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Abstract

The exploratory analysis of the differences between preprints and the corresponding peer reviewed journal articles for ten studies first published on ChemRxiv and on Preprints suggests outcomes of relevance for chemistry researchers and educators. The full transition to open science requires to undertake new educational work of doctoral students and young researchers on scholarly communication in the digital age. Learning that preprints differ only slightly in comparison to peer reviewed journal articles for all the basic sciences further supports the widespread adoption of preprints amid research chemists.

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Introduction

Publishing scientific articles in the form of "preprints" (though most preprints will never have a print version [1]), namely of freely accessible scientific documents posted on the internet before the peer review process, is rapidly replacing the conventional publishing process. For instance, the publication rate of arxiv.org (arXiv), a website managed by the Library of Cornell University, in 2019 approached 13,000 preprints per month (12,989/month) [2]. Originally aim ed at physics, mathematics and computer science scholars, the platform currently hosts works also from quantitative biology, quantitative finance, statistics, electrical engineering, systems science, and economics scholars. Similarly, the number of papers published by biorxiv.org (bioRxiv), a preprint repository for the life sciences managed by Cold Springer Harbor Laboratory since late 2013, in October 2020 exceeded the 100,000 threshold, with a publication rate of 2,943 preprints/month in the first 8 months of 2020 [3].

In slightly more than three years since its debut in May 2016 preprints.org (Preprints), the multidisciplinary preprint platform owned by the scientific publisher MDPI, reached the milestone of 10,000 preprints [4]. Yet, it took only 13 months to almost double the number of preprints to 17,000 by late October 2020. Showing the global impact of preprints, the latter studies at Preprints were co-authored by over 64,000 authors, whereas those at bioRxiv from close to 424,000 scholars.

We briefly remind that, in general, prior to publication of the preprint an editor working for the organisation owning the preprint server checks the uploaded manuscripts for minimum quality and lack of plagiarism. Eventually, the manuscript authored with no requirements on how to write and structure the article is posted online as PDF (portable document format) file.

Dubbed Chemistry Preprint Server (CPS), the first chemistry preprint server was launched online in August 2000 at http://preprint.chemweb.com. Two years later the CPS hosted already 500 preprints in numerous

areas of chemistry, from biochemistry to computational chemistry [5], co-authored by scholars based in 51 different countries. Alas, the website chemweb.com was subsequently closed because "changes in search algorithms resulted in a dramatic decline in traffic and a corresponding drop in revenue" [6]. Other attempts to launch chemistry preprint servers from large publishing companies were unsuccessful [7]. Publishing in the most oligopolistic sector of the highly profitable scientific publishing industry [8], chemistry scholars were recently found to be those publishing with the lowest frequency in open access (OA) journals. In detail, the analysis of 100,000 recent articles from all disciplines found that less than 20% of the chemistry papers were freely accessible [9].

In August 2017 the American Chemical Society joined by the Royal Society of Chemistry and the German Chemical Society launched a new chemistry preprint server at chemrxiv.org (ChemRxiv, today partly owned also by the Chemical Societies of Japan and of China). By late October 2020, the platform hosted 6,422 preprints, with an average publication rate of 324 preprints/month recorded in the first 8 months of 2020 [10]. By the same time, Preprints hosted close to 1,000 chemistry preprints.

Getting back to arXiv, a study published in 2016 comparing more than 12,000 preprints with the corresponding refereed journal, concluded that little differences exist between the preprint and peer reviewed articles when considering titles, abstracts and the body of the text (both on the semantic and on the editorial level) [11]. Similarly, extending the same statistical analysis to 2,500 preprints from bioRxiv revealed very little changes between the final published scientific papers and their preprint versions [12]. Focusing the analysis on a few (56) preprints published by bioRxiv in 2016, the preprints were found to be generally similar to the peer reviewed final published articles [13]. The following exploratory analysis looks at the differences between preprints and the corresponding peer reviewed journal articles for 10 studies first published as preprints in ChemRxiv and in Preprints. The outcomes are relevant for both chemistry researchers and educators.

