Educational Technology Quarterly, Vol. **2021**, Iss. 3, pp. 402-414 https://doi.org/10.55056/etq.19

Selecting tools to enhance scholarly communication through the life cycle of scientific research

Olena H. Kuzminska

National University of Life and Environmental Sciences of Ukraine, 15 Heroiv Oborony Str., Kyiv, 03041, Ukraine

Abstract. Education and science digitalization belongs to the priority areas of information society development. However, we can observe that while Ukraine enters the European educational and scientific space, Ukrainian scientists cannot yet efficiently compete in the international labor market. One of the reasons behind this is that Ukrainian scientists and researchers are not fully integrated into the world system of digital scholarly communication. To help researchers use digital tools supporting scholarly communication, many companies carry out various educational events to support open science and initiate international research and projects. Under modern conditions the digitalization of scientific communication went to the front-burner due to the COVID-19 pandemic. At the same time, the forced transition to digital scholarly communications through the COVID-19 pandemic can help integrate young scientists into the international scientific space. This article provides an analysis of tools to support scholarly communication developed within the "101 Innovations in Scholarly Communication" project. The international survey demonstrates the tools that scientists prefer to use at each stage of the research. This paper characterizes the advantages of particular tools on different stages of scientific research process induced by the current tendency for scholarly communication digitalization. During the work, we outlined the scope for future research and found it necessary to conduct an additional survey for the scholarly community.

Keywords: scholarly communication, digital tools for scholarly communication, scientific research, early career researchers, Higher Education Institution

1. Introduction

Overall digital transformation affects the scientific community and actualizes the demand for tools applicable to conduct research and facilitate both scientific and educational activities and communication.

The supply of software tools for searching, collecting, and processing data, writing scientific papers, selecting journals and publishing is growing following innovations of scientific communication [15]. The traditional scientific communication model aimed to develop the knowledge transforms into the model of digital scientific communication (Brünger-Weilandt [5]) that concentrates on information availability and open access to data and results of scientific research.

The problems of open science and scientific communication are a subject of research for Bielikov [3], Bronnikova [4], Canet [6], Davis, Coppock and Vowell [9], Higgs [12], Horbenko

o.kuzminska@nubip.edu.ua (O. H. Kuzminska)
https://nubip.edu.ua/node/3983 (O. H. Kuzminska)
0000-0002-8849-9648 (O. H. Kuzminska)

© Copyright for this paper by its authors, published by Academy of Cognitive and Natural Sciences (ACNS). This is an Open Access article distributed under the terms of the Creative Commons License Attribution 4.0 International (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

[13], Hurd [14], Manca [20], Mayer [21], Yaroshenko [26]. Analysis of the achievements of these scientists is presented in [17].

Though the emergence of new tools for scientific communication doesn't increase their popularity, the digitalization of scientific communication went to the front-burner due to the COVID-19 pandemic [11].

At the same time, the forced transition to digital scientific communications has the potential to integrate early career researchers into the international scientific space.

The authors' experience [18] allows assuming the integrating Ukrainian scientists into the international community (European and American researchers more actively use the means of scientific communication) requires special preparation [25]. Against the background of a small amount of research related to students' perception and understanding of scholarly communication [23] and behaviour of early career researchers [22] such research tasks are actualized:

1. Review the tools of supporting scholarly communication;
2. Provide recommendations to early career researchers on the selection of tools to support scientific communication at different stages of their own research.

2. Results and discussion

There are different approaches to define the scientific research life cycle that serves as a basis for creating collections of resources to support their implementation and recommendations for selection [16]. However, the most popular is the model of the research workflow (figure 1) developed by Kramer and Bosman [15] within the "101 Innovations in Scholarly Communication" project. According to each stage (preparation, discovery, analysis, writing, publication, outreach, assessment) recommendations have been developed to ensure openness in accordance with the model of the life cycle of scientific research [2, p. 10].

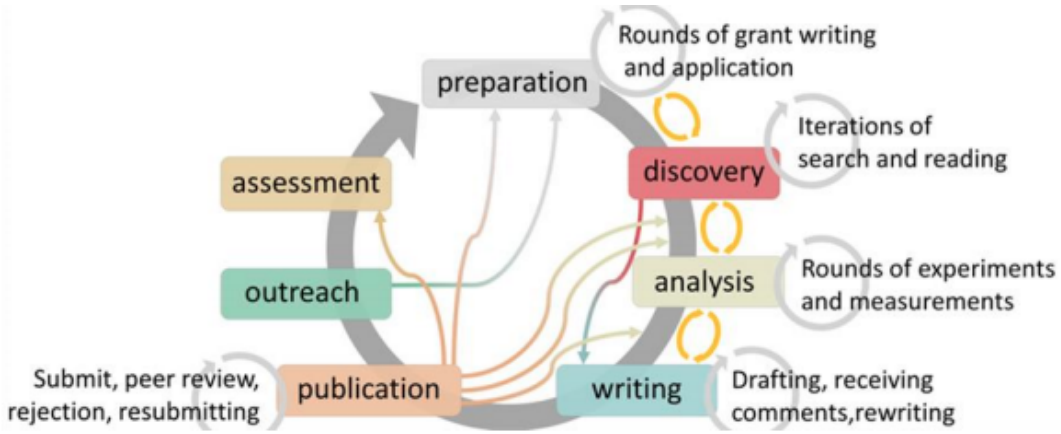

Figure 1: A model of the research workflow (Kramer and Bosman [15]).

