The Chilean higher education system is formed by three types of institutions: universities, technical training centres and professional institutes (known as a technical colleges), which can also award some professional or bachelor's degrees.

At the Instituto Profesional Providencia (IPP),[5] the higher education institute where this study was situated, more than half (52%) of first-year students drop out of their studies. In order to address this situation, the institution has established an innovation fund and project to profile, assess and monitor student performance through an early warning information management system. IPP stakeholders envisioned that a strategy to promote OER uptake could complement these efforts, but there was little on-the-ground institutional awareness of OER or Open Education at the time of the study.

The lack of awareness and level of indifference towards OER is not restricted to IPP, and can be seen in most higher education institutions in Chile. This study attempts to aid advocacy initiatives by addressing the need for empirical evidence on the impact of OER adoption. Specifically, the study is concerned with identifying ways in which OER can provide new tools, opportunities and contexts to address student performance challenges and dropout rates. In line with these ambitions, the study asks the following research questions:

1. What is the effect of OER use on first-year students' mathematics course performance?
2. In face-to-face instruction, what is the effect of OER use on first-year students' class attendance?
3. What are teachers' and students' perceptions of the OER adoption process?

It is hoped that findings of this study will not only contribute to the emerging field of impact studies in OER research, but also raise awareness amongst IPP stakeholders on how OER can contribute to addressing institutional challenges for accessible and quality higher education.

Literature review and conceptual framework

Literature review

OER, and Open Education more broadly, have become a major trend in public educational policy-making. A series of initiatives have demonstrated how momentum in the OER movement has led to numerous institutional, local, regional and national policies supporting OER throughout the world, such as Policies for OER Uptake,[6] the European Open Education Policy Project,[7] and the Creative Commons OER Policy Registry.[8] These have been mapped by projects such as the OER Impact Map[9] and promoted by initiatives such as the Institute for Open Leadership.[10] Coinciding with the growth of the OER movement, the OER research agenda has also matured considerably. As the first phase of global OER initiatives was focused on providing infrastructure and delivery mechanisms for OER, initial OER research was mainly focused on measuring the deployment, access and use of these resources. The

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5   http://ipp.cl
6   http://www.poerup.info
7   http://oerpolicy.eu/
8   https://wiki.creativecommons.org/wiki/OER_Policy_Registry
9   http://oermap.org/policy-map/
10   https://openpolicynetwork.org/iol

first objectives in this field were to investigate and develop solutions in terms of access to knowledge in the context of key OER repository projects (e.g. Merlot, OpenCourseWare, Curriki, OER Commons and Temoa),[11] and to address challenges related to copyright management (UNESCO–IITE, 2011). As the OER movement evolved, a new wave of research studies manifested in order to assess the efficacy and impact of OER adoption and deployment[12] (Santos-Hermosa, Ferran-Ferrer & Abadal, 2013). A nationally representative survey of over 2 100 faculty members in the United States (US) recently rated "proven efficacy" and "trusted quality" as the two most important criteria for selecting teaching resources among a wide variety of factors (Allen & Seaman, 2014). In order for OER to gain traction in the higher education sector, it is important to gather empirical evidence demonstrating the efficacy and quality dimensions of OER adoption. In line with this principle, there is an overarching need for rigorous, controlled impact studies in a variety of settings to establish the impact of OER on learning outcomes and the cost of education in comparison with other digital or more traditional materials (Shear, Means & Lundh, 2015).

This research study was scoped in 2012, at a time when the OER impact field was relatively nascent, and utilised the JISC 2011 OER Impact report[13] as its main frame of reference. The OER research landscape has since evolved quite rapidly, shifting its focus to effectiveness and impact issues as OER initiatives are increasingly deployed and scaled.

OER effectiveness and impact studies have principally focused on whether and how adoption at the institutional level brings about financial benefit for students and institutions. Within this context, most impact research has been focused on the cost-effectiveness of "packaging" OER into courseware or textbooks (Bliss, Hilton III, Wiley & Thanos, 2013; Wiley, Hilton III, Ellington & Hall, 2012). While cost savings represent a major feature of OER advocacy for OER adoption in the Global North, this does not seem to be as much of a critical factor in developing countries as digital "piracy" and reproduction through photocopying appear to persist and are often overlooked at the institutional level.[14] This research study therefore focuses on the effectiveness of OER as relates to the teaching and learning process, rather than its efficacy in matters such as cost-saving.

Prior studies have attempted to investigate the impact of the use of OER on educational processes. The OER Research Hub[15] defined 11 hypotheses which represent some commonly stated beliefs and motivations regarding OER (Weller, de los Arcos, Farrow, Pitt & McAndrew, 2015). Three of those hypotheses are particularly pertinent to this study:

- Performance: Use of OER leads to improvement in student performance and satisfaction.
- Openness: The "open aspect" of OER creates different usage and adoption patterns.
- Reflection: Use of OER leads to critical reflection by educators, with evidence of improvement in their practice.

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11 Merlot (https://www.merlot.org/merlot/index.htm), OCW (http://ocw.mit.edu/index.htm), Curriki (http://www.
    curriki.org/), OER Commons (https://www.oercommons.org/) and Temoa (http://www.temoa.info/es)
12 http://www.hewlett.org/library/ruminations-on-research-on-open-educational-resources/
13 http://www.webarchive.org.uk/wayback/archive/20140614114910 and http://www.jisc.ac.uk/media/
    documents/programmes/elearning/oer/JISCOERImpactStudyResearchReportv1-0.pdf
14 http://blogs.lse.ac.uk/impactofsocialsciences/2016/04/07/how-do-students-access-the-resources-they-need/
15 http://oerresearchhub.org/

Previous research has also helped to shape this study with regards to the specific type of OER selected, namely, open textbooks and their relationship to learning outcomes. Hilton and Laman (2012) compared the performance of 690 students from Houston Community College in the US using an open textbook in an introductory psychology class of 370 students who had used a traditional commercial textbook in a previous semester. They concluded that students who used the open textbook achieved better grades in the course, had a lower withdrawal rate and scored better on the final examination. Feldstein et al. (2012) found that, in a sample of 991 students in nine core courses at the Virginia State University's School of Business, those using open textbooks typically had higher grades and lower failure and withdrawal rates than those in courses with traditional commercial textbooks.

Fischer, Hilton III, Robinson and Wiley (2015) recently published a multi-institutional study examining the academic outcomes of more than 16 000 students from 10 higher education institutions in the US who were assigned open textbooks, versus those assigned traditionally published textbooks. The main finding was that conventional, expensive textbooks were not superior to open ones, and that students assigned to work with open textbooks did as well as or better than their peers in terms of grades, course completion and other measures of academic success. Overall, students in more than half of the courses that used open textbooks improved according to at least one academic measure used in the study, and students in 93% of these courses did at least as well on all other measures (Fischer et al., 2015).

In terms of concern about whether OER might in some way negatively affect the learning endeavour, Allen, Guzman-Alvarez, Molinaro and Larsen (2015) studied a class of 478 students at the University of California, Davis, who used an OER known as ChemWiki as their primary textbook while a control class of 448 utilised a traditional textbook. These two classes were taught in the same semester at consecutive hours by the same faculty member and teaching assistants in order to control for potential bias. Students in the classes also took the same exams. No substantial differences were found between the two groups in terms of performance. Beginning of the semester pre-tests combined with final exams showed no noteworthy differences in individual learning gains between the two groups, indicating that OER could be substituted without any negative impact on learning.

There is great diversity in the kinds of educational resources currently referred to as OER, and many factors influence the ultimate "success" of a teaching resource, making it difficult to isolate the "openness" dimension and draw meaningful conclusions about use and value based on the open nature of a resource. This issue, which the OER Research Hub refers to as the "level of openness" dimension (Shear et al., 2015), is pertinent in that we need to investigate more deeply specific types of openness as enablers for educational quality, innovation and sustainability.

Conceptual framework

To estimate the effectiveness of OER use in improving the academic performance of first-year IPP students, the OER selected had to cover the curriculum comprehensively so that they could be used with high frequency throughout the course.

The first type of OER employed in this study was Khan Academy collections. Khan Academy is a not-for-profit organisation whose main goal is to "change education for the better by providing free world-class education for anyone anywhere".[16] This is achieved through sharing thousands of openly licensed resources, including an extensive library of video content (more than 4 500 video lessons and growing), complemented by a modular and interactive assessment process that incorporates practice exercises. It also offers a personalised learning dashboard that empowers learners to study at their own pace in and outside of the classroom. Unlike many other open content platforms, Khan Academy has translated its web platform, and the resources contained therein, into Spanish,[17] enabling broader global reach.

Khan Academy has organised its numerous resources by subject, K–12 educational level and different standardised test categories arranged in "courses", which are a suggested sequence of learning resources. Khan Academy has enhanced features for teaching, enabling a "coach" to build "courses" by selecting and sequencing (in a sense, remixing) Khan's resources for delivery to subscribed users in the "course". The coaches can be educators or parents; in fact, anyone who can mentor or follow a learner through detailed analytics in order to track the learning process. Both teachers participating in this study utilised the Khan Academy platform to curate (or "bundle") "courses" designed to fit their specific teaching challenges and needs. Students were provided with access to the content via the online platform, under the teachers' attentive monitoring, which is made possible through platform analytics. In order to avoid confusion with formal institutional courses, the specific "courses" curated in the Spanish Khan Academy website for this intervention will be referred to as "**Khan Academy Collection 1**" and "**Khan Academy Collection 2**".

To avoid exclusive focus on the potential efficacy of a specific digital educational resource, a second OER was incorporated in order to better analyse the characteristics of the resource in the learning process, rather than their digital nature. In the absence of any OER similar to the Khan Academy in terms of focus and, most of all, extensive coverage of the course syllabus, an open textbook crafted by the Arithmetic teacher involved was developed for the purposes of this study. Based mainly on teachers' materials, notes and resources, the open textbook was published on Wikibooks – a wiki platform which enables easy, participatory editing of the content, exports material to a wide range of formats and supports LaTex (a coding language for generating mathematical formulas). For a face-to-face course, the Arithmetic open textbook adapted and published in Spanish on the Wikibooks platform was *Numeros y Operaciones* ("Numbers and Operations")[18] (Figure 1). It was delivered in both print and digital format and is referred to as the "**Open Textbook**" in the context of this study.

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16 http://khanacademy.org
17 http://es.khanacademy.org
18 https://es.wikibooks.org/wiki/Matem%C3%A1ticas/N%C3%BAmeros_y_Operaciones

Figure 1: Screenshot of the Open Textbook homepage on the Wikibooks platform

The Khan Academy collections and the Open Textbook sought to replace (in the case of Scenario 1) or supplement (in the case of Scenario 2) the traditional, proprietary textbooks which serve as the usual mandatory resources in the formal course syllabus. There are issues relating to resource access because of a limited number of printed volumes or copies of e-books in the institutional library. The usual procedure students adopt to get around this access challenge is to make photocopies; this is, however, much more difficult with the e-books.

In Scenario 1, the two proprietary textbooks were e-books,[19] which have a low cost (USD 16) but are only accessible to five students, who can each only access the book for a limited time period through the library.

In Scenario 2, the proprietary textbook was a printed volume,[20] which cost USD 45. There were only six printed copies in the library, which had to be shared across three different IPP campuses. In addition to the mandatory printed textbook, there was also an online version of proprietary course notes made available by the institution, which was used as a supplementary resource.

