OUTPUT, COLLABORATION AND IMPACT OF E-LEARNING RESEARCH: BIBLIOMETRIC ANALYSIS AND VISUALIZATIONS AT THE COUNTRY AND INSTITUTIONAL LEVEL (*SCOPUS* 2003-2016)

Producción, colaboración e impacto de la investigación en e-learning: análisis bibliométrico y visualizaciones a nivel de país e instituciones (*Scopus* 2003-2016)

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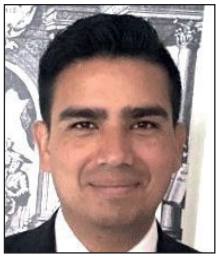

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Abstract

Bibliometric indicators of production and impact of e-learning research are analyzed to know the contribution of countries and institutions in the scientific development of this subject and to strengthen its characterization as knowledge domain. We extracted bibliometric indicators from 39,244 documents indexed in *Scopus* and *SCImago Institutional Rankings*, and generated maps of production and collaboration networks and graphics about the impact of e-learning research in countries and institutions. The results of this combined analysis showed that at country level the United States produce most of the works and generated the greatest international collaboration. At institutional level, the *University of Hong Kong* is the most productive and *National Taiwan University of Science and Technology* is the one with the greatest collaboration. In addition,

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the analysis showed that Taiwan ranks first in productivity and impact, which is why we linked these results to a brief analysis of its national policies. This study presents a new method to analyze both emerging and established knowledge domains.

Keywords

E-learning; Bibliometrics; Output, Normalized citation; International collaboration; Scientific excellence; Georeferencing; *Scopus*; *SCImago Institutions Rankings*; SJR; Taiwan.

Resumen

Este trabajo analiza los indicadores bibliométricos de producción e impacto de investigación sobre e-learning, para conocer el aporte de los países y de las instituciones en el desarrollo científico de esta temática y para fortalecer su caracterización como dominio de conocimiento. Se extrajeron los indicadores bibliométricos de 39.244 documentos indexados en *Scopus* y en *SCImago Institutional Rankings* y se generaron mapas de la producción y de las redes de colaboración y gráficas del impacto de la investigación de países e instituciones. Los resultados de este análisis combinado muestran que, a nivel de país, los Estados Unidos producen la mayor cantidad de trabajos y la mayor colaboración internacional. A nivel institucional, la *Universidad de Hong Kong* es la más productiva y la *Universidad Nacional de Ciencia y Tecnología de Taiwán* es la que cuenta con la mayor colaboración. Además, el análisis mostró que Taiwán ocupa los primeros lugares en productividad e impacto, por lo cual se vincularon estos resultados con un breve análisis de sus políticas nacionales. Este estudio presenta una nueva metodología para analizar dominios de conocimiento tanto emergentes como establecidos.

Palabras clave

E-learning; Bibliometría; Producción; Citación normalizada; Colaboración internacional; Excelencia científica; Georreferenciación; *Scopus*; *SCImago Institutions Rankings*; SJR; Taiwán.

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1. Introduction

E-learning is a field of extensive growth worldwide, with initiatives ranging from classroom experiments to national and regional training plans, supported by institutional projects and national development policies (**Bengtsson**, 2013; **Chang**; **Wang**; **Chen**, 2009). According to the *Scopus* database developed by *Elsevier*, the search term "e-learning" in the title, summary and keywords fields has been included in 51,181 papers published in 78 journals and conference proceedings, affiliated to 160 institutions (the query was made on *https://www.scopus.com* on January 29, 2018).

The bibliographic information of these works is the result of scientific discoveries and research outputs that are published in international scientific journals, cited and read by other researchers. The bibliometric analysis is a valuable tool for the scientific community since it offers elements to analyze science and technology policies (**Okubo**, 1997). Additionally, they provide measurements of connections between researchers and research areas through the statistical analysis of joint publications and citations (**Mingers**; **Leydesdorff**, 2015).

To perform these analyzes, bibliometrics has a set of indicators to organize, combine and extract relevant information on large volumes of bibliographic data, offering a global view of the scientific results obtained by the most productive institutions (**Guerrero-Bote**; **Olmeda-Gómez**; **De-Moya-Anegón**, 2016a). Among them are production and impact indicators (**Rehn** *et al.*, 2014). The set of production indicators include those related to international collaboration, based on international co-authorship networks that distribute the world production according to the needs of science (**Barjak** *et al.*, 2013). International collaboration also brings deep implications for the governance of science and everything related to knowledge creation, since the discovery context is no longer local or institutionalized by disciplines in university departments (**Elzinga**, 1997). In Europe, for instance, the continuous process of integration between countries is eliminating territorial borders, generating considerable heterogeneity between regions and countries in their propensity to collaborate (**Hoekman**; **Frenken**; **Tijssen**, 2010). Impact indicators, instead, denote the quality that the scientific community refers to a specific scientific production, regardless the size of that set of publications. The impact can be measured through various indicators related to citation. Among the most common are the *h index* (**Hirsch**, 2005), the *Impact Factor* (IF) (**Garfield**; **Sher**, 1963), the SNIP (**Moed**, 2010), the *Crown* indicator (**Waltman** *et al.*, 2011), the *SCImago Journal Rank* (SJR) (**González-Pereira**; **Guerrero-Bote**; **De-Moya-Anegón**, 2010), and the *Eigenfactor* (**Bergstrom**, 2007).