Methodology

Ten preprints which underwent subsequent publication as peer reviewed articles in international scientific journals were selected, five from ChemRxiv (Table 1) and five from Preprints (Table 2).

Table 1 . Selected ChemRxiv preprints and journal hosting the peer reviewed article.

Preprint no.	**Year of publication** (number of views)*	**Title**
1	2019 (3,203)	*N*-Heterocyclic carbene-functionalized magic number gold nan
2	2020 (1,525)	Responsible Science, Engineering and Education for Water Re
3	2019 (2,369)	SilverSil: A New Class of Antibacterial Materials of Broad Sc
4	2018 (4,344)	General Cyclopropane Assembly via Enantioselective Redox-A
5	2018 (60,352)	The cryoEM method MicroED as a powerful tool for small mo

*Views by October 23, 2020. Source: Altmetric, 2020.

Table 2 . Selected chemistry preprints at Preprints and journal hosting the peer reviewed article.

Preprint no.	**Year of publication** (number of views)*	**Title**
6	2018 (710)	Single-Atom Catalysis: A Practically Viable Technology?
7	2018 (309)	Nanoparticles and Single Atoms in Commercial Carbon-Suppo
8	2019 (297)	High Yields of Shrimp Oil Rich in Omega-3 and Carotenoids:
9	2020 (93)	Synthesis, Antimicrobial and Antioxidant Activities of 2-Isoxa
10	2018 (928)	Solvent Free-microwave Green Extraction of Essential Oil from

*Views by October 23, 2020. Source: Altmetric, 2020.

Each Table includes the preprint title, the journal in which the peer reviewed article was eventually published and the current (2019) journal impact factor (JIF), a citation-based measure of impact [14]. The number of unique views of the selected preprints by October 23, 2020 is also included. The preprints are identified (numbered) with bold numbers, rather than referred to them by type in the following, in order to generalize the text or non-chemistry experts (*i.e.* , for readers not familiar with chemical terms and processes).

Results and Discussion

Table 3 lists number and types of changes across each of the 10 article's titles, abstracts, and texts.

Table 3 . Number and types of changes across each of the 10 study's titles, abstracts, and texts between final published journal articles and selected preprints.

Preprint identifier	Title	Abstract	Text
1	No change	No change	No difference
2	No change	One change, minor	Minor difference, includes Author biographie
3	No change	No change	Minor difference, three more references and
4	No change	Two changes, minor	No change
5	No change	No change	Minor change brief, brief post preprint text,
6	No change	Two changes, minor	Minor difference, three more references and
7	No change	Two changes, minor	No change
8	Minor change (shortened)	Three changes, minor	Minor change, five new references and slightl
9	No change	No change	Minor change, five new Schemes and one nev
10	No change	Four changes, significant	Noticeable change, more succinct presentatio

Upon acceptance for publication in different journals following peer review, all journal articles had the same title of the selected preprints deposited at ChemRxiv, and at Preprints. Only in the case of preprint **8** first posted at Preprints, the title of the corresponding journal article was shorter.

The abstracts of the preprints published in ChemRxiv and the corresponding journal articles were the same in three out of five cases. The journal article deriving from preprint **2** specified that the article derived from interaction with the members of the Association of Environmental Engineering and Science Professors in a workshop organized at the 2017 association conference. The journal article published after preprint **4** includes two minor writing style changes.

The abstract of the preprints published in Preprints and the final published journal articles was the same in two out of five cases, specifically for preprints **6** and **9** and the corresponding journal articles. In the case of preprint **10** the abstract of the journal article [15] was significantly shorter than that in the preprint. The abstract of the final published article [16] is longer and slightly more informative than that of preprint **7** , similarly to what happens for the abstract of the journal article [17] when compared to that of preprint **8** .