The Open Textbook developed by the Arithmetic teacher for this study is licensed with a Creative Commons Attribution (CC BY) 4.0 International license, one of the more permissive forms of open licences in terms of facilitating reuse. The Khan Academy Terms of Use[21] state that all its educational content and resources are licensed under a more restrictive Creative Commons Attribution Non-Commercial ShareAlike (CC BY-NC-SA) United States 3.0 licence. It is recognised that the OER selected and developed in the context of this study have different properties in terms of their degrees of openness, where the legal openness is just one of the key attributes of OER, along with technical and social attributes (Hodgkinson-

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19 The two e-books are: Goñi, J. M. (2011) *Didáctica de las matemáticas*; and Goñi, J. M. (2011) *Matemáticas, Complemento de la formación disciplinar*.

20 Zill, D. (2011). *Álgebra y Trigonometría*.

21 https://www.khanacademy.org/about/tos

Williams & Gray, 2009). In that sense, the Open Textbook treated in this study would be "more open", while the Khan Academy resource is "less open".

The Khan Academy collections had some limitations in terms of their technical openness, in that they could not be integrated into IPP's learning management system (LMS). A javascript function prevented presentation/duplication of the resources on another web-based system or platform, with the exception of the video lessons that were accessible via YouTube. This meant that a second or parallel environment (in addition to the IPP LMS) had to be accessed (via a link from the LMS) by students utilising the Khan Academy collections (Figure 2).
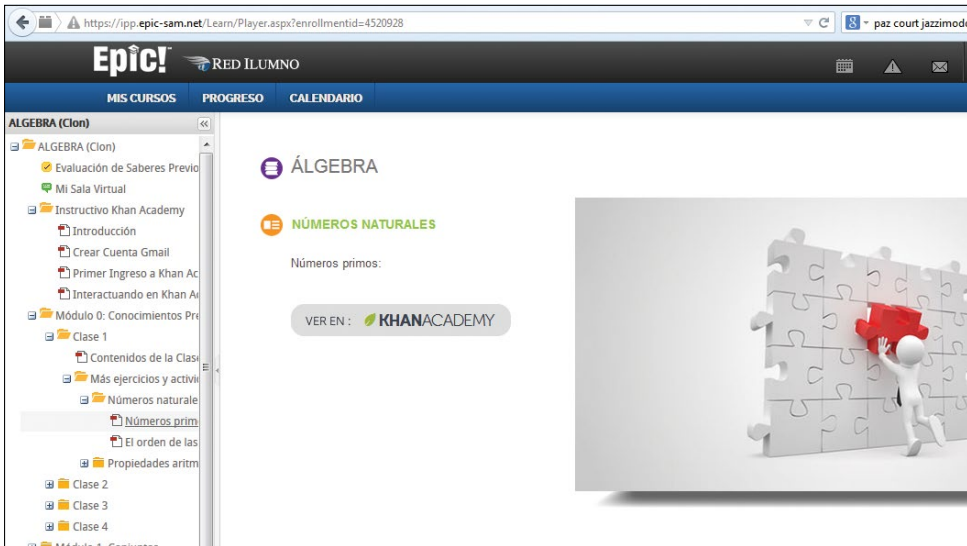

Figure 2: **Screenshot of Khan Academy Collection 2 linked from courseware in the IPP LMS**

From a legal perspective, the Khan Academy was also more restrictive in terms of reuse, as it is "impermissible […] to provide training, support, or editorial services that use or reference the Licensed Educational Content in exchange for a fee".[22]

In the face-to-face mode classroom, the Open Textbook was available via the Wikibooks platform. The wiki functionality of this platform, combined with the affordances of the CC BY licence, enabled a different degree of participation in terms of content creation on the part of students, who could add and revise exercises as well as contribute other notes complementing existing material. In order to overcome constraints in internet access, each student in the class utilising the Open Textbook was also given a low-cost printed version of the textbook at the start of the course (Figure 3).

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22   https://www.khanacademy.org/about/tos#7

Figure 3: **Students in Treatment Group 2 received printed copies of the Open Textbook on day one of their course**

Methodology

This study employs a mixed-methods approach. The first part of this methodological overview outlines the quantitative methods used to estimate the effect of OER use on students' mathematical course performance and class attendance. The mixed methods used to understand student and teacher perceptions are then described. The two components of the study are complementary in that the mixed-methods component attempts to expand upon and cross-check the quantitative results.

Quantitative method to address research questions 1 and 2: What is the effect of OER use on first-year students' mathematics course performance and class attendance?

In order to answer research questions 1 and 2, a quasi-experiment with non-equivalent control groups was undertaken. Five groups of first-year students in courses in the School of Education and School of Engineering were compared based on the analysis of two scenarios (Figure 4). The three courses were chosen in consultation with IPP academic authorities in order to ensure that each scenario was filled randomly with students pursuing different degrees within each school (Education has four degree streams and Engineering has 12 degree streams).
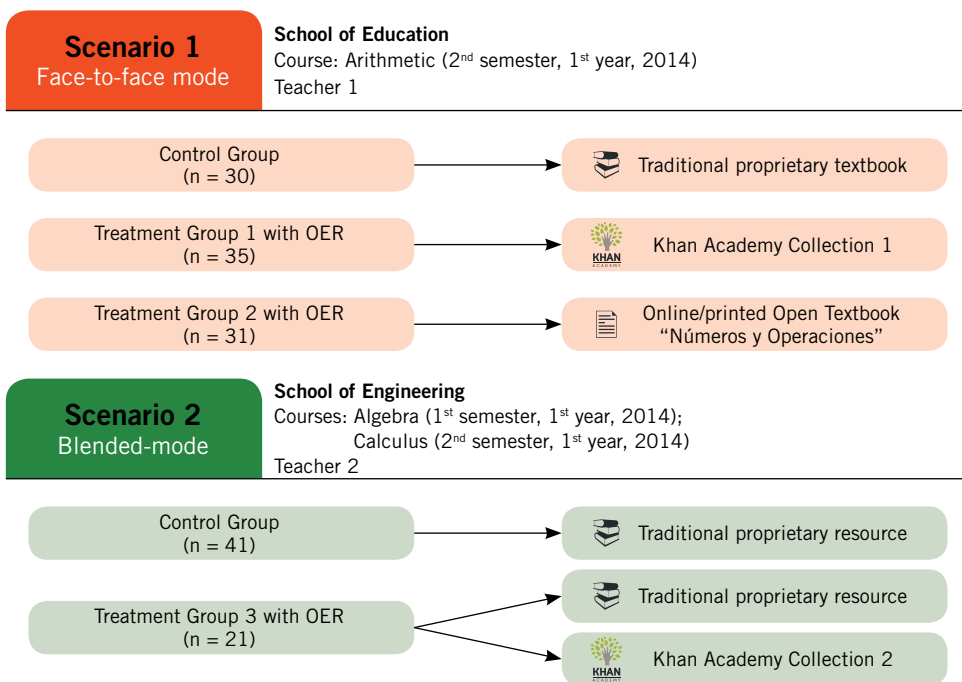
Figure 4: **Overview of scenarios comprising the study**

In Scenario 1, there were three classes in an Arithmetic course in the School of Education offered in a traditional classroom setting (face-to-face mode). The first class (Control Group, n = 30) relied on a traditional proprietary textbook. The second class (Treatment Group 1, n = 35) was taught with the help of Khan Academy Collection 1. And, finally, a third class (Treatment Group 2, n = 31) was taught by means of a custom-designed Arithmetic Open Textbook, *Números y Operaciones* ("Numbers and Operations"). This scenario was enacted during the second term of 2014 over a period of four months. In this scenario, the OER were the sole mandatory resources used by students (as opposed to the proprietary textbook).

Scenario 2 compared two classes in blended-mode Algebra and Calculus courses, delivered across two "bimesters", in the School of Engineering. Students met physically only for tests and the final exam. The first class (Control Group, n = 41 students) relied on a traditional proprietary (institutionally produced) resource. The second class (Treatment Group 3, n = 21 students) used Khan Academy Collection 2. This scenario was implemented during the first and second terms of 2014. In this scenario, the OER was complementary and used in addition to the traditional proprietary resource.

In order to estimate the effectiveness of OER use on students' mathematical performance, an impact analysis database was established, comprising two different datasets. It was envisioned that these data components could provide baseline information against which students' overall progress could be measured.

The first dataset contained information about students in the three student cohorts which comprised Scenario 1. This dataset contained information on which resource grouping each student was associated with (i.e. traditional proprietary, Khan Academy Collection 1 or Open

Textbook), students' course attendance during the term and three specific result variables: (1) students' marks before the final exam, (2) students' final exam marks, and (3) students' final course marks after the exam. This information was provided by the Arithmetic teacher, and was complemented with sociodemographic data on the students (income, mother's education level, age and geographical region of origin) which were sourced in a survey designed for this purpose.

The second dataset contained information regarding students in Scenario 2. The information contained in this dataset was the same as the data captured in the first dataset, the only difference being that in this case there were only two resource groupings (traditional proprietary and Khan Academy Collection 2).

All classes in each course were taught by the same teacher in order to counter potential bias factors arising from different teacher practices.

Mixed methods to address research question 3: What are teachers' and students' perceptions of the OER adoption process?

In order to answer research question 3, a mixed-methods approach was applied in the form of a series of semi-structured interviews, a focus group discussion and a student survey. Specifically, the students who used the Khan Academy collections or an Open Textbook (in face-to-face as well as blended mode) were asked to participate, in light of the fact that they were the groups with direct exposure to OER.

This component of the study provided an opportunity to gain a better understanding of the association between OER and improved mathematics course performance, and to better comprehend end-user (learners' and teachers') perceptions of the benefits and challenges related to their experience of using OER. It involved the implementation of the following research processes over the three-month period between June and August 2015:

- One semi-structured interview with a student from Scenario 1, Treatment Group 1 (n = 1).
- Two semi-structured interviews with students from Scenario 1, Treatment Group 2 (n = 2).
- One focus group discussion with students from Scenario 1, Treatment Group 2 (n = 5).
- Two semi-structured interviews with Teachers 1 and 2 (n = 2).

Given that students participating in the blended-mode course were spread throughout the country, it was not possible to conduct a focus group discussion with students in Scenario 2.

Based on the data provided by participants in this initial qualitative phase (n = 10), an online survey was designed in order to gauge student perceptions regarding their use of OER. The categories utilised in the survey were drawn from the interviews and focus group discussion with students and teachers. A total of 49 students from Scenarios 1 and 2 were surveyed following an open call for survey participation. The low number of respondents was largely due to the high dropout rate in the course, resulting in a relatively small pool of students who could be drawn upon.

The survey probed students' perceptions of OER use, focusing specifically on their evaluation of a number of resource characteristics, problems identified and recommendations

for better use of these resources in the future. Lime Survey,[23] an online open source survey tool, was used to administer the survey.

Quantitative data analysis

With the various comparison groups and scenarios now defined, it is necessary to demonstrate if and how these groups can be compared in order to estimate the effect of OER use on student mathematical course performance.

The effect of OER use was estimated for each of the two scenarios through two separate processes. The first compared performance results between students of the three classes in Scenario 1 to establish whether students of the two Treatment Groups obtained different results to those of the Control Group. The second process conducted the same comparison between the two classes of the blended mode (Scenario 2) to ascertain whether students who used Khan Academy Collection 2 obtained better results than those who used the traditional textbook.

In all comparison processes, the effect of the use of OER among the first-year students was measured as the difference of a result variable of students having used OER (or not) during their studies. This can be represented as follows:

$$\Delta_i = Y_{i,D=1} - Y_{i,D=0}$$

Where $Y_{i,D=1}$ is the result of the student if he/she received the treatment[24] and $Y_{i,D=0}$ is the result of the student if he/she did not receive the treatment.