In the specific case of e-learning, there have been bibliometric studies focused on the identification of research trends (**Shih**; **Feng**; **Tsai**, 2008; **Hung**, 2012; **Schiebel**, 2012; **Maurer**; **Salman-Khan**, 2010), regarding thematic coverage (**Chiang**; **Kuo**; **Yang**, 2010) and application in work environments (**Cheng** *et al.*, 2014), based on predefined sets of scientific publications. Refining the focus, **Tibaná-Herrera**, **Fernández-Bajón** and **De-Moya-Anegón** (2018a) identified a set of 219 scientific publications on which the emerging discipline has been developed, proposing the creation of a new subject category on which bibliometric and georeferen-

cing analysis can be made. The mentioned work was used by *SCImago Research Group* to create the E-learning subject category in its information systems, both in the *SCImago Journal & Country Rank*, on which the *SCImago Journal Rank* (SJR) is based to classify journals in quartiles by thematic area (**Gómez-Núñez** *et al.*, 2011), as in the *SCImago Institutional Rankings*, that organizes institutions around the world based on their performance in research, innovation and social character (**Bornmann**; **De-Moya-Anegón**, 2014). These information systems use *Scopus* bibliometric data. According to the *SCImago Institutional Rankings*, 4,090 institutions generate research products in this recent subject category. This is a much higher figure than that found in the query of the term made to *Scopus*, since this information system identifies all the institutions that have primary scientific production, published in the 219 journals and conference proceedings classified by the *SCImago Journal & Country Rank* in the "e-learning" subject category.

Another way to analyze bibliometric data is through the application of visualization techniques. In particular, georeferenced maps allow extracting and highlighting spatial data from bibliometric data, which in turn permit having geographical indications of the analyzed content. **Guerrero-Bote** and **De-Moya-Anegón** (2015) used these maps to visualize collaboration networks between Spanish institutions on scientific production in food science. **Kanai**, **Grant** and **Jianu** (2017) applied them in the context of globalized cities to assess the impact of urban globalization research on these. In library and information sciences, georeferencing techniques have been used to determine the global and local areas within the elements arranged in the catalogs of libraries, museums and archives (**Maggio**; **Kuffer**; **Lazzari**, 2017). However, there has been no research using this visualization technique in e-learning.

Although there is already a set of publications included in the e-learning subject category, researchers in this field face the impossibility of knowing the geographical indication of the knowledge source and the relationships that have been established for its development. Although this spatial information is sometimes included in the keywords, it is of little help when it comes to making a global analysis.

Therefore, a global bibliometric analysis requires answering the following questions:

- What are the countries and institutions with the greatest production and impact on e-learning?
- How is the map of international collaboration between countries and institutions established?
- What is the contribution of the georeferenced maps to the bibliometric analysis of the e-learning scientific domain?

These concerns are addressed through bibliometric and georeferenced analysis of global scientific production in e-learning along with its impact, identifying the main actors at country and institution level.

2. Materials and methods

In this study, the *SCImago Institutions Rankings*, an information system that uses the bibliographic information contained in *Scopus* to generate various worldwide rankings of institutions (higher education, government, private, health) was used as a source of information for the bibliometric analysis. This system arranges the institutions according to their productivity and performance in research, innovation and social impact. The primary scientific production that the institutions have published in the journals and conference proceedings that constitute the subject category of e-learning was analyzed, according to the categorization made by **Tibaná-Herrera**, **Fernández-Bajón** and **De-Moya-Anegón** (2018a).

The bibliometric analysis addresses the productivity and performance of primary scientific production in the 2003-2016 timespan, to describe the performance of the institutional scientific activity, its evolution and international collaboration. Data extraction and analysis methodologies have been accepted and used both by the international scientific community and by national science and technology organizations, as well as international organizations.

To perform this analysis, two units were defined: The producing institution and its country of origin. The following bibliometric indicators allow identifying the productivity of countries and institutions producing knowledge in e-learning:

1. Output: number of documents published in scientific journals indexed in *Scopus* (**Romo-Fernández** *et al.*, 2011) which have been classified in the E-learning subject category in *SCImago Journal & Country Rank*.

2. International collaboration: number of scientific publications of a country that have been developed with institutions from another country (**Chinchilla-Rodríguez** *et al.*, 2010).

To describe and understand the performance of the country and the institutions in the development of e-learning, the following impact indicators that do not depend on the size of the country or institution were considered:

3. Normalized citation: Value obtained at the article level that shows the relation between the average scientific impact of an institution/country and the global average set (**Rehn**; **Kronman**, 2008).

4. % Leadership: percentage of works of an institution/country as the main contributor (**De-Moya-Anegón**, 2012).

5. % Excellence10: percentage of works that are among the 10% most cited in the same category, year and document type (**Bornmann**; **Wohlrabe**; **De-Moya-Anegón**, 2017).

6. % Excellence10 with Leadership: percentage of works in Excellence10 in which the institution/country is the main contributor (**De-Moya-Anegón** *et al.*, 2009).

For a better understanding of the bibliometric analysis, two visualization tools were used. First, the multidimensional scaling to represent the production evolution in the set of institutions and countries (**Lévy-Mangin**; **Varela-Mallou**, 2003) and second, the georeferencing technique to show the place where knowledge is created and from which is disseminated (**Guerrero-Bote**; **Olmeda-Gómez**; **De-Moya-Anegón**, 2016b). The tools used in each technique were *Tableau* and *Google Maps* with *GPS Viewer*, respectively.