Little or no differences were found between the texts of the final journal articles and the preprints published in ChemRxiv months or weeks before. Preprint **1** even used the template of the subscription journal in which it was eventually published five months after the preprint. Interestingly, the study made freely accessible as preprint includes on each page the sentence "Submitted manuscript: confidential" [18]. Preprint **2** makes use of the template of the subscription journal in which it was published two months after the preprint as open access (OA), with a Table (Table 1) resulting of even higher readability (using colors) in the preprint [19] than in the peer reviewed article. In the case of preprint **3** , the final article published four months after the preprint in a OA journal includes three more references and slightly longer conclusions [20].

Preprints **4** and **5** do not use a journal template, but their content is virtually the same of the final published

articles. Preprint **4** does not include page numbers [21] but embeds high resolution colored Figures and Schemes. Downloading the preprint from ChemRxiv, users would also download the Table of Contents graphics and the same 470-page long Supporting Information section found four months later in the final published article. When compared to the text of preprint **5** , the peer reviewed article published 16 days after the preprint [22], includes at the end of the article a brief "Post preprint addendum", and five more references.

The latter preprint was uploaded, approved and published on the same day (October 17, 2018). The day before *Angewandte Chemie* published a manuscript [23] of a Swiss-German team reporting the invention of a similar method to obtain the molecular structure of microcrystalline molecular compounds via electron diffraction. The manuscript had been received by the journal editorial office on October 2, 2018.

Larger, though still not significant differences were noted between the selected preprints deposited at Preprints and the published journal articles. When compared to the text of preprint **6** , the final published article illustrates concepts through new research in a quickly developing field of chemistry published in the literature in the 20 months between the publication of the preprint and that of the journal article [24]. The final published article was virtually identical to preprint **7** , unless for a minor mistake in the sequential order of the Figures in the preprint that was corrected in the journal article [16].

When compared to preprint **8** , the final published article [17] had a substantially higher number of references (22 *vs.*17) and a longer and more informative conclusions section. In comparison to preprint **9** , the final published article [25] includes five new Schemes and one new Figure. The experimental section and the conclusions were identical.

The largest differences in the present analysis were noted between preprint **10** and the corresponding journal article [15]. The latter embeds a more succinct presentation, with only four Tables in the journal article *vs.* six in the preprint. Furthermore, the journal article includes both an elegant and highly explanatory image (Figure 1) displaying the experimental design and a new Figure (Figure 2) showing electron microscopic pictures of treated and non-treated orange peels. Both were absent in the preprint. Finally, the journal articles includes a richer conclusion section.

Published between 2018 and 2020, all selected preprints but one had more than 100 reads (unique views) by October 23, 2020. In general, the number of views was significantly higher for preprints published in ChemRxiv. For comparison, the most viewed preprint at Preprints among those selected herein had 928 views whereas the most viewed preprint at ChemRxiv had 60,352 views. In general, by the same date the most viewed preprint published by Preprints had 5,369 views (See at the URL: www.preprints.org/subject/browse/chemistry?filter=most_viewed).

The high number of reads for preprints posted at ChemRxiv was noted since the early days of the preprint server, when a manager of the OA programme of the ACS was "pleasantly surprised" [26] by the fact that by June 12, 2018, the 400 preprints posted had about 378,000 downloads/views. The trend continued, and two years later the editor of the online publishing platform remarked how preprints at ChemRxiv had been accessed "more than 10 million times, with upwards of 250,000 visitors to the site each day" [27].

Outlook and Perspective

Though exploratory and statistically non-significant, the analysis of 10 preprints selected from ChemRxiv and Preprints repositories and the respective published journal articles offers preliminary evidence that also in chemistry little difference exists between preprints and their final versions published as peer reviewed articles. Following studies and even experiments with reviewers involving the peer review process when editor of a prestigious medical journal, Smith in 2006 concluded that peer review "is a flawed process, full of easily identified defects with little evidence that it works" [28].