The problem with this formula is that it is not possible to know, in the same time period, the result that the student would have had in both situations (of receiving the treatment and not). Based on this limitation, it is necessary to make inferences about the results that a treatment student obtained. Even though it is not possible to know this for only one student, the average impact for a group of students can be estimated as far as two statistically equal groups are compared. In this case, the average effect is the average result in a result variable of those students who used OER, minus the average of those students who did not use OER in their courses. However, as this is a quasi-experiment with non-equivalent control groups, the group of people who received the treatment is not statistically equal to the group of students who did not receive the treatment.

When comparing both groups there is a possibility that they may have observable and unobservable differences, making them incomparable. One way to address this problem is to randomly assign students to the Treatment and Control groups. This means that from the 100% of students who participated in the study, we randomly selected those students who would use OER in their courses and those who would not use them. Because it is not always possible to randomly assign people to Treatment and Control groups, one sometimes has to look for alternative methodologies that assure the comparability of both groups.

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23   https://www.limesurvey.org
24   In the context of this study, to be "treated" means that a student took a course that included the use of OER as a compulsory element of the learning process.

In the case of this research study, students were pseudo-randomly assigned[25] to the comparison groups; therefore, in order to estimate the effect of the treatment, one merely has to compare means of the result variables of both groups through mean difference tests. In order to be more certain that groups are statistically identical, the study also applied a quasi-experimental methodology known as Propensity Score Matching (PSM) (Dehejia & Wahba, 1999; Heckman, Ichimura, Smith & Todd, 1998; Rosenbaum & Rubin, 1983).

PSM is a technique used for impact evaluation studies, and is based on the estimation of the probability of receiving a specific treatment. In this sense, the PSM takes cognisance of the selection bias by comparing Treated and Control groups with the same probability of being treated. The fact of having been taught with the use of OER is first modelled using a set of observable variables that could affect the situation and influence the result. The probability of being treated is then predicted, the outcome of which is used to match students that received and did not receive the treatment in order to define two groups with the same probability of having participated in a course that included the use of OER. Finally, the effect is calculated as the difference in the results of both groups.

In order to estimate the effect of the use of OER on mathematical course performance, once the probability of being treated was calculated, it was necessary to define the mechanisms through which Treated and Control students would be compared. There are different ways to do so. This study used the Inverse Probability Weight matching algorithm, which compares the results of individuals from the Control Group that are most similar compared with Treated individuals, giving a greater weight in the estimations to those Control individuals who have a higher probability of being Treated and less weight to those Control individuals with a lower probability of being Treated (Imbens & Hirano, 2002).

In sum, when comparing students' results in the two scenarios, this study examined result variable means of the Treatment and Control groups through both mean difference tests that directly compare group means and tests that consider PSM in their estimations.

The last elements that had to be defined regarding these estimations were the results variables. These are the measures that were used to compare the Treatment and Control groups regarding the subject upon which the use of OER is supposed to have an effect. The result variables used in this study were:

- Student results in the final exam of the evaluated course.[26]
- Student final grades in the evaluated course.
- Percentage of student attendance (in the case of Scenario 1).

Each of these result variables was used as a dependent variable in ordinary least squares models that have as an independent variable a dummy variable that indicates whether the student was part of Treatment or Control groups, and several variables about students' sociodemographic characteristics that were used as control variables.[27] Moreover, in order

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25 The process of allocating students to comparison groups is considered "pseudo-random" in that there was not a rigorous group allocation process, taking into account specific variables that could have influenced the study. Administrative staff were asked to assign students in each class according to their date of registration – in the sense that the first student who registered was assigned to the first class, the second student to the second class, and so on. This process had a random element, but it cannot be stated that students were rigorously distributed among the different classes of each course.

26 This exam is exactly the same for every student in each of the examined scenarios.

27 These control variables included age, family income and number of education years of the mother.

to have more comparable results, all result variables were standardised so that analyses of OER effects could be conducted in terms of standard deviations.

Mixed-methods data analysis

Once transcribed, qualitative data from interviews and focus group discussion were analysed using a content analysis technique, whereby the more recurrent ideas presented in the analysis were identified and grouped. Content analysis is a research technique that aims to be an objective, systematic and quantitative study of the manifest content of communication (Berelson, 1952).

Information was therefore organised according to the questions posed to the students and teachers who used both sets of OER in Scenario 1. In each of the investigated aspects, first responses or key ideas shared by the two profiles and refer to the two types of OER were pooled; then, in the second stage, the most relevant and specific points regarding use of the Open Textbook or Khan Academy Collection 1 were identified and disaggregated.

Data sharing

The data utilised to assess performance in the first phase of this study, as well as Spanish-language instruments and transcripts of the student focus group discussion and teacher interviews, have been published on the DataFirst Data Portal[28] after undergoing a multi-phased quality assurance and de-identification process. The author and the Research on Open Educational Resources for Development Curation and Dissemination team checked data files for consistency and correctness, whereafter a de-identification process was undertaken utilising an omission and revision strategy.

The resulting dataset, published under a Creative Commons Attribution (CC BY) licence, is comprised of the interview transcripts shared in Rich Text (.rtf) and Excel (.xlsx) formats, survey data shared in CSV, SAS, SPSS and STATA formats, as well as data collection instruments, a dataset description, a project description and a de-identification overview in PDF format.

Findings

Estimation of the effect of OER use on student mathematical course performance

OER effect in School of Education face-to-face Arithmetic course (Scenario 1)

The first approach analyses students' mathematical course performance considering only academic results of first-year undergraduate students enrolled in the face-to-face mode Arithmetic course offered by the IPP School of Education in the second term of 2014 (Scenario 1).

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28   https://www.datafirst.uct.ac.za/dataportal/index.php/catalog/577

Table 1 shows the effect of OER use when comparing the Treatment Group 1 (n = 35) and the Control Group (n = 30). It estimates the effect of the use of OER (in this case, Khan Academy Collection 1) in comparison with the use of a traditional textbook, considering the three result variables previously described.

Each coefficient shown in the first row of Tables 1 to 6 describes the effect of the use of Khan Academy Collection 1 in relation to the Control Group in terms of standard deviation, while the second row specifies the standard deviation of these effects. In simpler terms, these coefficients indicate the average difference between Treatment Group 1 and the Control Croup regarding three result variables when controlled for other variables, namely age, family income and number of education years of the mother.

Table 1: **Estimation of the effect of using Khan Academy Collection 1 versus the traditional textbook**

Attendance	Final exam	Final course score
-0.90**	0.66**	0.15
(0.28)	(0.29)	(0.30)

*** = p < 0.01; ** = p < 0.05; * = p < 0.1; n = 65*

All tables represent the effect of a dummy variable, where 1 = use of OER and 0 = no use of OER, in several regression models that separately used each of the result variables as the dependent variables.

The first coefficient indicates that the use of Khan Academy Collection 1 had a negative effect of 0.9 standard deviations on student attendance levels, which is significant at the 5% level. This means that students in the Control Group have significantly higher levels of attendance than those who used OER. Table 1 also shows that the effect of OER on students' final exam marks was positive and significant at the 5% level of significance. These results indicate that students who used the Khan Academy Collection 1 had significantly better examination results than those who did not use it. However, when we consider students' final grades in their courses (tests and final exam, in which the final exam constitutes 40% of the final grade), there is no significant difference between the comparison groups.

Table 2 shows the same estimations as in Table 1 (Scenario 1: Treatment Group 1 versus Control Group), but in this instance each effect was estimated with the PSM method to make both groups more comparable.

Table 2: **Estimation of the effect of using Khan Academy Collection 1 versus the traditional textbook (using PSM)**

Attendance	Final exam	Final course score
-0.86**	0.54*	0.13
(0.36)	(0.30)	(0.33)

*** = p < 0.01; ** = p < 0.05; * = p < 0.1; n = 65*

In this estimation, and all others done with the PSM method, sample size is reduced due to the fact that PSM only considered students with a specific probability of being treated.

It can be observed that results are very similar to what was found without the use of PSM.[29] The use of Khan Academy Collection 1 had a negative effect on attendance (-0.86) and a positive effect on final exam grades (0.54), but no effect regarding students' final course scores. This reaffirms the suggestion that OER appear to improve students' examination performance, but decrease their attendance levels. The second exercise compared Treatment Groups 1 and 2 of Scenario 1 (i.e. the class that used Khan Academy Collection 1 and the class that used the Open Textbook as the sole resource). Table 3 shows the effect of using Khan Academy Collection 1 versus the Open Textbook (n = 66). The data indicate that those students who used Khan Academy Collection 1 had significantly lower attendance levels than those who used the Open Textbook.

Table 3: **Estimation of the effect of using Khan Academy Collection 1 versus the Open Textbook**

Attendance	Final exam	Final course score
-1.38***	1.49***	0.21
(0.21)	(0.18)	(0.25)

*** = p < 0.01; ** = p < 0.05; * = p < 0.1; n = 66

The use of Khan Academy Collection 1 had a negative effect on attendance of -1.38 standard deviations. Moreover, it was also observed that students who completed their courses with the help of this resource obtained better results in their final exam when compared with students who used the Open Textbook as the sole resource. The magnitude of this effect is 1.49 standard deviations, which means the Khan Academy Collection 1 OER had a strong effect on students' final exam results when compared with the results of students who used the traditional textbook. However, the results also indicate that OER use had no effect on students' final scores (tests and final exam) in their courses.

Table 4 compares students who used Khan Academy Collection 1 with students who used the Open Textbook (Scenario 1), but through the PSM estimation method.

Table 4: **Estimation of the effect of using Khan Academy Collection 1 versus the Open Textbook (using PSM)**

Attendance	Final exam	Final course score
-1.24***	1.55***	0.28
(0.25)	(0.20)	(0.24)

*** = p < 0.01; ** = p < 0.05; * = p < 0.1; n = 66

As in the first examined comparisons, similar results are obtained when the estimation method is changed. It can be seen that the effect of the use of OER on attendance is negative and significant at the 1% level of significance (-1.24). Moreover, it is observed that students who used Khan Academy Collection 1 had significantly higher exam results than

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29   This was expected due to the fact that students were assigned to each group in a pseudo-random way, which made both groups comparable without the use of PSM.

those who used the Open Textbook, and that there was no effect with respect to final course scores. This result reaffirms that use of Khan Academy Collection 1 had a more positive effect on students' final exam performance than the traditional proprietary textbook (Control Group) or the Open Textbook (Treatment Group 2).

Table 5 presents the final analysis concerning Scenario 1, evaluating whether those students who were taught through the use of the Open Textbook obtained better results than those who were taught with the traditional textbook (n = 61). It shows that the only result variable where significant differences were found was the final exam score. This difference does not, however, have the expected direction as it is observed that the use of the Open Textbook has a negative effect of -0.88 standard deviations on students' final exam grades, which is significant at the 1% level of significance. This means that students who were taught with the traditional textbook have higher exam grades than students who were taught with the help of the Open Textbook. Regarding attendance levels and final course scores, Table 5 shows that it did not make any difference whether students were taught with the help of the Open Textbook or with the traditional textbook.

Table 5: **Estimation of the effect of using the Open Textbook versus the traditional textbook**

Attendance	Final exam	Final course score
0.51	-0.88***	-0.10
(0.29)	(0.25)	(0.30)

*** = p < 0.01; ** = p < 0.05; * = p <0.1; n = 61

Table 6 shows that when the same comparisons are made using the PSM method, similar results are obtained to those in Table 5.

Table 6: **Estimation of the effect of using the Open Textbook versus the traditional textbook (using PSM)**

Attendance	Final exam	Final course score
0.11	-0.80***	-0.14
(0.33)	(0.25)	(0.27)

*** = p < 0.01; ** = p < 0.05; * = p < 0.1; n = 61

The exam score is again the only result variable where significant differences are found and the direction of this association is negative. These results appear to confirm that the use of the Open Textbook in this examined course did not improve students' academic performance.