The bibliometric analysis of productivity and impact indicators allows identifying those countries and institutions that display a positive correlation between production and quality of scientific results in terms of citations impact (**Persson**, 2010; **Leydesdorff** *et al.*, 2013). Moreover, the combination of visualization techniques allows to highlight extremes and identify publication patterns and connection between countries or institutions that are generated thanks to collaboration (**Rehn**; **Kronman**, 2008).

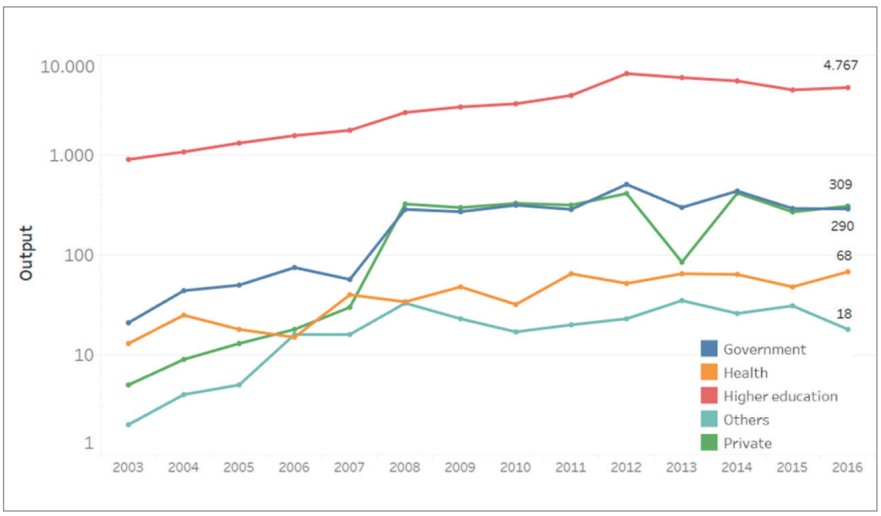

Figure 1. Evolution of production (Output) in e-learning by sector. Source: *SCImago Institutions Ranking*.

3. Results and analysis

The results and analysis of this study are composed of two parts. The first one refers to productivity and the second to impact. Each one is seen from the country and institution levels, with their respective visualizations.

In the 2003-2016 timespan, the world scientific production in e-learning was 39,244 works, made by 4,390 institutions in 162 countries. This production was mainly fed by works from the Higher Education sector by 86.9%. Figure 1 shows a growing contribution of the Government (5.1%) and Private sectors (4.1%). Additionally, there is an output decrease since 2012, justified by the contribution reduction in Computer Sciences, especially in conference proceedings and reviews (**Tibaná-Herrera**; **Fernández-Bajón**; **De-Moya-Anegón**, 2018b).

Table 1. Main countries in the scientific production of e-learning (2003-2016). Source: *SCImago Institutions Ranking*.

Country	Output	Country	Output
1. United States	9472	6. Canada	1821
2. United Kingdom	3894	7. Germany	1717
3. Australia	2448	8. Japan	1493
4. Taiwan	2165	9. China	1492
5. Spain	1972	10. Italy	1257

Country level

When analyzing this information with georeferenced maps, we found 52 countries with a production exceeding 100 works (Annex 1). United States, the United Kingdom, Australia, Taiwan and Spain are the countries that represent the highest production in the timespan (Figure 2).

Table 1 contains the first 10 countries in scientific production in e-learning.

Figure 2. Distribution of production (Output > 100 for visualization purposes) in e-learning at country level in the 2003-2016 timespan. The color corresponds to the region. Source: *SCImago Institutions Ranking*.

Furthermore, there is evidence of the concentration of scientific production in e-learning in the Northern hemisphere, with very few representatives in the southern hemisphere, including Australia, South Africa, Brazil and Chile.

To know the evolution in production at country level, we compared 2003-2010 and 2012-2016 timespans (Table 2). The first period had 115 countries and the second had 152. It is of note that the same three countries (the United States, the United Kingdom and Australia) lead both timespans. In addition, Spain, Taiwan, China and Germany strengthened their presence on the world stage.

Regarding the international collaboration, in 2016, 16.47% of the works were produced in collaboration, with 2014 being the highest point with 18.34%.

Table 3 shows the countries with the most international collaboration in the last five years compared to the percentage that this collaboration represents. It is highlighted that the United States is the country with the highest production in international collaboration and that Western Europe is present with 6 countries among the top 12 under this indicator. On the other hand, Switzerland, United Arab Emirates, Saudi Arabia, Netherlands and France stand out as the countries with the highest percentage of international collaboration in e-learning.

The map in Figure 3 shows 38 countries that have a production greater than 100 works. The size of each sphere corresponds to the normalization of the volume of collaborative works, where the United Kingdom has more representation than the United States; the link between

Table 2. Production (output > 100) distribution comparison in e-learning at country level between 2003-2007 and 2012-2016 timespans. Source: *SCImago Institutions Ranking*.

2003-2007		2012-2016	
Countries: 115		Countries: 152	
Country	Output	Country	Output
1. United States	2,091	1. United States	4,532
2. United Kingdom	772	2. United Kingdom	1,867
3. Australia	380	3. Australia	1,390
4. Canada	377	4. Spain	1,328
5. Taiwan	229	5. Taiwan	1,235
6. Netherlands	178	6. China	1,135
7. Spain	154	7. Germany	1,066
8. Germany	144	8. Japan	852
9. Greece	136	9. Canada	837
10. India	109	10. Italy	764

Table 3. Countries with the greatest international collaboration in the scientific production of e-learning. NDoc IC and %IC indicators in 2003-2016 timespan. Source: *SCImago Institutions Ranking*.