Chemistry scholars massively read preprints, with close to 13.5 million views for about 6,500 preprints posted on ChemRxiv by late October 2020. Furthermore, preprints deposited at ChemRxiv that had been cited 430

times in 2019 and 85 times in 2018, in 2020 started to be cited at fast rate with close to 1,050 citations in the first 10 months of 2020 (Source: Scopus, October 2020). By reading preprints, research chemists learn new methods and outcomes of relevance to their research several months ahead of time. Even in 2013, when virtually all chemistry journals were published on the internet, the average publication time (submitted to published time) for chemistry manuscripts was 9 months (and 4.5 months for submitted to accepted) [29].

Rather than striving to publish their work in journals of high journal impact factor, young chemistry researchers should be aware that the JIF is a poor statistical indicator imposed by a very small number of highly cited papers for which most papers published in high impact factor journals actually get *fewer* citations than indicated by the JIF [30]. In brief, by making their work freely and immediately accessible on the internet as preprints, chemistry scholars will rapidly reap the benefits of open science already demonstrated in closely related disciplines (life sciences and physics) in terms of enhanced citations, media attention, collaborations, job and funding opportunities [31]. Research chemists posting their research manuscripts on preprint servers, for instance, immediately enhance the visibility of their work. Also for chemistry scholars, the accurate measurement and wise evaluation of scientific output promoted by numerous scholars subscribing to the San Francisco Declaration on Research Assessment [32], today includes numerous other indicators beyond citations collectively called alternative metrics ("altmetrics", for which even an international OA journal was established in 2018, *Journal of Altmetrics*). The number of reads (views) and downloads of each preprint, for example, is a common feature for both Preprints and ChemRxiv preprint servers, and a clear indication of interest of the scholarly community.

Table 4 . Average journal price by discipline in 2020. Top five ranking. [Source: Library Journal Periodicals Price Survey, 2020].

Rank	**Discipline**	**Price** (in $)
1	Chemistry	6,316
2	Physics	5,137
3	Engineering	4,218
4	Biology	3,977
5	Food science	3,414

A few economic figures may help to explain why chemistry scholars showed reluctance to adopt open science practices, including pre-publishing their work in preprint form after the early successful attempts with the Chemistry Preprint Server [5]. It is enough to ask even a prolific author in the chemical sciences if she/he knows what is the cost paid by her/his institution's library to access a chemistry journal, and what is the market concentration level of the publishing industry in chemistry. Most often, she/he will be generally surprised to learn that chemistry has *historically* recorded the highest average journal serial prices [33]; and that in 2020 the average price for chemistry journals, exceeding the $6,300 threshold, was the highest amid all disciplines (Table 4). For comparison, in 2016 the average price for chemistry journals was $5,105 [34]. Similarly, a few chemistry scholars are aware that only five publishing organisations control publishing of more than 70% of chemistry studies [8].

Today, chemistry scholars can publish their work in preprint form on several preprint servers including ChemRxiv, Preprints, SSRN, Authorea, ResearchSquare, Zenodo, Beilstein Archives, OSF Preprints, ResearchGate and many others. Learning that preprints differ only slightly in comparison to peer reviewed journal articles for all the basic sciences (physics, mathematics, chemistry and biology) further supports the widespread adoption of preprints amid scholars of all basic sciences, including chemistry.

I agree with Polka [35] and with other open science researchers [36] who found that the key challenge for the transition to open science is cultural change. To effectively foster said cultural change requires, in its turn, to expand the education of doctoral students and young researchers to include scholarly communication in the digital age [37]. The preliminary findings of this study will contribute to inform the curriculum of the

aforementioned new courses for young chemistry scholars, eventually promoting accelerated innovation in chemistry [38], and the associated social, economic and environmental benefits due to the fact that chemistry, unique amid all basic sciences, originates a huge global industry which is central to the economic wealth of every nation [39].

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