OER effect in School of Engineering blended Algebra and Calculus courses (Scenario 2)

This section analyses the effect of OER on student performance in Scenario 2. In this case, the examined course was a blended-mode course on Algebra and Calculus offered by the School of Engineering in the first and second semesters of 2014. In this scenario, a Control Group (n = 41) relied on a traditional proprietary resource, while Treatment Group 3 (n = 21) utilised Khan Academy Collection 2.

The data presented in Table 7 show that there were no significant differences in either of the two results variables analysed in this scenario. There was no significant difference between those who used Khan Academy Collection 2 and those who used the traditional resource in terms of improved final exam grades or final course scores. As this was a mostly online course, attendance levels were not used as a result variable.

Table 7: **Estimation of the effect of using Khan Academy Collection 2 versus traditional resource**

Final exam	Final course score
-0.22	0.12
(0.30)	(0.31)

*** = p < 0.01; ** = p < 0.05; * = p < 0.1; n = 62

When the same two estimations are calculated with the PSM method in order to make both groups more comparable, similar results are obtained (Table 8). Neither of the effects is statistically significant, which means that the use of OER did not result in a discernible improvement in students' mathematical performance in the blended course.

Table 8: **Estimation of the effect of using Khan Academy Collection 2 versus traditional resource (PSM method)**

Final exam	Final course score
-0.26	0.04
(0.29)	(0.28)

*** = p < 0.01; ** = p < 0.05; * = p < 0.1; n = 62

In sum, analysis of the effect of OER (Khan Academy Collections 1 and 2 and the Open Textbook) on students' mathematical performance in the two scenarios shows that only in Scenario 1 can it be observed that some students who used OER obtained significantly better academic results than students who relied on the traditional textbook (i.e. when students were taught with the help of the Khan Academy Collection 1). In this same scenario it was also observed that students who were taught with the traditional textbook obtained better results than those who were taught with the Open Textbook. In relation to Scenario 2, non-significant effects were found.

Student and teacher perceptions of the use of OER

In this section, findings regarding teacher and student perceptions of the experience of using OER are examined.

Data are presented according to the different themes that informed the questions posed to students and teachers who used OER during the initial qualitative phase. The views of students and teachers are presented for each of these aspects. In addition, where possible, qualitative data are complemented with information obtained from the student survey that was developed based on the qualitative initial-phase results.

Student and teacher experience of using OER

Overall, students and teachers in the study felt satisfied about the use of OER. They pointed out that OER were important tools in supporting the deployment of the courses, and their use was therefore beneficial to both students and teachers.

Khan Academy collections

In the case where Khan Academy Collection 1 was used (Scenario 1), teachers and students pointed out that these resources provided them with vital support, contributing to the achievement of different types of learning outcomes in the face-to-face classroom mode, as well as in the home environment. In both scenarios, teachers positively highlighted the characteristics of the Khan Academy collections as having appropriate theoretical content and corresponding practical exercises that allow students to easily comprehend the content. Students considered the resources to be user friendly and felt that the various mechanisms of the platform enabled them to learn easily.

Regarding use of Khan Academy Collection 2 (Scenario 2), the evaluation of the experience was also positive for both classes that utilised OER. It was considered a very good support mechanism in terms of providing complementary material, and was also reported to be dynamic. From the point of view of the students, it provided a way to support learning more comfortably, in a more visually appealing manner – and even sometimes, for some students, more effectively – than was the case when using the traditional textbook.

> It is complementary, because it replaces a teacher more efficiently, because I can repeat, repeat, repeat and I see the result and I can move forward ... Because sometimes the texts are not as motivating when you're tired ... Sometimes, it is as if very pedagogical things make you go to the next step, they get you excited. (Student, Treatment Group 1, Scenario 1)

> It was very pedagogical, didactic. I liked it better, because other Algebra classes I had had – or related to mathematics – included very little support material other than documents, texts, it was not enough. (Student, Treatment Group 3, Scenario 2)

Open Textbook

Teachers and students also spoke of the experience of using the Open Textbook as beneficial. Students indicated that they used the Open Textbook instead of the traditional proprietary textbook in Scenario 1 in order to engage with content covered in the course syllabus, and as a means to continue their exercises at home. As a positive factor, they emphasised that the use of the resource was voluntary and was never positioned as being obligatory by the teacher.

In terms of the Wikibooks platform on which the Open Textbook was hosted, the teacher highlighted the positive aspect of being able to intervene and directly edit the resource, as well as the fact that she could access information regarding how often and what type of exercises were being used by the students.

> It was personal, in fact, the teacher gave it to us and everyone decided what they wanted to do ... Sometimes he also recommended the book, saying that in certain page there were exercises about what we had seen that day ... Yes, but it was not as an obligation, she made us see that it was a kind of help. (Student, Treatment Group 2, Scenario 1)

With respect to the use of OER, the survey (n = 49) provided a means to examine levels of use. Students were asked to indicate their approximate frequency of use based on an ordinal variable with six categories, ranging from "no use" to "use it every day". Based on these data, the frequency of use was shown to be dissimilar: while 12% did not use it, or did so sporadically, a similar percentage reported daily use of this resource. The most frequently cited use of the resource was once a week (35%).

We can also compare levels of use by student attributes. Given the small sample size (n = 49), the six original categories of the variable frequency of use were captured in two categories: one that included students who used it once a week or less, and another that included those who used it more than once a week. In this regard, the data in Table 9 suggest that the Khan Academy collections were used far more frequently than the Open Textbook: 62% of those who used the Khan Academy collections declared that they used these more than once a week, while 30% of Open Textbook users reported this frequency.

Table 9: Frequency of use by resource type, age group and income category (n = 49)

		Once a week or less (%)	More than once a week (%)
Resource type	Khan Academy collections	38	62
	Open Textbook	70	30
Age group	19–24 years	62	38
	25 years and over	43	57
Monthly household income	USD 400 and below	62	39
	Over USD 400	39	61
Total		**51**	**48**

These data show that OER as a joint category was most frequently used by older students (57%) and those from higher-income families (61%). The latter could be explained hypothetically by the greater likelihood of higher-income students having access to these resources in their own households on personal computers or electronic devices.

Student and teacher perceptions of platform functionality

The second general aspect examined in terms of student and teacher perception is the overall assessment of Khan Academy and Wikibook web platform functionality. Both scenarios highlighted certain characteristics or applications as positive or negative (depending on the resource in question).

Khan Academy

In the case of the Khan Academy, teachers in Scenarios 1 and 2 provided specific opinions about the differing learning mechanisms the platform provides. They highlighted the following positive features: the fact that levels of difficulty increase according to student progress; the fact that the use of video is more appealing to students than text-based resources (and may therefore improve their learning levels); and the fact that when students perform an exercise poorly, the hint system offered by the platform motivates them to keep trying until they achieve the correct result.

From the teacher perspective, the only thing that did not work well was the Khan Academy reward system, which was perceived as a "childish" mechanism for higher education students.

> The use of Khan was very didactic, because it has different areas, in the preparation part, application and theory, giving students enough explanations if they do not understand an exercise. So I found Khan very useful, not for the whole class, but certainly for several parts of it. (Teacher 1, Scenario 1)

Students in Scenarios 1 and 2 provided positive feedback on the functionality of the Khan Academy platform. They emphasised the speed of connection to the site and ease of use as features that contributed to good performance.

> It was a good experience because when you were completing an exercise, for example if there was something you did not understand you had the possibility of using YouTube to understand through videos or online with other teachers. You can understand it, it is easy to understand. (Student, Treatment Group 1, Scenario 1)

Wikibooks

The general functionality of the Wikibooks platform, as well as the ancillary resources and applications it contains, were evaluated by teachers and students in Scenario 1. Both cohorts highlighted how useful the printed version of the book was, in that it served as a supportive, complementary resource that allowed students to learn about alternative ways to create exercises and solve problems. Also positively highlighted were the fact that the

platform allowed students to undertake exercises at their own pace; the level of interaction provided by the application; and the coherence between the functionality of the digital media and the printed book.

The ability to edit content was highlighted by Teacher 1, who could modify the language of the exercises, and by students, who also used the language editing function.

> It allowed me to edit it and be constantly checking it. My students also liked it for that matter. They liked being able to edit it, to be participants of their own book. (Teacher 1)

> We created the Wikibooks account and we could see the same subject matter we were studying in class there. We could also find it in the account. And besides, we could improve ourselves by making up exercises and uploading them to the account and support ourselves with the book. (Student, Treatment Group 2, Scenario 1)

Student survey responses relating to the use of OER

Evaluating the functionality of the OER used was an important element of the student survey, which complemented initial information obtained in the qualitative phase. Results from student perceptions represented in the survey are presented in three different ways: first, the distribution of student responses is analysed at different levels according to 39 statements in the student survey about different aspects relating to the use of OER; second, an evaluation index of OER is generated from the 39 statements, analysing the average of this index as a number of respondents' attributes; and third, responses to evaluation questions that inquired directly into how students rated different aspects of the OER on a scale of 1 to 7 are examined.

Figure 5 presents statements of the survey that reflect a positive view of the OER used. From these data we can see that a large majority of students from Scenarios 1 and 2 agreed with all the positive statements about OER. In most cases, the responses "agree" or "strongly agree" reach 80% or more. In particular, those aspects for which there is greatest consensus are related to the use of video as a medium which stimulates teaching, feedback delivery and ease of study – all with more than 90% of answers as "agree" or "strongly agree".

Figure 6, by contrast, presents statements where agreement implied a negative view of OER in general. In this instance, the percentage of cases where students expressed their agreement around issues of usability of the resources and platforms led to confusion and a less positive sense of OER.
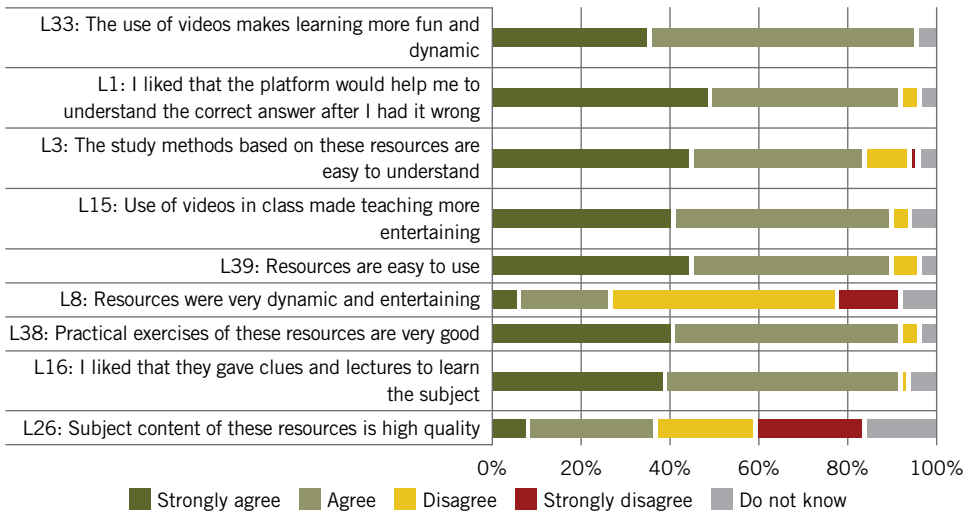
Figure 5: Level to which students agreed with statements regarding positive aspects of OER (n = 49)
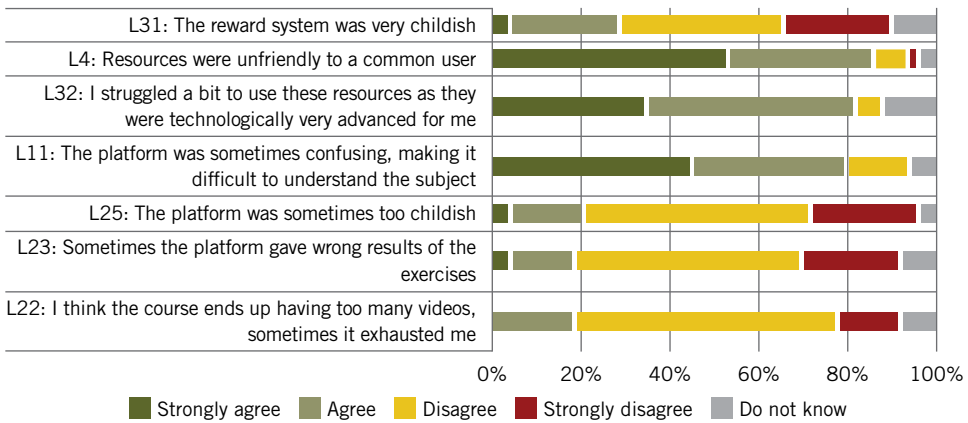
Figure 6: Level to which students agreed with negative statements regarding the use of OER (n = 49)