Country	Ndoc IC	%IC	Country	Ndoc IC	%IC
1. United States	1,083	23.90	7. Canada	307	36.68
2. United Kingdom	670	35.89	8. Netherlands	290	47.54
3. Germany	455	42.68	9. France	237	47.40
4. Spain	400	30.12	10. Italy	226	29.58
5. Australia	391	28.13	11. Japan	216	25.35
6. China	327	28.81	12. Taiwan	201	16.28

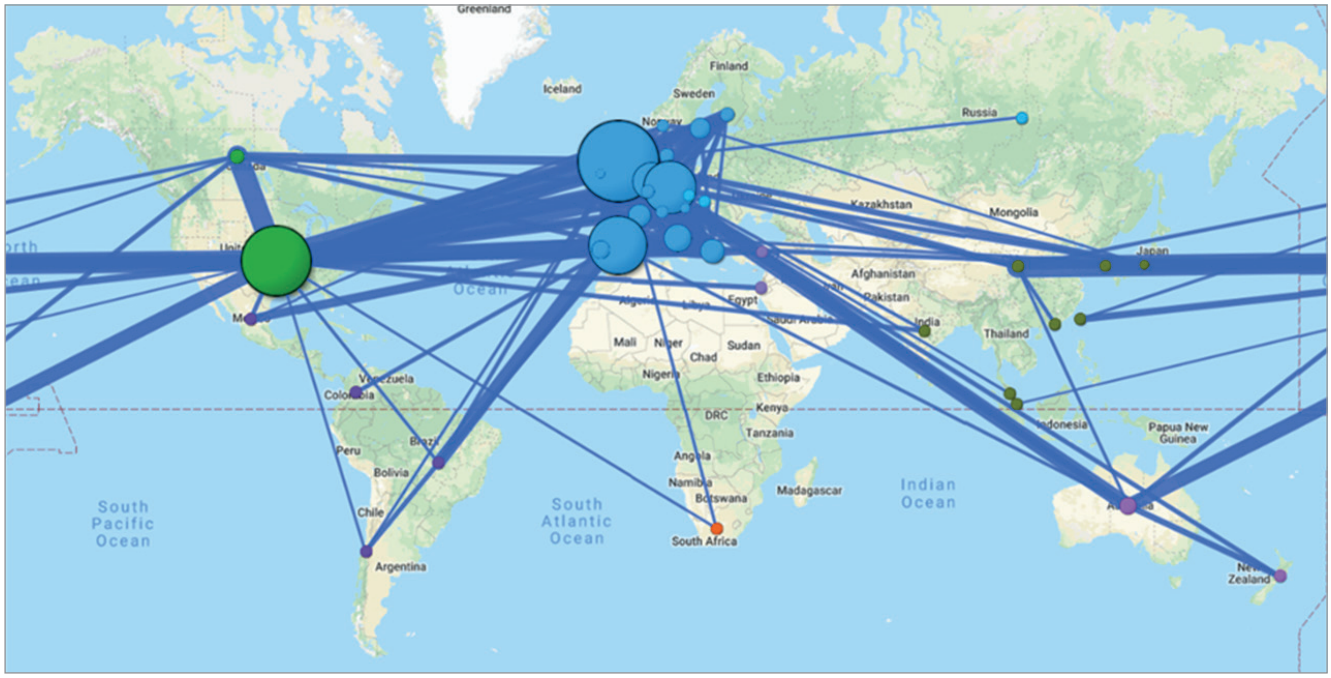

Figure 3. International collaboration in e-learning at country level in 2012-2016 timespan. Source: *SCImago Institutions Ranking*

two countries corresponds to the number of works that have been developed in collaboration among them, as can be seen, in Western Europe the countries with the greatest collaboration are concentrated, except the United States.

Among the countries with greater collaboration are Spain and the United Kingdom (1,332), Germany and the United Kingdom (1,170), the United Kingdom and the United States (1,116), The Netherlands and the United Kingdom (1,035) and China with the United States (872).

Regarding the impact of these publications, the analysis of the indicators %Leadership, %Excellence10 and %Excellence with Leadership during 2003-2016 timespan (Figure 4) shows that the leadership of Taiwan, Turkey, Czech Republic, Slovakia and Algeria is superior to 93%. Additionally, in publication of excellence and excellence with leadership, Chile and Taiwan are prominent. The latter is 4th in world production, compared to place 48 of Chile.

