The impact of Computers & Education measured beyond traditional bibliographical metrics

Echeverria, Alejandro; Nussbaum, Miguel; Albers, Casper J.; Heller, Rachelle S.; Tsai, Chin-Chung; Van Braak, Johan

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Editorial

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1. Introduction

The goal of research in any applied science should be to provide value to society and generate a positive impact (Bornmann, 2013). In the learning sciences, for example, research should aim to improve our understanding of how we learn and thus improve our ability to create learning environments, learning experiences and learning organizations (Fischer et al., 2018). However, the way the scientific community measures the importance of research is not by assessing its societal impact. We measure the impact on the academic community, with bibliographic metrics, that show how much an article is used, e.g., number of citations, impact factor, etc. These measures have the limitation of knowing the relevance of the article for the scientific community but not for the society as a whole.

The reason we use citations as a metric instead of using an actual measure of societal impact is simple: measuring citations is easy, while measuring societal impact is very hard. There are several problems that make measuring societal impact hard, to name a few: each field impacts society in a different way (e.g. some fields generate patents or companies, while other do not); it is very hard to make a causal link between an effect in society and one piece of research; the timescales of societal impact can vary enormously for different research studies (Bornmann, 2013).

In recent years a new set of metrics, called alternative metrics or "altmetrics", have been started to be used to measure the impact and importance of research (Priem, Taraborelli, Groth, & Neylon, 2010). These alternative metrics include a varied range of metrics, including the number of times an article is downloaded in online sites, number of citations in any online document beyond academic journal and conferences (e.g. Google Scholar citations), number of times an article is shared in social media, appearances in Wikipedia and news outlets, etc. The promise of this type of metrics is that they could be a way of measuring the impact of research beyond the limits of the scientific community, and maybe become a way of measuring the societal impact of research. It is still unclear if this is the case, because limited research studies have enough alternative metrics information (Costas, Zahedi, & Wouters, 2014). Altmetrics have also some important limitations: being more prone to techniques that aim to artificially increase the relevance of an article; and an important language bias because of mostly using English written sources. Still, these new kinds of metrics provide a promising alternative way of analyzing research.

The goal of this editorial is to explore if these alternative metrics can shed light of the societal impact of all the articles published in Computers & Education (1976–2018). For this purpose, we compare all the articles of this journal through the lens of both traditional and alternative metrics. We want to understand if Computers & Education had mainly an impact in the academic community, or also had an impact in society.

2. Methodology

To perform this exploratory study, we selected the complete list of articles published in Computers & Education since the beginning of the journal (1976). We included all 3957 articles that were published online before June 2018. From the 3957 articles we analyzed the gender of the first author. We only analyzed western names, which was 2932 articles. From these 1102 articles (37.59%) were written by women as first author with 34204 cites (41.59%). While men, had 1830 articles (62.41%) and 48029 cites (58.41%). From these numbers we observe that even men are more present than women, no citation bias can be observed.

For each of these 3957 articles, we obtained both traditional and alternative metrics. The single traditional metric used was the number of citations of each article through the citation information of Scopus (Scopus, 2018). The first alternative metric we included was the number of times an article was downloaded from the journal website. Although this metric is venue-dependent (e.g., an open access journal will get more downloads), by focusing only in one journal we reduce a possible bias between articles. However,

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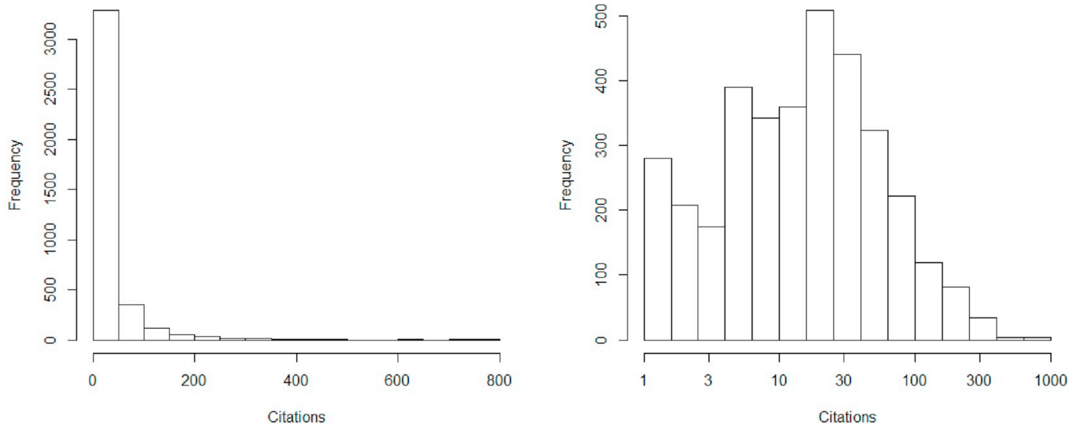


Fig. 1. Histogram of the number of citations on a regular scale (1a; left) and on logarithmic scale (1b; right).

different results, than the ones obtained in this study, can be obtained for open access journals. For additional alternative metrics, we used the information provided by Altmetric.com (Altmetric, 2018a). This site provides, for each article, one aggregate metric (*Altmetric Score*) that is obtained by doing a weighted sum of the number of times an article is referenced in different type of sources: social networks (Facebook, Twitter, etc), blog posts, news articles, patents and public policy documents (Altmetric, 2018b).