Figures 7 and 8 present views on the use of OER in specific educational contexts. In terms of the main positive features of OER (Figure 7), the majority of respondents thought that these "resources were a good complement to the course" (86%) and allowed for better understanding of the content (84%). Likewise, up to 83% of respondents felt that the IPP technological infrastructure allowed for good use of these resources. In contrast, only 38% of respondents said their teacher had adequate knowledge to use the tools required.
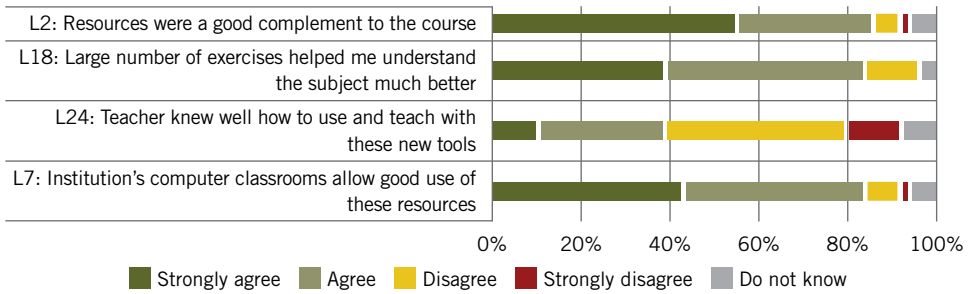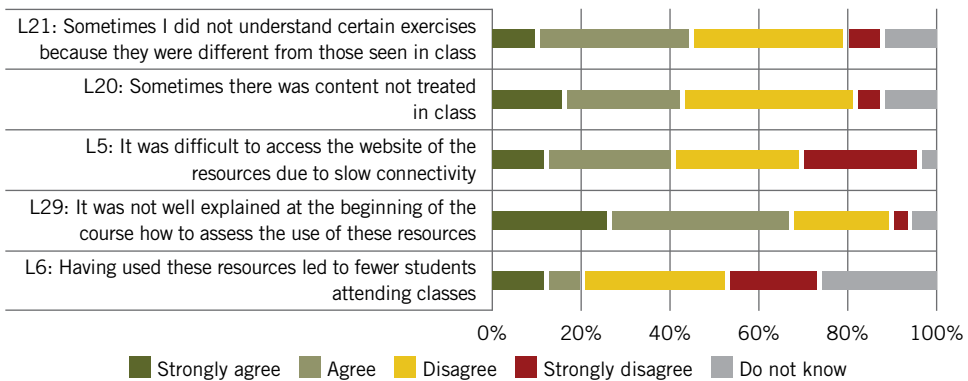
Figure 7: Level to which students agreed with positive statements regarding the general use of OER in a specific context (n = 49)

Figure 8 presents negative aspects associated with the use of OER in Scenarios 1 and 2. Just over 40% of students identified problems associated with inconsistency between content presented in the classroom and the OER. They also pointed out the challenge of slow internet connectivity in terms of accessing OER online via IPP infrastructure (40%), and the lack of information provided at the beginning of the course on the evaluation mechanisms used (67%). Moreover, only 20% expressed that the use of OER affected attendance.

Figure 8: Level to which students agreed with negative statements regarding the general use of OER in a specific context (n = 49)

Figure 9 presents an evaluation of the personal experience of using OER, which was generally positive. In this regard, around 90% of respondents said that the resources helped them study, they enjoyed the experience, they preferred these resources and the OER improved their learning outcomes.

Also positive was the fact that between 70% and 80% of respondents liked the resources as they could be used at home, were fun to engage with and helped with personal mathematical problems. Over 60% also said that they would not have performed as well without these resources.
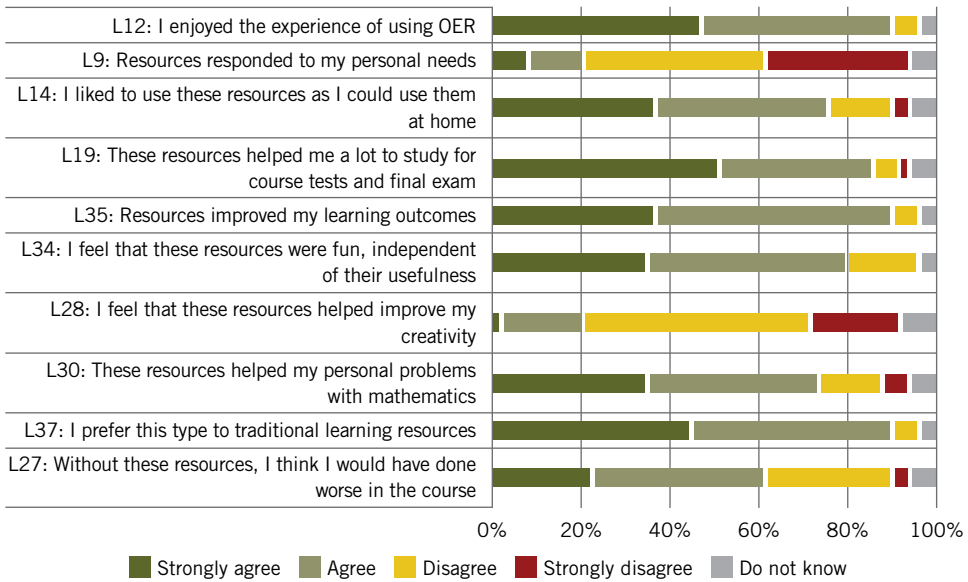
Figure 9: **Level to which students agreed with statements regarding their personal experience of using OER (n = 49)**

Figure 10 contains various statements that relate to recommendations for general use of OER. In this regard, 84% would recommend these resources to other students, and 84% were in favour of extending their use to all subjects. Almost half of the respondents (47%) said that their use should be optional, not mandatory. A total of 61% were in favour of being evaluated on their use of these resources, while 35% rejected it.
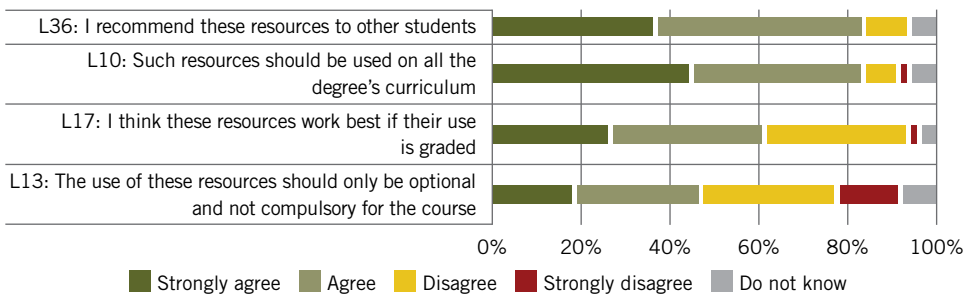

Figure 10: **Level to which students agreed with recommendations regarding OER use**

Following analysis of the perception of the resource in its various dimensions for the total sample, the next step is to review some of the statements made about OER by users of the different resources. Even though the evaluation of OER by the students of both Scenarios 1 and 2 is similar in most of the dimensions studied, some differences can be highlighted.

"The resources led to fewer students attending contact-mode classes"

Figure 11 shows that while 70% of Open Textbook users argued that its use did not affect attendance, only 41% of the Khan Academy collection users held this opinion, while a high percentage (38%) answered that they did not know.
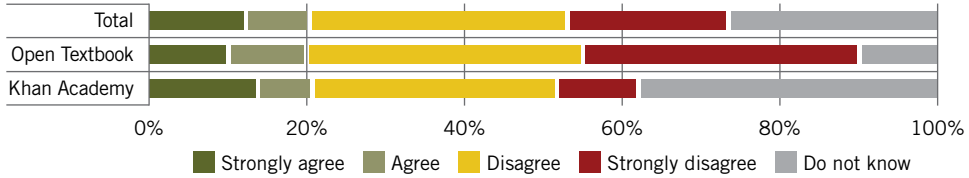

Figure 11: **Level to which students agreed with the statement that OER led to lower attendance in Scenario 1 (n = 49)**

"The use of these resources should be optional and not compulsory"

Another important difference can be seen in Figure 12: almost 65% of Open Textbook users agreed with the statement that the use of this resource should be optional, while only 34% of Khan Academy collection users thought so.
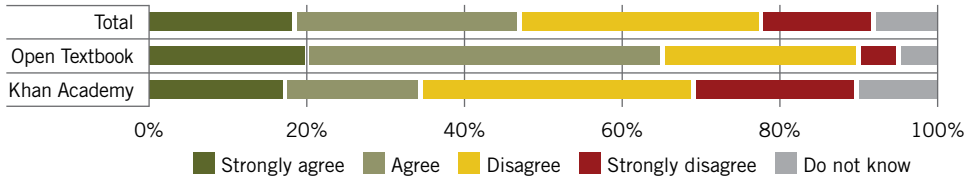

Figure 12: **Level to which students agreed with the statement that the use of OER should be optional and not obligatory (n = 49)**

"My teacher taught us well on how to use these resources"

Figure 13 shows that 45% of students using the Khan Academy OER thought their teachers were able to teach them how to use the resources effectively, while only 30% of the Open Textbook users agreed that their teacher knew how to use the resource.
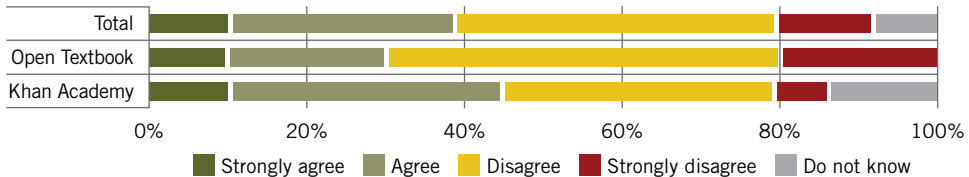

Figure 13: **Level to which students agreed with the statement that teachers taught them well on how to use resources (n = 49)**

"I think the course ends up having too many videos, sometimes it exhausted me"

Another important difference relates to the belief that both types of OER contained too many videos. In this regard, Figure 14 shows that although only a minority in both groups believed that the use of video was excessive, this view was held by a discernibly lower number of Open Textbook users (10%) than Khan Academy collection users (24%). No respondents indicated that they "strongly agree" with the assertion.
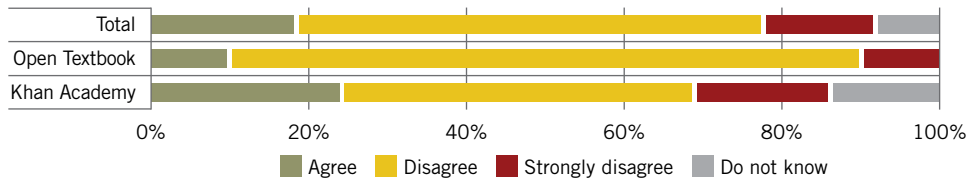