During this project, in 2015–2016 conducted a global survey joined by more than 20,2000

scientists to determine the demand for scientific communication. The survey results, provided in open access, prove that we can study the changes to scientific communication both on the global and on the local levels [24]. We will use the results of the "101 Innovations in Scholarly Communication" project to inform early career researchers on digital tools applicable to support scientific communication (figure 2) through 6 stages of scientific research: review (search), analysis, creation (writing), publication, dissemination, and evaluation.

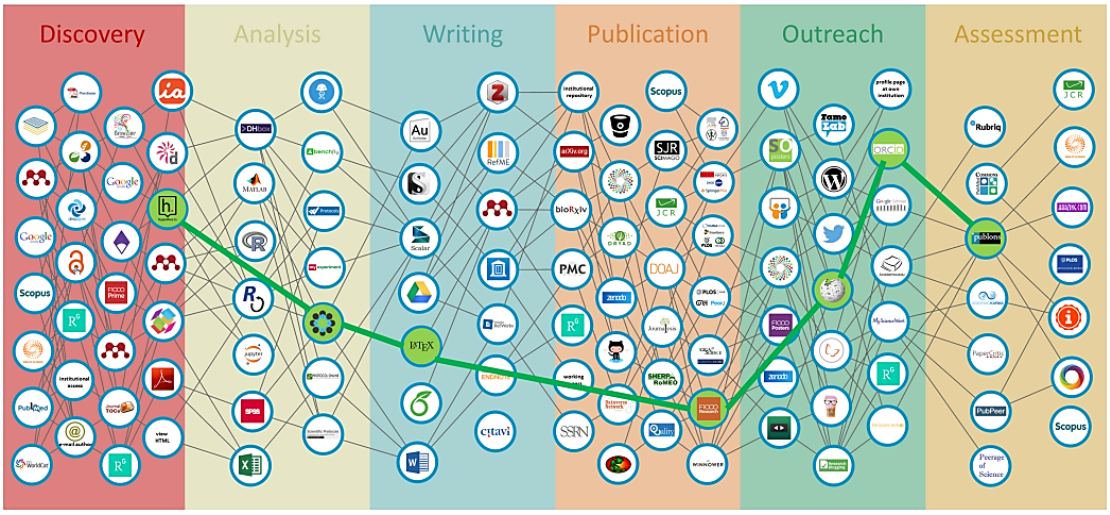

Figure 2: Digital tools used scientific communication (source: https://101innovations.wordpress.com/).

We will showcase a comparative characteristic of the most popular tools among scientists (as of 2016) (figure 2) per certain stages of the scientific research life cycle, and make several assumptions about the benefits of using specific tools (as of 2021) occasioned by the digitalization of scholarly communication [8]. Though, we should mention that the formats for the tasks and results submission are regulated by the requirements of the grantees (stage Preparation, figure 1) or by the provision on the preparation of of specific research.

The discovery stage involves the search and investigation of scientific content, in particular relevant scientific publications. We can divide the tools applicable on this stage into tools for searching for relevant data (Search), getting accesses (Get access), getting recommendations (Get alerts), and reviewing and leaving comments on the material (Read/view/annotate). By the results of an international survey (https://101innovations.wordpress.com/survey-results/research-activities/), the most popular sources to browse for publications are Google Scholar and Web of Science (figure 3).

Over the past five years, the availability of the materials in the Scopus database significantly increased. In particular, starting from 2019 Ukrainian higher educational institutions can access Scopus and Web of Science [10] provided at the expense of the state budget.

Since foreign universities' experience shows that the use of these analytical platforms allows benchmarking both at the level of the educational institution and individual scientific communities and researchers, we provide a comparative analysis of several scientometric databases (table 1).