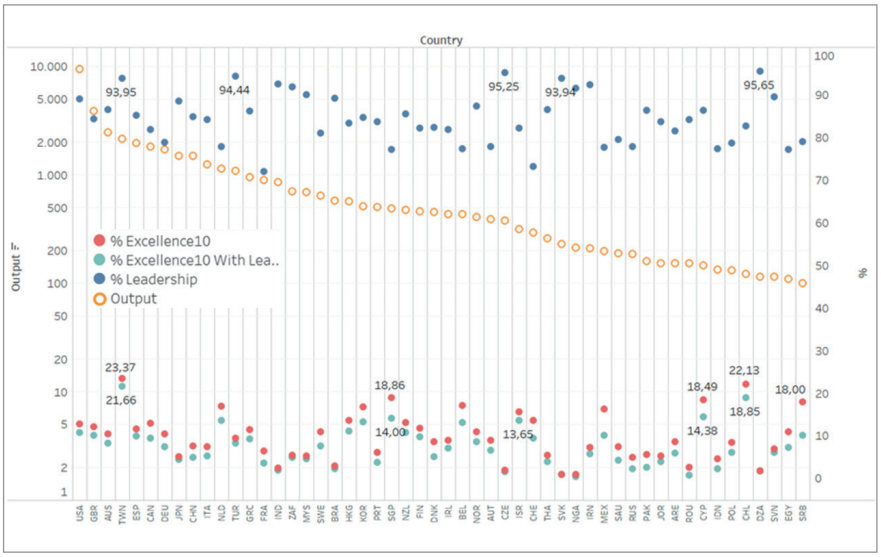

Figure 4. Values superposition of the entire production (Output > 100) with the percentages of citable production of excellence (%Excellence10), led production (%Leadership) and citable production of led excellence (%Excellence10 with Leadership), versus ranking of countries positions. Source: *SCImago Institutions Ranking*.

> The United States is the country with the highest output in e-learning

Regarding the normalized citation of countries with more than 100 works in the selected timespan, Chile, Belgium, Taiwan, Serbia and Netherlands stands out with the highest impact. Figure 5 shows a change in the hegemony of the countries that lead the production indicators, where the United States, the United Kingdom, and Australia ceased to be protagonists. Only Taiwan shows a positive correlation between production and the impact of scientific results.

Taiwan is the only country that consistently ranks among the first places of production and impact on e-learning.

Institutional level

Sixty-one institutions have produced more than 100 works in 2003-2015 timespan (Annex 1). The *University of Hong Kong*, *Nanyang Technological University*, *The Open University*, *Athabasca University* and *National Central Univer-*

Figure 5. Normalized citation of countries against their production (Output > 100) in 2003-2016 timespan. Source: *SCImago Institutions Ranking*.

sity (Taiwan) are the institutions that have contributed to most of the works for the development and consolidation of e-learning (Figure 6). As can be seen in this list, Taiwan has 7 institutions, which account for the largest number of works per country, higher than the United States that has 11, Australia with 10, the United Kingdom with 6 and The Netherlands with 4 institutions. Likewise, 3 government institutions (*Centre National de la Recherche Scientifique*, *Fraunhofer Gesellschaft* and *Consiglio Nazionale delle Ricerche*) and 4 private institutions (*Alcatel-Lucent*, *Nippon Telegraph and Telephone Corp.*, *Alcatel-Lucent USA* and *Nokia*) are present.

In order to know the evolution in production at the institution level, the same country level temporal comparison was made. Table 4 shows that the number of institutions has doubled in the analyzed periods, in addition, in the final period the presence of Taiwanese universities at the top of the list is noted.