Figure 14: Level to which students agreed with the statement that the course ends up exhausting them because there is too much video in the OER (n = 49)

"The platform was sometimes too childish"

A final observable difference, presented in Figure 15, relates to the level of agreement that the Khan Academy and the Open Textbook platform were too simplistic, or "childish". Only 20% of both Khan Academy and Open Textbook users agreed that the resources were too simplistic or "childish", while 80% of Open Textbook users and 72% of Khan Academy users disagreed.
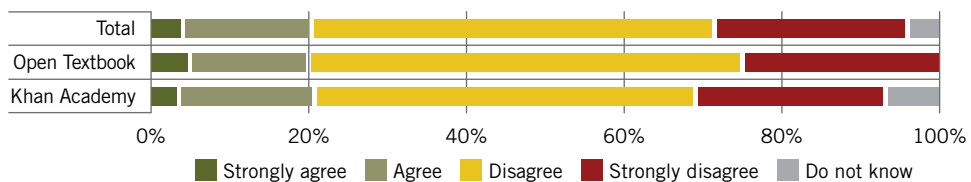

Figure 15: Level to which students agreed with statements about a negative "childish" characteristic of OER (n = 49)

The second level of analysis for evaluating student survey responses relating to the use of OER involved the generation of an index. For this purpose, an index value was calculated for each respondent based on information from 37 of the 39 survey items developed using a Likert scale, noting that agreement with two of these items does not imply positive or negative evaluation of the resource. To develop this index, affirmations where agreement implied a negative evaluation of the resource were recorded to allow that the highest score in each item entailed a higher evaluation. In other words, index ranges between 1 and 10 were established from the information of the 37 items, with 10 being the highest rating. This scale was also tested regarding its internal consistency, with a Cronbach Alpha reliability coefficient of 0.93 being established (implying that the scale has good internal consistency).

Table 10 shows the average of this index as a number of characteristics of respondents. It is noted that, although averages of the groups being compared are fairly similar, there may

be some differences. First, we see that Open Textbook users had a slightly more positive evaluation than the Khan Academy collection users (7.17 versus 6.97). At the same time, the younger respondents had a greater appreciation of the use of OER, as the group aged 19–24 had an average of 7.25, while the group aged over 25 had an average of 6.91.

Table 10: **OER use evaluation index mean by resource type, age group and income category (n = 47)**

		Mean
Resource type	Khan Academy collections	6.97
	Open Textbook	7.17
Age group	19–24	7.25
	25 and over	6.91
Household monthly income	USD 580 and under	6.91
	Over USD 580	7.24
Level of use	Once a week or less	6.95
	More than once a week	7.17
Total		**7.06**

Table 10 also shows that students with higher incomes and those with a higher level of use revealed a more positive evaluation of OER. This could be explained by the previously described phenomenon in which those who declared having higher incomes used OER more frequently.

Evaluation questions inquiring how students rated different aspects of OER
The final analysis of student survey responses relating to the use of OER involves analysing how students evaluated different elements of the two kinds of OER. Specifically, respondents were asked to rate, on a scale from 1 to 7, different aspects involved in the use of OER, with 7 being the best possible score. Figure 16 shows that in all evaluated aspects the majority of respondents assigned 6 or 7 points, and 90% or more assigned at least 4 points. The exception was the rating of infrastructure and equipment at IPP.
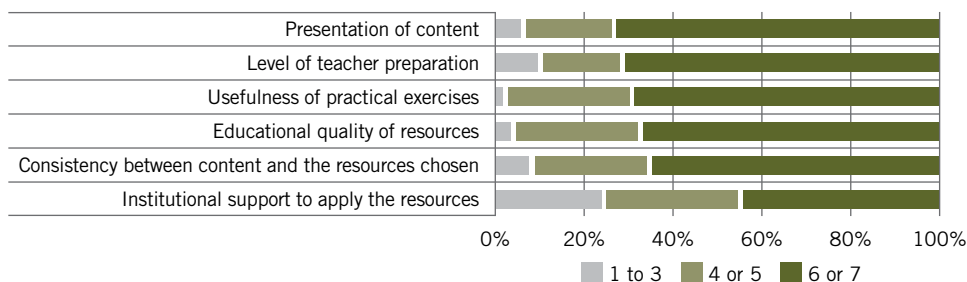

Figure 16: **Level (scale of 1 to 7) to which students agreed with statements about how they evaluate the use of OER (n = 49)**

This analysis of the various aspects related to the use of both OER can also be examined against the particular resource in question. Table 11 shows the averages obtained in each area according to the type of resource used by students. The comparison shows that higher averages are obtained in all aspects by Open Textbook users.

Table 11: Evaluation of different aspects of the use of OER on a scale from 1 to 7 (mean) by resource type and age group (n = 49)

Aspect of OER use	Resource type			Age group	
	Total	Khan Academy collections	Open Textbook	19–24	25+
Educational quality of resources	5.82	5.72	5.95	5.86	5.79
Usefulness of delivering practical exercises	5.90	5.69	6.20	6.23	5.64
Presentation of subject content	5.98	5.66	6.45	6.23	5.79
Consistency between content covered in the class and content covered in the resources	5.80	5.59	6.10	6.20	5.50
Level of teacher preparation	5.90	5.52	6.45	6.40	5.50
Institutional support to apply resources	4.76	4.17	5.60	4.95	4.61

Table 11 also shows evaluation by age group. In all aspects the group aged 19–24 gave better evaluations of the different dimensions of OER use. The biggest differences are in the level of teacher preparation and consistency between the subjects of the classes and those treated in the resource, where younger students provided a more favourable evaluation.

Table 12 presents an evaluation of the same dimensions, but according to income group and level of use. Regarding the former, lower-income students provided a more positive evaluation of the different dimensions, particularly as relates to level of teacher preparation and quality of resources. Regarding the latter, those who used the resource most frequently were more positive about the usefulness of the practical exercises.

Table 12: Evaluation of different aspects of OER use on a scale from 1 to 7 (mean) by income group and level of use (n = 49)

Aspect of OER use	Income group			Level of use
	Total	USD 400 000 and under	Over USD 400 000	Once a week or less
Educational quality of resources	5.82	5.96	5.65	5.68
Usefulness of delivering practical exercises	5.90	6.04	5.74	5.72
Presentation of the subject content	5.98	6.03	5.91	5.92
Consistency between content covered in the class and content covered in the resources	5.80	5.92	5.65	5.76
Level of teacher preparation	5.90	6.08	5.70	5.88
Institutional support to apply resources	4.76	4.92	4.57	4.68

Based on the data presented in this section, it can be observed that both forms of OER were positively evaluated by students and teachers. Moreover, the Open Textbook appeared to be more beneficial than the Khan Academy collections. These results could appear contradictory in terms of the data presented in the first part of the Findings section, which suggested that students who used the Khan Academy collections obtained better academic results than those who used the Open Textbook. Moreover, even those students who used the traditional textbook obtained better results than those who used the Open Textbook. This apparent inconsistency can, however, be understood in light of the fact that perceptions about a process do not always concur with the specific results of that process. For example, Open Textbook users highly valued the use of this kind of resource in terms of improving mathematical performance, despite the fact that use of the Open Textbook did not appear to improve their actual grades.

Positive aspects of resource use

The data presented in this section pertain to the most positive aspects perceived by students and teachers regarding use of the two kinds of OER. The qualitative section data reflect that responses vary depending on the resource, with a wider variety of comments being made in reference to Open Textbook use.

Khan Academy collections

Regardless of the study mode (face-to-face or blended), teachers and students highlighted the high level of accessibility of the Khan Academy collections as what they liked most about this platform, with use being possible at IPP, at home or on mobile devices. Blended-mode students also pointed out that the accessibility and stability of the page display was good.

> As I say, it was always available and did not fail. It would have been terrible to be in the middle of an exercise and have the page fail. So that was important to me. (Student, Treatment Group 3, Scenario 2)

Open Textbook

Students and teachers typically agreed on which aspects of the Open Textbook resources they liked most. Among the positive features mentioned, and one of the most frequently cited factors, was the ability to edit content. For teachers, this was a positive factor in that they could adapt content and language to better suit the needs of the class. Consistent with this view, students reported that the aspects they liked most included the ability to edit and upload exercises they created, the fact that the printed book provided valuable support, and the fact that there were many practical exercises.

> It allowed us to edit. Because, for example, I didn't write this book, someone else did. So the language that I use, and the one someone else uses were relatively different, so in some cases, I simplified a few things, I added some exercises or changed some definitions or missing content. (Teacher 1, Scenario 1)

Having identified the most positive aspects of OER use perceived by students and teachers through the qualitative phase, the survey complemented examination of this issue by asking students to select the top three positive aspects of OER from a list of 12. The results are presented in Figure 17, which highlights the contribution of OER to understanding course content, an aspect mentioned by 65% of the students. Other positive features highlighted included explanations being delivered in a more didactic and entertaining way, and the presence of practical exercises.
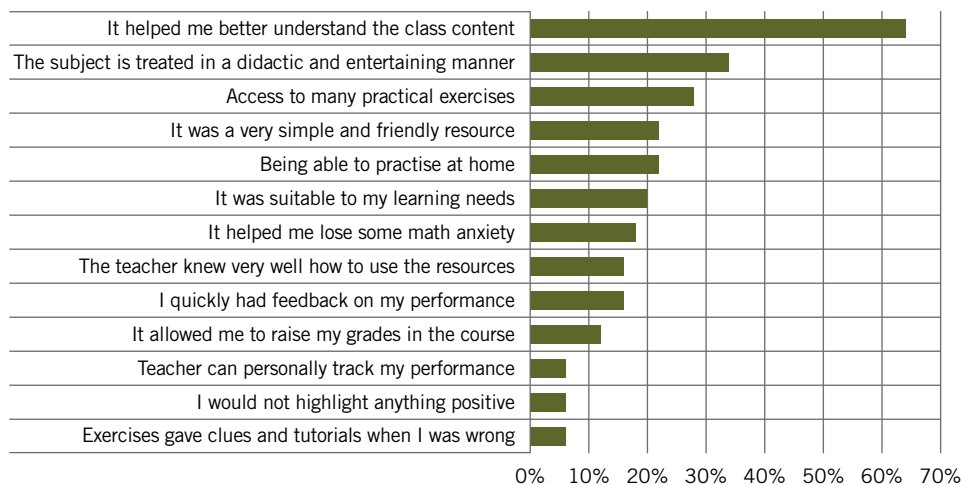

Figure 17: **Level to which students agreed with statements about the contribution of OER to understanding course content (n = 49)**

The benefits presented in Figure 17 can also be examined according to what kind of resource was used. Some notable differences were observed (Table 13). While didactic, entertaining teaching and the fact that exercises could be conducted at home were more prominent features for Khan Academy users, the access to practical exercises and the level of teacher preparation were more important for users of the Open Textbook.