For the study, we used the aggregate *Altmetric Score* plus the number of times the article was referenced in Altmetric for three specific type of sources: patents, news articles and public policies. These sources are considered as good proxies for societal impact (Bornmann, 2013), while other alternative metrics, such as number of blog posts and social network shares, have shown to be less relevant (Bornmann, 2015).

We provided and interpreted descriptive statistics on these impact variables. Using regression models, we studied which of these variables play a role in predicting the number of citations a paper receives.

3. Results

An initial review of the data showed that 77 of the 3957 papers (1.94%) are not present in the Scopus Database, so these were removed from the study. Of the remaining 3880 papers, 389 had zero (0) citations (10.00%), and this were kept as part of the dataset.

Fig. 1a shows a histogram of the number of articles that have a certain amount of citations. The citation data is severely skewed (Fig. 1a) showing that most articles have a few citations. This skewness is relevant because it breaks the traditional normal distribution assumption of many statistical methods, so instead of using directly the number of citations, the log of number of citations was used (Fig. 1b).

Fig. 2 shows that there is a clear relation between number of citations and publication year, until 2008. The increase can be attributed to two factors: (i) there are simply more scientists now than, 20 years ago; thus, there are more papers being written, more papers being cited, etc. (Nature, 2014). (ii) C&E has improved in quality (see in Appendix the history of its Impact Factor in Web of Science), and because better papers are published, these get more citations. The decrease since 2008 can be explained by the life cycle of an article (Galiani et al., 2017). In our comparison of the submissions and citations by male or female first authors, we noted that since 1998, the percentages of papers and citations are moving towards parity, an indication that outside efforts to recuit and retain women are having a positive impact and that there is no apparent difference in quality between male and female authored papers

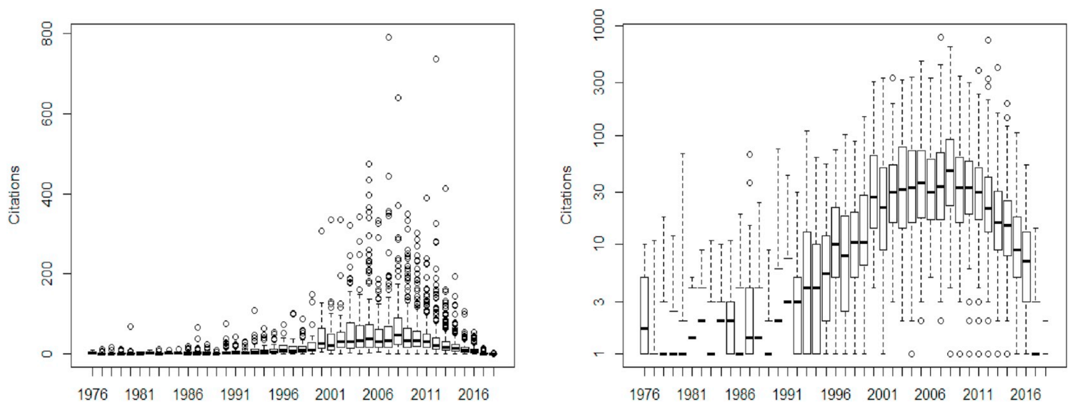


Fig. 2. Scatter plots of the number of citations vs publication year on a regular scale (2a; left) and logarithmic scale (2b; right).

Table 1
Descriptive statistics for alternative metrics including (% of papers where the metric is zero (%zeroes)), Minimum (Min) and Maximum (Max) values, the median for the score and the 1st and 3rd quantile.

Variable	% zeroes	Min	1st quantile	median	3rd quantile	Max
Altmetric score	74.4	0	0	0	1	803
Nº of News	98.1	0	0	0	0	25
Nº of Policies	98.0	0	0	0	0	2
Nº of Patents	99.7	0	0	0	0	3
Nº of Downloads	0	5	96	1138½	2610	224,867

(Rincón & George-Jackson, 2016).

Now, analyzing the *Altmetric Score*, Table 1, we observe that for the majority of papers, roughly 75%, have a zero value, i.e., these papers are not referenced in any of the alternative sources considered by Altmetric (Table 1). Only < 2% of the papers score on the variables of news, policy and patent, while 23% (not shown in the table) score on other variables, such as Social networks, Wikipedia, Blogs, etc. On the other hand, for Number of downloads, there are no papers with zero value.