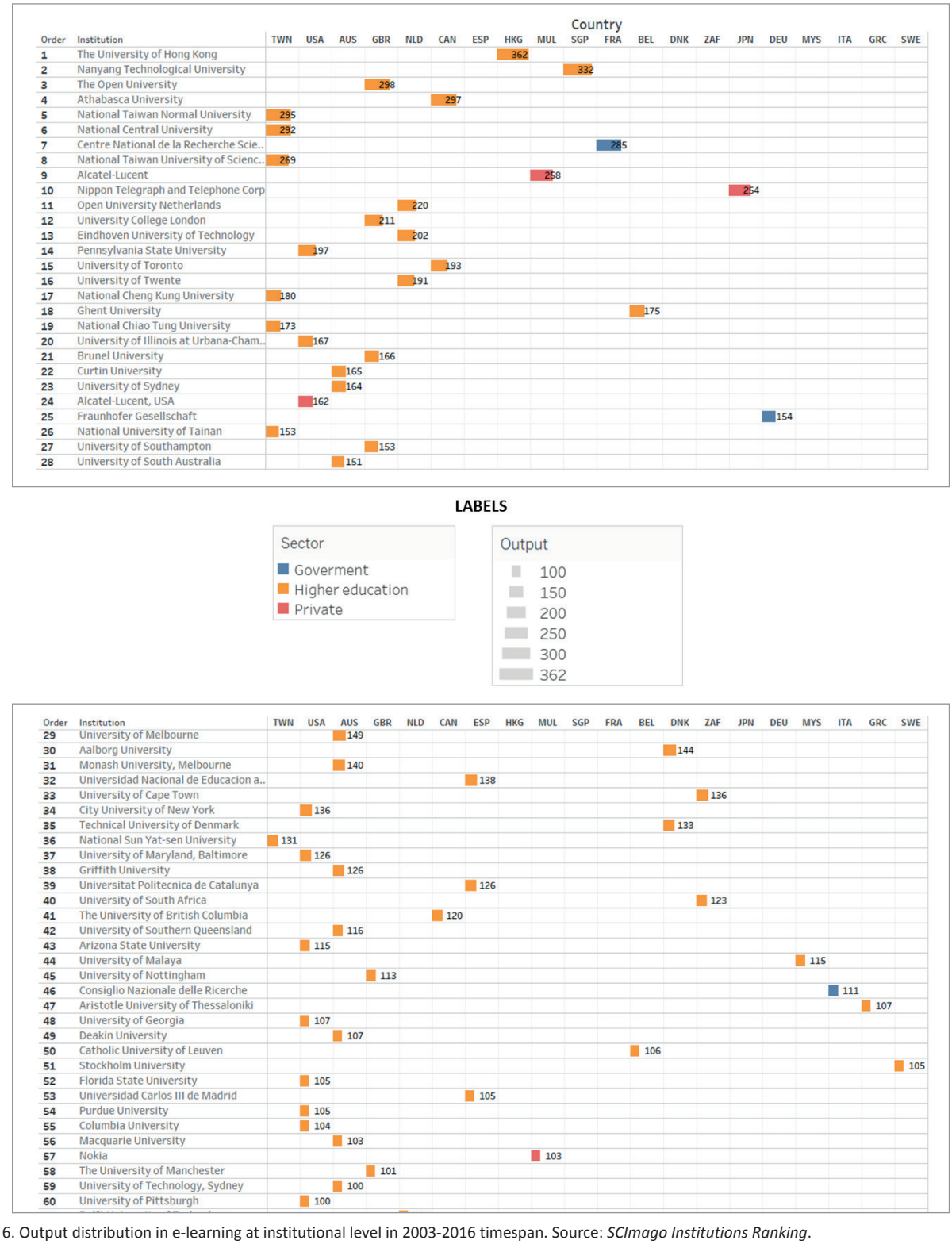

Figure 6. Output distribution in e-learning at institutional level in 2003-2016 timespan. Source: *SCImago Institutions Ranking*.

Table 4. Comparison of production in e-learning at institutional level between 2003-2007 and 2012-2016 timespans. Source: *SCImago Institutions Ranking*.

2003-2007		**2012-2016**	
Institutions: 1,705		Institutions: 3,725	
Institution	Output	Institution	Output
1. *Athabasca University*	71	1. *National Taiwan University of Science and Technology*	194
2. *The University of Hong Kong*	66	2. *National Taiwan Normal University*	193
3. *Pennsylvania State University*	65	3. *The University of Hong Kong*	178
4. *The Open University*	61	4. *Centre National de la Recherche Scientifique*	157
5. *University of Twente*	48	5. *National Central University*	155
6. *Open University Netherlands*	44	6. *Nanyang Technological University*	145
7. *University of Pittsburgh*	44	7. *Alcatel-Lucent*	143
8. *University of Toronto*	43	8. *The Open University*	135
9. *University of Georgia*	41	9. *Athabasca University*	134
10. *Florida State University*	39	10. *Aalborg University*	129

The group of 47 institutions has produced works in international collaboration. Figure 7 shows the 26 institutions with the highest production in collaboration, the size of each sphere corresponds to the normalization of the volume of collaborative works and the link between two institutions corresponds to the number of works that have been developed in collaboration among them. It is observed that the greatest international collaboration at an institutional level is held by the Taiwanese institutions. Table 5 shows the detail of the international collaboration between the institutions, highlighting the strong link between the institutions of Taiwan, Canada and Singapore. In addition Taiwan and Netherlands are distinguished as the countries with the highest representation of institutions in international collaboration, followed by Australia and the United Kingdom. The institutions with the greatest diversity in international collaboration are *National Central University* (*TWN*) and *Nanyang Technological University* (*SGP*).

> The institutions with the most international collaboration are Athabasca University (CAN), National Sun Yat-sen University (TWN), National Taiwan University of Science and Technology (TWN), Nanyang Technological University (SGP) and National Central University (TWN)

Figure 7. International collaboration in e-learning at institution level in 2003-2016 timespan (Output > 100). Source: *SCImago Institutions Ranking*.

Table 5. International collaboration between institutions in 2003-2016 timespan. Source: *SCImago Institutions Ranking*.

CO	Institution	Ndoc CI	Institution	CO
CAN	*Athabasca University*	24	*National Sun Yat-sen University*	TWN
TWN	*National Taiwan University of Science and Technology*	16	*Nanyang Technological University*	SGP
CAN	*Athabasca University*	15	*National Central University*	TWN
AUS	*Curtin University*	15	*Technische Universitat Graz*	AUT
BEL	*Ghent University*	12	*Eindhoven University of Technology*	NDL
TWN	*National Central University*	9	*Brunel University*	GBR
DEN	*Technical University of Denmark*	8	*Centre National de la Recherche Scientifique*	FRA
DEN	*Technical University of Denmark*	6	*Nippon Telegraph and Telephone Corp*	JPN
BEL	*Ghent University*	6	*Centre National de la Recherche Scientifique*	FRA
HKG	*The University of Hong Kong*	6	*National Central University*	TWN
BEL	*Catholic University of Leuven*	5	*University of Twente*	NDL
NDL	*Eindhoven University of Technology*	5	*University of Southampton*	GBR
AUS	*Griffith University*	5	*National Sun Yat-sen University*	TWN
BEL	*Catholic University of Leuven*	5	*Open University Netherlands*	NDL
AUS	*Curtin University*	5	*The University of Hong Kong*	HKG
GRC	*University of Macedonia*	5	*Stockholm University*	SWE
AUS	*Curtin University*	5	*University of Twente*	NDL
GBR	*University College London*	5	*Carnegie Mellon University*	USA
TWN	*National Taiwan Normal University*	5	*Nanyang Technological University*	SGP
NDL	*Delft University of Technology*	5	*Brunel University*	GBR
AUS	*University of Sydney*	5	*Nanyang Technological University*	SGP
TWN	*National Central University*	5	*Nanyang Technological University*	SGP

The analysis of impact indicators at institutional level shows that the average number of works in %Leadership is 72.35, among which are the universities *Aalborg University*, *University of South Africa* and the private companies *Alcatel-Lucent* and *Nippon Telegraph and Telephone Corp* with more than 85% of their work in leadership. Regarding %Excellence10, the average works are 16.1. *National Taiwan University of Science and Technology*, *National University of Taiwan*, *National Cheng Kung University*, *Florida State University* and *Delft University of Technology* stand out with more than 30% of their works in Excellence10, five of them being from Taiwan. In %Excellence10 with Leadership, the average is 18.87, where *National Taiwan University of Science and Technology*, *Florida State University*, *Delft University of Technology*, *National Cheng Kung University* and *Ghent University* are worth mentioning, with more than 20% of works in this indicator (Figure 8).