Table 13: **Positive aspects highlighted regarding the use of OER by resource type (n = 49)**

Aspect of OER use	Khan Academy collections (%)	Open Textbook (%)
Helped better understanding of class content	62.1	70.0
Subject treated in a didactic and entertaining manner	44.8	20.0
Access to many practical exercises	20.7	40.0
Ability to practise at home	31.0	10.0
Simple and friendly resource	20.7	25.0
Suitable to learning needs	17.2	25.0
Reduced mathematics anxiety	20.7	15.0
Rapid feedback on performance	10.3	25.0

Teacher proficient in use of resources	6.0	30.0
Facilitated improved grades	13.8	10.0
Teacher can personally track performance	10.3	0
Exercises provide clues and tutorials in cases of error	10.3	0
Nothing particularly positive	6.9	5.0

Main problems in resource use

Another topic analysed was the main problems relating to OER use identified by the study participants. The main problem identified by teachers and students in the qualitative phase was lack of time to use the resource. For both types of OER, teachers identified a longer list of inconveniences. A problem expressed by teachers in both scenarios was that some older students were not familiar with computers, and did not know how to create or use the resources.

> Not everyone used it. I was able to check directly the movements each student did on Khan [Academy]. ... In fact I talked to the kids in a friendly way and at some point I also had to get angry, and ask why. And it was because there was no time; it was mainly because there was no time. (Teacher 1, Scenario 1)

With regards to infrastructure and equipment, Teacher 1 identified infrastructure problems such as a lack of computers and the fact that computers were in poor condition, as negatively influencing optimal use of OER by students. By contrast, students did not generally observe any major problems, although when comparing the two types of resources, more difficulties were perceived by Khan Academy users.

Khan Academy collections

From the point of view of face-to-face mode Teacher 1 (Scenario 1), the most discernible difficulties identified were: slow uptake on the part of the cohort that was supposed to be using the resource (utilising their personal notes instead); the fact that certain aspects of the content covered in the class were not included in the resource; and that some students struggled to understand exercises posed in a different manner to how they would have been presented by their class teacher.

Teacher 2 of the blended-mode courses (Scenario 2) pointed out that some students believed that this mode of delivery was easier and required less commitment than the traditional face-to-face mode. Students therefore tended to put in less effort and sometimes became frustrated and discouraged when they found more complex content or activities that they struggled to solve and did not have a teacher at hand to consult. The low level of student participation was noted as a problem, and, given the fact that the Khan Academy Collection 2 had many videos and educational activities, it was felt that the resource was not used to its full potential benefit.

From the point of view of the face-to-face mode students in Scenario 1, the only problem observed was that the right answer in the case of a particular exercise in Khan Academy Collection 1 was not listed among the answer options, which was communicated to the corresponding Teacher 1.

The blended-mode students in Scenario 2 pointed out that they were initially not adequately informed that the use of the platform was to be assessed, which resulted in a lack of interest at the start of the course.

> I had not understood that it was another grade ... so at first I didn't take it into consideration. So, then I got behind, so I tell you that, at the end I quickly absorbed it, I used it all, but I wasn't really aware what the final goal was. (Student, Treatment Group 3, Scenario 2)

Open Textbook

In terms of Open Textbook use, the level of difficulty in understanding the Wikibooks editing platform (built with the Latex programming language) was identified as a problem by some students, particularly the older ones.

> I had students in that section that were a little older, that in some way had a little reluctance to the Wikibook. Then, in the editing part when they uploaded their exercise, they refused a little, because it was complicated. (Teacher 1, Scenario 1)

The principle difficulties of OER use were also explored in the survey administered to students. Figure 18 shows that 30.6% of respondents reported no particular problem. The main difficulties identified by the rest of the class included the time lag in loading resources, IPP's technological infrastructure, and, to a lesser extent, the lack of time for student use. Only 2% of respondents declared that OER use required a level of knowledge that they did not have.
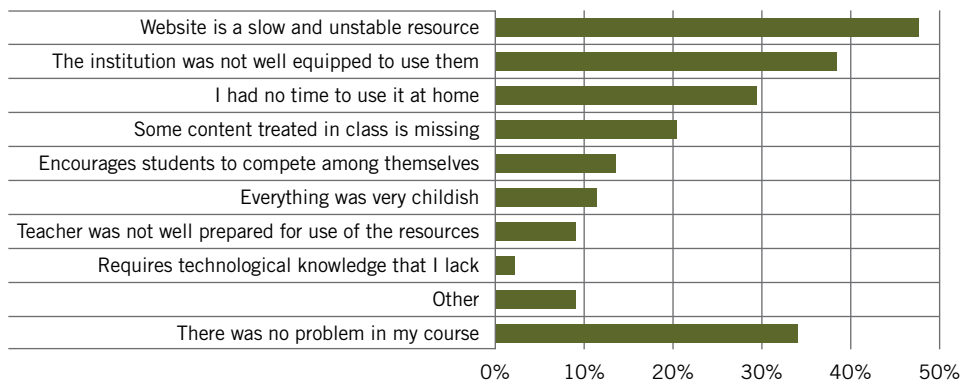

Figure 18: **Level to which students agreed with statements about the perceived difficulties of OER use (n = 49)**

Table 14 presents the difficulties associated with OER use expressed by resource type. Issues related to IPP infrastructure were more prevalent for users of the Khan Academy collections, while difficulties associated with bandwidth and the lack of certain kinds of content were identified by Open Textbook users.

Table 14: Main perceived difficulties of OER use by resource type (n = 49)

Difficulties of OER use	Khan Academy collections (%)	Open Textbook (%)
Internet connectivity	37.9	50.0
Institutional infrastructure	37.9	30.0
No time for use at home	24.1	30.0
Some content covered in class not represented	13.8	25.0
Encourages students to compete among themselves	6.9	20.0
Lack of sophistication	10.3	10.0
Teacher not adequately prepared	10.3	5.0
Required restrictive level of technological knowledge	0	5.0
Other	13.8	0
None	31.0	30

Suggestions to improve OER use

The final topic examined with regard to student and teacher perceptions of OER deals with suggestions to improve OER use. The main suggestion of teachers and students engaged in the qualitative phase was to extend OER use to more subjects. Concerning the observed problems, another shared suggestion mentioned by Teacher 1 was that computer labs should be in working condition in order to optimise the use of learning tools by students.

> For example, starting with computer labs, they must be in good condition so I do not need someone else to help me do my classes. Because it happened to me many times that I took them to the computer lab and half of the computers were inoperable. (Teacher 1)

> It should be used in all sessions for a larger use in mathematics, to complement more, everyone should use it constantly. It should be used by a lot of people. (Student, Treatment Group 2, Scenario 1)

Khan Academy collections

Teachers 1 and 2, who both used the Khan Academy collections, made two suggestions for improvement. First, they suggested changing the reward system, as the current system was seen to lack sophistication. Second, and specifically in the case of Teacher 2, they suggested that the content of the courses should be more coherent with different topics covered in the resources.

Scenario 1 students considered the fact that teachers used competition as an incentive as a negative factor, in the sense that they felt that the environment should be more collaborative. Scenario 2 students suggested that the details of resource use and implications should be better explained earlier in the course.

> I think it would work well if you didn't have to compete. Because teachers tend to do that ... She projected the platform on a screen and showed who

had logged on, who had the highest score, who had less ... It was graded, they gave it a grade. (Student, Treatment Group 1, Scenario 1)

Open Textbook

Students who used the Open Textbook made very specific recommendations. First, they suggested that the printed book should contain more exercises. They also suggested that, since the use of the platform was somewhat complex, it would be a good idea to provide training for teachers before the course.

Yes, because that way we could be told how to use it ... How to do the exercises, because there were definitions of what it was about or how it was done. But without the guidance of a teacher we could not have done it. (Student, Treatment Group 1, Scenario 1)

The student survey helped to deepen findings regarding the main recommendations for improving OER use. In a similar way as was done with the questions about positive and negative aspects of OER use, students were asked in the survey to select up to three recommendations for improving the use of OER from a list of predefined alternatives. According to the results (Figure 19), the most frequently identified recommendations relate to implementing strategies to encourage participation in the use of OER (43%), allocating more time in class to use OER (39%), improving institutional infrastructure for OER use (37%) and expanding OER use to other courses (35%).
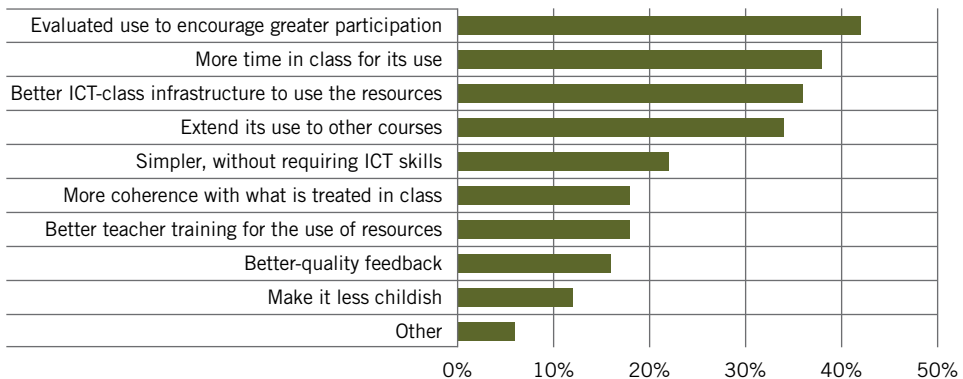

Figure 19: Level to which students agreed with recommendations to improve OER use (n = 49)

Table 15, which highlights recommendations for improving OER use based on resource type, reflects that users of the Open Textbook stated that the OER approach should be expanded to other courses, and that the resource should be easier to implement in the classroom. Khan Academy users recommended that there be more consistency between the content that is taught in the class and what is presented in the resource.

Table 15: Recommendations to improve OER use by resource type (n = 49)

Suggestions for improving OER use	Khan Academy collections (%)	Open Textbook (%)
Evaluate use of the resource in order to encourage greater participation	44.8	40.0
Make more time in class for use	34.5	45.0
Establish better ICT infrastructure	37.9	35.0
Extend use to other courses	27.6	45.0
Less ICT skills required	17.2	30.0
More coherence with what is covered in class	24.1	10.0
Better teacher training	20.7	15.0
Better-quality feedback	13.8	20.0
More sophisticated interface	17.2	5.0
Other	6.9	5.0

Discussion

Research question 1 of this study asked: "What is the effect of OER use on first-year higher education students' mathematics course performance?" The most noteworthy result appears to be that students who used Khan Academy Collection 1 (Treatment Group 1) obtained significantly better exam grades than students who used the traditional proprietary resource ($p < 0.05$) or those who used the Open Textbook ($p < 0.01$).

In Scenario 1, results were consistent in terms of showing that the Open Textbook did not enhance student performance, and that students who were taught with the help of this resource sometimes obtained poorer results than students who used the traditional proprietary textbook. This finding leads to the conclusion that not all kinds of OER have the same effect and that differences regarding types of OER always have to be considered when analysing the impact or efficacy of these resources. Other factors, such as the design of the materials and teachers' expertise in using the platform, also need to be considered.

In Scenario 2, it was found that there was no improvement in mathematical course performance amongst students using OER. This finding should not, however, be considered categorical with regards to the utility of OER in blended-mode course delivery, and should be tested in a larger sample. It may be the case that, in order to take full advantage of OER, there needs to be a teacher who insists on the importance of these resources within the course.

With regard to research question 2, relating to the effect of OER use on class attendance, another important finding was that face-to-face mode students (Scenario 1) who used one of the two types of OER had significantly lower attendance levels than students who relied on the traditional proprietary textbook. This situation might be explained by the fact that when students have access to the infrastructure required to access OER remotely, they tend to work more from home.