If we analyze recent papers (e.g., the 801 papers published since 2014), the results are slightly better: only 44.9% have and *Altmetric Score* of zero. However, the median altmetric score for these papers is just 1. The numbers for news, policies and patents are: zeroes for median and 3rd quantile; max is respectively 25, 1, and 1.

To understand the relationship between the different type of metrics, a regression analysis was performed to try to predict the value of the logarithm of the number of citations from the five alternative metrics: altmetric score, number of news, number of policy documents, number of patents and number of downloads. The logarithm is used instead of the actual value, based on the skewness of the original data described in Fig. 1. As the logarithm of zero is undefined, the papers without any citations are left out of this analysis. The results of this analysis (Table 2) shows that the altmetric score, number of policy documents and number of downloads have a significant relation with number of citations; the number of patents have a mildly significant relation; and the number of news is non-significant. The model predicts a small amount of variance in the log-number of citations: the adjusted R^2 is 0.1099.

From Table 1 we can see that the altmetric score is zero for three quarters of the papers, and the effect size of altmetric is practically zero: you need 99 Altmetric points for the expected citation count to double. For most of the variables (altmetric score, patents, policy, news) the score is zero for > 98% of the papers, so including this in the model only affects the < 2% of papers with a score here. Because of this we also performed a regression analysis trying to predict citations (on a logarithmic scale) based on downloads (on a log scale) only (the distribution of downloads is just as skewed as the citations, see Figure in Appendix 2) (Table 3). In this analysis the percentage-explained-variance was significantly higher: 38.3% (adjusted R^2 of 0.3831) (Fig. 3).

As a final analysis we performed a regression model based only on the papers published after 2013 (Table 4), considering all altmetric except number of downloads. The goal of this analysis was to isolate the effect of non-downloads altmetric score for the period where the most papers have an altmetric score greater than zero. This model predicts only a very small amount of variance in the log-number of citations, with an R-squared of 0.017.

4. Discussion

This exploratory study represents an initial effort on trying to understand how to measure the societal impact of Computers & Education. In this study we focused on understanding what can alternative metrics tells us about the journal's articles and how they relate to the traditional metric of number of citations.

The predictive analysis performed, shows that the alternative metrics variable with most predictive power is the number of downloads of an article, which highly correlates with the number of citations. This is expected: highly cited articles are likely to be downloaded the most because of the fact being highly cited gives more saliency. It might therefore be, that citations are actually (and in contrary to what we thought) good metrics for societal impact. More research is needed.

The analysis performed with only non-download alternative metrics, for the articles after 2013 shows that two alternative metrics, number of public policy documents and number of patents, are significant predictors of number of citations, albeit with small effect sizes. These two alternative metrics are considered important proxies for societal impact (Bornman, 2013), so this result suggests that citations do capture some of the societal impact as measured at least by these two variables. From the percentage-explained-variance

Table 2
Predictive analysis of the logarithm of the number citations from alternative metrics.

	Estimate	Standard Error	t value	p-value
(Intercept)	2.563	0.0248	108.711	< .001 (significant)
Altmetric Score	−3.043e-03	6.057e-04	−5.024	< .001 (significant)
News	−7.260e-03	1.730e-02	−0.420	0.6747
Policy	4.846e-01	5.387e-02	8.996	< .001 (significant)
Patents	2.739e-01	1.103e-01	2.483	0.0131 (significant)
Downloads	3.074e-05	1.801e-06	17.074	< .001 (significant)

Table 3
Predictive analysis of the logarithm of the number citations from alternative metrics.

	Estimate	Standard Error	t value	p-value
(Intercept)	−0.139	0.028	−4.873	< .001 (significant)
log (Downloads)	0.445	0.010	46.566	< .001 (significant)

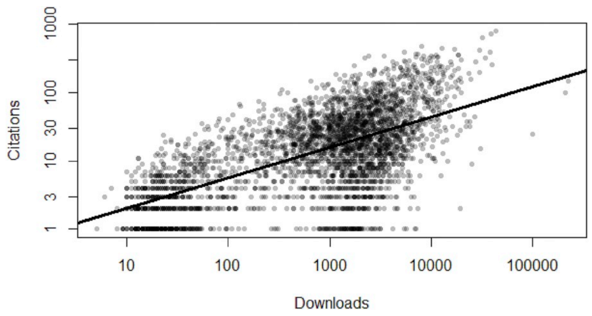


Fig. 3. Number of citations vs number of downloads.

Table 4
Predictive analysis of number citations from alternative metrics, recent papers only (2013 on).