Finally, we established and represented the impact at institutional level based on the normalized citation indicator. Figure 9 shows the contrast between the indicators of production and normalized citation. The private company *Alcatel-Lucent* has the greatest impact. In terms of universities, *National Taiwan University of Science and Technology*, *Delft University of Technology*, *Ghent University*, *National University of Tainan* and *Arizona State University* stand out.

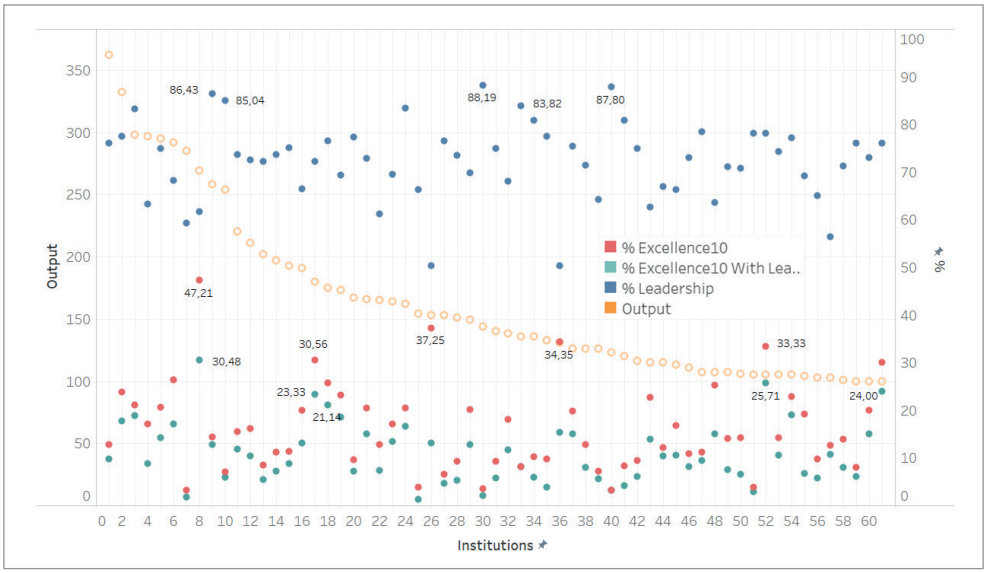

Figure 8. Total production (Output > 100) values superposition with the percentages of citable production of excellence (%Excellence10), led production (%Leadership) and citable production of led excellence (%Excellence10 with Leadership), versus institutions ranking. Source: *SCImago Institutions Ranking*.

Figure 9. Normalized citation of institutions against their production (Output > 100) in 2003-2016 timespan. Source: *SCImago Institutions Ranking*.

The combined analysis of bibliometric indicators and visualization techniques has made possible the identification of the following facts:

- The countries that produce knowledge in e-learning have increased their production by 56% in the last five years, being the main producers The United States, the United Kingdom, Australia and Taiwan.
- The Government and Private sectors have contributed significantly to the development of the category in the last five years.
- Taiwan is the only country that consistently ranks first in the production and impact indicators.
- The United States is the country that generates the most international collaboration in the scientific domain of e-learning, followed by the United Kingdom and Australia.
- The European institutions are the most oriented to co-

llaborate with institutions of the same community as in other regions of the world.

- The Taiwanese institutions are in the top 10 with the greatest test impact in the analyzed timespan.

> *Alcatel-Lucent* and *National Taiwan University of Science and Technology* are the institutions with the greatest impact on e-learning

4. Discussion and conclusions

This study has demonstrated the arrival of a new contender in the scientific development of e-learning, this is Taiwan, which has grown in its production and quality performance, placing seven institutions in the first places of the production and impact indicators. The positive results of Taiwan and its main institutions are associated with the development of a national public policy that since 2003 promotes the development of culture and education through the *Taiwan E-learning and Digital Archives Program* (*Teldap*) (**Lin**; **Yen**, 2012), which has allowed increasing the access and use of digitized knowledge and has strengthened the e-learning industry. This program has carried out two projects to promote e-learning inside and outside the country. These projects are *Digital Education & e-Learning* that has arranged more than 1300 virtual courses and 7.8 million digital resources in 2010. Also, the *International Collaboration & Promotion of Taiwan e-Learning & Digital Archives that* promotes the internationalization and achievement of *Teldap* goals by establishing an international cooperation network of 69 institutes in 13 countries and producing content in multiple languages, as well as an annual conference (*International Convention of Asia Scholars - ICAS*) as main dissemination strategies in Asia and around the world.

From another point of view, the growth and impact of Taiwan can be associated with the scientific development that this country has had in other knowledge fields, where the highest production is concentrated in engineering, computer science and medicine. This production profile is similar to that of the countries with the highest production in e-learning, such as the United States, the United Kingdom and Australia, which shows that the development in this area responds to the focus in engineering and computer science that these countries have.

Therefore, Taiwan should be considered as a point of reference and focus on the subject, ahead of the United States and Western Europe.