With respect to research question 3, related to student and teacher perceptions of the OER adoption process, the qualitative and quantitative material examined reconfirmed

the assumption that OER can be a relevant asset to Chilean students. Qualitative data demonstrated that both teachers and students had a positive experience of using the two types of OER. These positive views were reinforced by the survey results, which demonstrated a positive evaluation of OER. The majority of respondents in the student survey indicated that teaching with OER was more dynamic, resources were easier to use, there was good explanatory and support material, and practical exercises were available. A positive evaluation of the personal experience of using these resources was also observed, as most students declared that they liked using both types of OER, which led to improved learning, and that they would recommend OER use in other subjects as well as in their same degree. Finally, the survey also highlighted the fact that teachers were well prepared in terms of integrating OER into the teaching process.

This positive evaluation of OER contrasts somewhat with findings relating to the first research question on whether the use of OER led to an improvement in student performance. In this first component of the research it was found that only one of the studied groups (Treatment Group 1) performed significantly better in the exam than the group of students who did not use OER. It was also found that the use of the Open Textbook did not improve mathematical performance.

This discrepancy does not have to be understood as an inconsistency in the context of the examined data, since results and perceptions of the learning experience are not necessarily always in accordance. Simply because OER was not found to have a positive effect on the specified result variables, it does not mean that these resources were not seen as useful by students. The data merely suggest that in several considered cases, course averages and exam grades were not significantly higher amongst students using OER versus those who did not use OER. This means that the positive effect perceived by students may not be reflected in higher grades, but could manifest in other ways, such as increased motivation or improved ICT skills. It is also possible that students' increased skills or capabilities may not necessarily be reflected by the tests used here.

Beyond general results about the effect of OER and how these resources are valued, the second, mixed-methods component of the research (which was aimed at addressing research question 3) shows that there were also negative perceptions about specific problems that emerged from the use of OER. The data highlight the fact that OER implementation did not work well when students lacked adequate time and the appropriate infrastructure in which to interact with these resources. With regard to this, the qualitative component of the research highlighted that one of the main reasons for not using OER was that there was not enough time to do so. Furthermore, the fact that optimal utilisation of resources relied on IPP providing computer labs in appropriate working condition was also highlighted. These findings were supported by the quantitative data, which identified areas for improvement. These data highlight the institutional infrastructure challenge in learning how to properly use and interact with OER, problems associated with OER platforms and websites, and lack of time. All of the suggestions for improvement were aimed at enhancing conditions in which OER strategies could be implemented rather than criticising the utility of these resources, reconfirming that students had a positive overall evaluation of their OER experience.

Finally, another important point addressed in the second component of the research process relates to student perceptions observed in the survey. The survey showed some differences by income level, age group and levels of student use. Although significant

differences were not found among the groups, it is possible to highlight some general trends. Younger students and those with higher levels of resource use valued the experience of using OER more. Income group, on the other hand, does not appear to generate discernible differences. When considering the Impact Analysis Database, students with higher income achieved higher scores, but when considering the specific evaluation of certain aspects of OER use, students with lower income had a more positive perspective.

However, these results about the effects of OER need to be treated with caution as they were obtained from a small not completely random sample, representing only a very specific cohort of Chilean students. In terms of their representativeness, these findings do not mean that OER cannot have a positive effect amongst other student cohorts. Nevertheless, these findings have little external validity and more research on the effect of OER is required in order to justify the use of these resources in a broader context.

Conclusion

Although there is more evidence today on how the "free" aspect of digital resources has a measurable educational impact, we are only at the beginning of assessing how the "open" aspect might contribute to accessible, high-quality education. In the same way that consensus has not been achieved in terms of measuring the impact of ICTs in education (despite the fact that there is widespread agreement regarding their importance), "openness" does not necessarily produce an impact in itself, but is instead part of a greater set of tools and practices in which many variables exert an influence. ICTs and openness are not tools or instruments that intrinsically cause a specific outcome.

This factor aside, they are surely game-changers and enablers of many uses and practices which draw on the power of human cooperation and that contain some combination of the aspects inherent to "digitally enabled openness": sharing ideas and knowledge; the ability to reuse, revise and repurpose content; increasing transparency of processes; expanding participation; and collaborative production (Smith & Reilly, 2013).

As the road to a global knowledge society and a new global economy can be either smooth or rocky, a short- or long-run effort, and more or less inclusive, the concept of "openness" reminds us that we inhabit a world rapidly on its way to becoming a networked society, which poses substantial opportunities and threats for international development. Capitalising upon the opportunities and diminishing the threats of openness is a major challenge, particularly for countries that need to make the transition towards openness in order to aid development.

Acknowledgements

References

Allen, I. E. & Seaman, J. (2014). *Opening the curriculum: Open Education Resources in U.S. higher education, 2014*. Babson Park, MA: Babson Survey Research Group & The William and Flora Hewlett Foundation. Retrieved from http://www.onlinelearningsurvey.com/reports/openingthecurriculum2014.pdf

Allen, G., Guzman-Alvarez, A., Molinaro, M. & Larsen, D. (2015). *Assessing the impact and efficacy of the Open-Access ChemWiki textbook project*. New York: EDUCAUSE. Retrieved from https://library.educause.edu/resources/2015/1/assessing-the-impact-and-efficacy-of-the-openaccess-chemwiki-textbook-project

Berelson, B. (1952). *Content analysis in communication research*. New York: Free Press.

Betancourt, M. C., Celaya, R. & Ramírez, M. S. (2014). Open Educational Practices and technology appropriation: The case of the Regional Open Latin American Community for Social and Educational Research (CLARISE). *Revista de Universidad y Sociedad del Conocimiento, 11(1),* 4–17. Retrieved from http://dx.doi.org/10.7238/rusc.v11i1.1794

Bliss, T. J., Hilton III, J., Wiley, D. & Thanos, K. (2013). The cost and quality of online open textbooks: Perceptions of community college faculty and students. *First Monday, 18(1–7).* Retrieved from http://firstmonday.org/ojs/index.php/fm/article/view/3972

Brunner, J. J. (2008). El sistema de educación superior en Chile: Un enfoque de economía política comparada. *Revista da Avaliação da Educação Superior (Campinas), Edición Especial, 13(2),* 451–486. Retrieved from http://www.scielo.br/scielo.php?pid=S1414-40772008000200010&script=sci_arttext&tlng=es

Dehejia, R. H. & Wahba, S. (1999). Causal effects in nonexperimental studies: Reevaluating the evaluation of training programs. *Journal of American Statistical Association, 94(448),* 1053–1062. Retrieved from http://users.nber.org/~rdehejia/papers/dehejia_wahba_jasa.pdf

EC (European Commission). (2012). *Rethinking education: Investing in skills for better socio-economic outcomes.* Brussels: European Commission. Retrieved from http://eur-lex.europa.eu/procedure/EN/202132

EC (European Commission). (2013). *"Opening up education": Innovative teaching and learning for all through new technologies and Open Educational Resources.* Brussels: European Commission. Retrieved from http://ec.europa.eu/education/news/doc/openingcom_en.pdf

Feldstein, A., Martin, M., Hudson, A., Warren, K., Hilton III, J. & Wiley, D. (2012). Open textbooks and increased student access and outcomes. *European Journal of Open, Distance and E-Learning, 2(1).* Retrieved from http://www.eurodl.org/materials/contrib/2012/Feldsteint_et_al.pdf

Fischer, L., Hilton III, J., Robinson, T. J. & Wiley, D. (2015). A multi-institutional study of the impact of open textbook adoption on the learning outcomes of post-secondary students. *Journal of Computing in Higher Education, 27(3),* 159–172. Retrieved from http://link.springer.com/article/10.1007%2Fs12528-015-9101-x

Fundación La Fuente/Adimark GFK. (2011). *Chile y los libros 2010*. Santiago de Chile: Fundación Educacional y Cultural La Fuente. Retrieved from http://www.fundacionlafuente.cl/wp-content/uploads/2010/11/Chile-y-los-libros-2010_FINAL-liviano.pdf

Heckman, J. J., Ichimura, H., Smith, J. A. & Todd, P. E. (1998). Characterizing selection bias using experimental data. *Econometrica*, *66(5)*, 1017–1098. Retrieved from http://jenni. uchicago.edu/papers/Heckman_Ichimura_etal_1998_Econometrica_v66_n5_r.pdf

Hilton III, J. L. & Laman, C. (2012). One college's use of an open psychology textbook. *Open Learning, 27(3)*, 265–272. Retrieved from http://scholarsarchive.byu.edu/cgi/viewcontent. cgi?article=1069&context=facpub

Hodgkinson-Williams, C. & Gray, E. (2009). Degrees of openness: The emergence of Open Educational Resources at the University of Cape Town. *International Journal of Education and Development using Information and Communication Technology, 5(5)*, 101–116. Retrieved from https://open.uct.ac.za/handle/11427/8860

Imbens, G. W. & Hirano, K. (2002). Estimation of causal effects using propensity score weighting: An application to data on right heart catheterization. *Health Services and Outcomes Research Methodology, 2(1)*, 259–278. Retrieved from https://scholar.harvard. edu/imbens/publications/estimation-causal-effects-using-propensity-score-weighting-application-data-righ

Keegan, H. & Bell, F. (2011). YouTube as a repository: The creative practice of students as producers of Open Educational Resources. *European Journal of Open, Distance and E-learning*. Retrieved from http://www.eurodl.org/materials/special/2011/Keegan_Bell.pdf

MINEDC (Ministry of Education of Chile). (2012). *Deserción en la educación superior en Chile. Serie Evidencias Año, 1(9)*. Santiago: Ministry of Education. Retrieved from http://portales. mineduc.cl/usuarios/bmineduc/doc/201209281737360.EVIDENCIASCEM9.pdf

Orr, D., Rimini, M. & Van Damme, D. (2015). *Open Educational Resources: A catalyst for innovation, educational research and innovation*. Paris: OECD Publishing. Retrieved from http://dx.doi.org/10.1787/9789264247543-en

Rosenbaum, P. & Rubin, D. B. (1983). The central role of propensity score in observational studies for causal effects. *Biometrika*, *70(1)*, 41–55. Retrieved from http://www.stat.cmu. edu/~ryantibs/journalclub/rosenbaum_1983.pdf

Santos-Hermosa, G., Ferran-Ferrer, N. & Abadal, E. (2013). Recursos educativos abiertos: repositorios y uso. *El profesional de la información, 21(2)*, 136–145. Retrieved from http:// www.accesoabierto.net/sites/accesoabierto.net/files/Santos-Ferran-Abadal-EPI.pdf

Shear, L., Means, B. & Lundh, P. (2015). *Research on open: OER Research Hub review and futures for research on OER*. Menlo Park, CA: SRI Education. Retrieved from http://www. hewlett.org/wp-content/uploads/2016/08/OERRH%20Evaluation%20Final%20Report%20 June%202015.pdf

Smith, M. L. & Reilly, K. M. A. (Eds.). (2013). *Open development: Networked innovations in international development*. Cambridge, MA: MIT Press. Retrieved from https://www.idrc.ca/ en/book/open-development-networked-innovations-international-development

UNESCO–IITE (United Nations Educational, Scientific and Cultural Organization–Institute for Information Technologies in Education). (2011). *Activity report 2010–2011*. Paris: United Nations Educational, Scientific and Cultural Organization. Retrieved from http://iite.unesco. org/publications/3214690/

Weller, M., de los Arcos, B., Farrow, R., Pitt, B. & McAndrew, P. (2015). The impact of OER on teaching and learning practice. *Open Praxis, 7(4)*. Retrieved from http://openpraxis.org/ index.php/OpenPraxis/article/view/227

Wiley, D., Hilton III, J. L., Ellington, S. & Hall, T. (2012). A preliminary examination of the cost savings and learning impacts of using open textbooks in middle and high school science classes. *The International Review of Research in Open and Distributed Learning, 13(3)*. Retrieved from http://www.irrodl.org/index.php/irrodl/article/view/1153/2256

How to cite this chapter

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