	Estimate	Standard Error	t value	p-value
(Intercept)	1.981	0.044	45.071	< .001
Altmetric Score	0.003	0.001	2.112	0.035 (significant)
News	−0.009	0.042	−0.213	0.832
Policy	1.439	0.459	3.138	0.002 (significant)
Patents	0.409	1.118	0.366	0.714

statistics, however, we can observe that the predictive power of the number of citations on societal impact is small. This may change if a longer period of time can be considered for the analysis, since patents and public policies in particular, take time to be developed.

A very important limitation from this work is how few articles of the journal have alternative metrics, at least as provided by Altmetric. This is consistent with results across other disciplines (Costas et al., 2014) which show that Altmetric information is only available for papers from the last 5 years. This suggests that although right now it is not possible to use this metrics to analyze the historical data of a journal, if the alternative metrics are still being tracked by sites like Altmetric in the coming decades, we might have available a rich set of metrics that could be used to asses more deeply the relation between metrics of societal impact and metrics of research impact.

A question that is left for future research is to understand if alternative metrics could be used to measure an article in a multi-dimensional way. Each alternative metrics could represent a different lens on how to understand the impact of an article: a higher presence in social media could be an assessment on the salaciousness of the title of the work; a higher number of news articles could indicate a measure of the clarity and brevity of the abstract. As more alternative metrics are gathered for every new article that is published, we may find that they represent a new way of understanding articles, providing different viewpoints, which could enrich the way we explore the continuously increasing sea of published research.

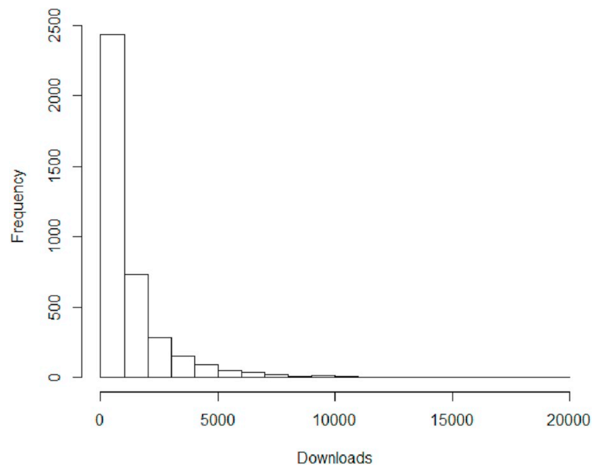
Appendix 1. The history of the Impact Factor of Computers & Education in web of science

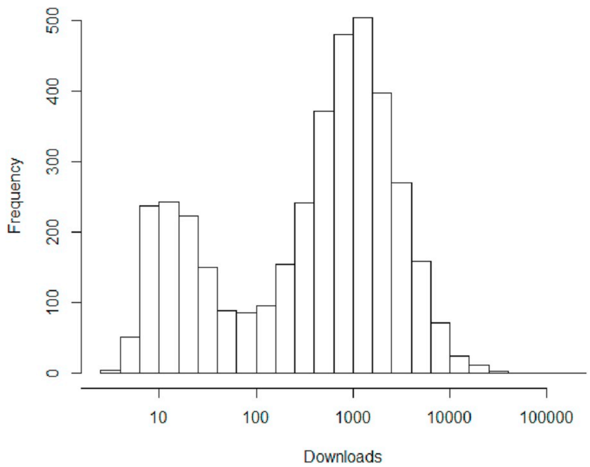
Only available since 1997. Data obtained from http://jcr.incites.thomsonreuters.com/JCRJournalProfileAction.action?pg=JRNLPROF&journalImpactFactor=n%2Fa&year=2017&journalTitle=COMPUT%20EDUC&edition=SCIE&journal=COMPUT%20EDUC.

YEAR	IF
2017	4.538
2016	3.819
2015	2.881
2014	2.556
2013	2.630
2012	2.775
2011	2.621

2010	2.617
2009	2.059
2008	2.190
2007	1.602
2006	1.085
2005	0.968
2004	0.625
2003	0.849
2002	0.442
2001	0.571
2000	0.300
1999	0.289
1998	0.402
1997	0.22

Appendix 2. Histograms for number of downloads; left regular scale, right log-scale





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Alejandro Echeverria
Facultad de Ingeniería y Ciencias Aplicadas, Universidad Los Andes, Chile

Miguel Nussbaum*
Computer Science Department, School of Engineering, Pontificia Universidad Católica de Chile, Chile
E-mail address: mn@ing.puc.cl.

Casper J. Albers
Heymans Institute for Psychological Research, University of Groningen, the Netherlands

Rachelle S. Heller
The George Washington University, United States

Chin-Chung Tsai
Program of Learning Sciences and Institute for Research Excellence in Learning Sciences, National Taiwan Normal University, Taiwan

Johan van Braak
Department of Educational Studies, Ghent University, Belgium

* Corresponding author.