Through a bibliometric analysis and visualization techniques, our research has identified the countries and institutions that produce the largest number of works in e-learning, with the United States and the *University of Hong Kong* being the main exponents.

Likewise, we analyzed and georeferenced the institutional collaboration to identify the context of discovery of e-learning and its main collaborative ties. In this regard, the United States is the country that generates the most collaboration, being the *National Taiwan University of Science and Technology* the most outstanding institution. We evidenced that there is extensive collaboration at country and institutional level, which has facilitated a 56% increase in scientific production in the subject in the last five years. This amount of collaboration demonstrates that scientific development is more inclusive at regional level, differentiating itself from the center-periphery grouping model that characterized the global system of scientific collaboration in the past. Furthermore, the developed maps show the consolidation of four nodes directly linked to the development of the subject category: North America, Western Europe, Australia and Taiwan.

Finally, by combining this bibliometric approach with georeferencing techniques we have a powerful research tool, which allows:

A) approaching the influence of countries and institutions in the development of the subject category,

B) comparing productivity and performance at different levels (country, institution),

C) facilitating the identification of the location of origin and knowledge dissemination generated by scientific research on the subject, and

D) revealing the importance of cognitive, organizational, social, institutional and geographic proximity in the generation of collaborative links, such as language, regional proximity and political affinity.

This work can be considered as a quantitative methodology to determine the contribution of countries and institutions to the conceptual, scientific and innovative development of a scientific domain.

> Taiwan should be considered as a point of reference and focus on e-learning, ahead of the United States and Western Europe

Statements

Availability of data and materials

The data related to this research was obtained from access to *Scopus*, as well as provided by *SCImago Research Group*. These are protected by licensing and copyright respectively.

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Does not apply.

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Contributions of authors

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Annex 1. Countries and institutions with more than 100 works in scientific production in e-learning (2003-2016)

Order	Country	Output	Order	Institution	Output
1	United States	9,472	1	*The University of Hong Kong*	362
2	United Kingdom	3,894	2	*Nanyang Technological University*	332
3	Australia	2,448	3	*The Open University*	298
4	Taiwan	2,165	4	*Athabasca University*	297
5	Spain	1,972	5	*National Taiwan Normal University*	295
6	Canada	1,821	6	*National Central University*	292
7	Germany	1,717	7	*Centre National de la Recherche Scientifique*	285
8	Japan	1,493	8	*National Taiwan University of Science and Technology*	269
9	China	1,492	9	*Alcatel-Lucent*	258
10	Italy	1,257	10	*Nippon Telegraph and Telephone Corp*	254
11	Netherlands	1,139	11	*Open University Netherlands*	220
12	Turkey	1,097	12	*University College London*	211
13	Greece	958	13	*Eindhoven University of Technology*	202
14	France	892	14	*Pennsylvania State University*	197
15	India	854	15	*University of Toronto*	193
16	South Africa	704	16	*University of Twente*	191
17	Malaysia	691	17	*National Cheng Kung University*	180
18	Sweden	645	18	*Ghent University*	175
19	Brazil	576	19	*National Chiao Tung University*	173
20	Hong Kong	569	20	*University of Illinois at Urbana-Champaign*	167
21	South Korea	512	21	*Brunel University*	166
22	Portugal	508	22	*Curtin University*	165
23	Singapore	493	23	*University of Sydney*	164
24	New Zealand	476	24	*Alcatel-Lucent, USA*	162
25	Finland	460	25	*Fraunhofer Gesellschaft*	154
26	Denmark	453	26	*National University of Tainan*	153
27	Ireland	435	27	*University of Southampton*	153
28	Belgium	433	28	*University of South Australia*	151
29	Norway	410	29	*University of Melbourne*	149
30	Austria	392	30	*Aalborg University*	144
31	Czech Republic	379	31	*Monash University, Melbourne*	140
32	Israel	315	32	*Universidad Nacional de Educacion a Distancia*	138
33	Switzerland	295	33	*University of Cape Town*	136
34	Thailand	261	34	*City University of New York*	136
35	Slovakia	231	35	*Technical University of Denmark*	133
36	Nigeria	213	36	*National Sun Yat-sen University*	131
37	Iran	209	37	*University of Maryland, Baltimore*	126
38	Mexico	197	38	*Griffith University*	126

39	Saudi Arabia	190	39	*Universitat Politècnica de Catalunya*	126
40	Russian Federation	185	40	*University of South Africa*	123
41	Pakistan	161	41	*The University of British Columbia*	120
42	Jordan	154	42	*University of Southern Queensland*	116
43	Romania	152	43	*Arizona State University*	115
44	United Arab Emirates	152	44	*University of Malaya*	115
45	Cyprus	146	45	*University of Nottingham*	113
46	Indonesia	133	46	*Consiglio Nazionale delle Ricerche*	111
47	Poland	131	47	*Aristotle University of Thessaloniki*	107
48	Chile	122	48	*University of Georgia*	107
49	Slovenia	115	49	*Deakin University*	107
50	Algeria	115	50	*Catholic University of Leuven*	106
51	Egypt	110	51	*Stockholm University*	105
52	Serbia	100	52	*Florida State University*	105
			53	*Universidad Carlos III de Madrid*	105
			54	*Purdue University*	105
			55	*Columbia University*	104
			56	*Macquarie University*	103
			57	*Nokia*	103
			58	*The University of Manchester*	101
			59	*University of Technology, Sydney*	100
			60	*University of Pittsburgh*	100
			61	*Delft University of Technology*	100