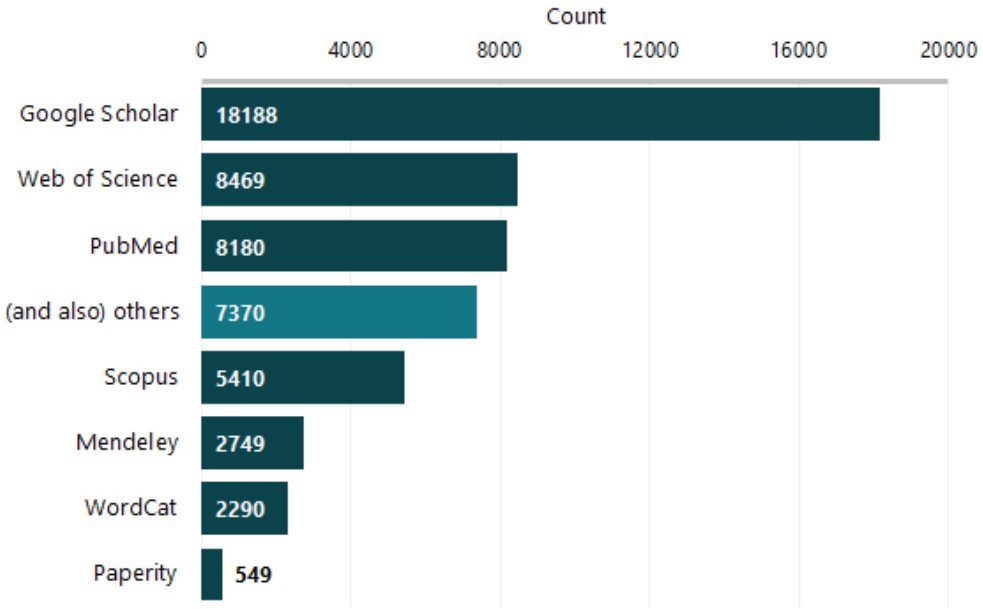

Figure 3: Fragment from the survey results demonstrating the usage of digital tools for data search (source: https://101innovations.wordpress.com/survey-results/research-activities/search/).

Table 1
Comparative analysis of several scientometric databases (source: https://instr.iastate.libguides.com/c.php?g=901522&p=6492159).

Characteristic	Web of Science	Google Scholar	Scopus
The number of journals	13,100	Unknown	21,950
Focus	Science, technology, social sciences, arts and humanities	All subject areas	Physical sciences, health sciences, life sciences, social sciences and humanities
Publications not in English	Yes, if there is an abstract in English	Yes	Yes, if there is an abstract in English
Citation analysis	Yes	No	Yes
Export reports	Yes	Yes	Yes

In addition to the institutional resources mentioned by the majority of global survey participants (18,016 out of 20,663 respondents), to access the scientific content the researchers mostly use the institutional access and ResearchGate social network (https://101innovations.wordpress.com/survey-results/research-activities/get-access/). The most used tool for receiving notifications (Get alerts) is Google Scholar (figure 4), although approximately half of the scientists

surveyed use it (10,051 out of 20,663).

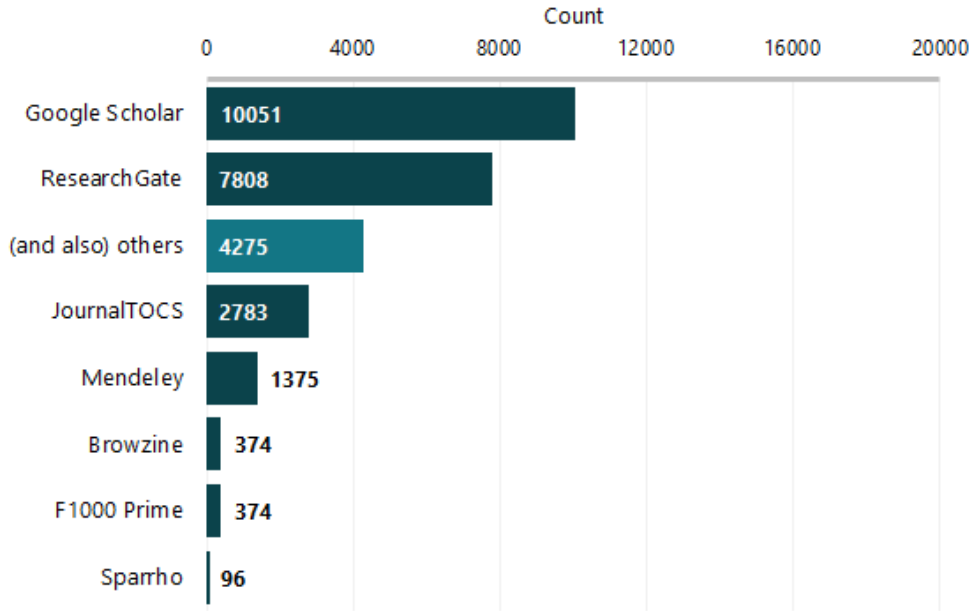

Figure 4: Fragment from the survey results demonstrating digital tools used to Get alerts (https://101innovations.wordpress.com/survey-results/research-activities/get-alerts/).

To work with texts (view and comment on them), users mostly leverage Acrobat Reader (18,319 out of 20,663 survey participants chose this tool).

Managing Big Data and code is a regular task for many researchers today, for these skills are required to get the grant or implement international research projects. Among the data management tools we can mention GitHub (https://github.com/), registry of research data repositories Re3data (https://www.re3data.org/), etc. Also, Google launched the Dataset Search (https://datasetsearch.research.google.com/) that allows for browsing the data in open access. This service complements Google Scholar and can be used for academic research [7].

Here, we should mention that only 1/5 of the global survey participants support the Share notebooks/protocols initiative: 6,021 of 20,663 responses answered this question, and 1,084 researchers use the most common tool for Share protocols – Dropbox; GitHub – only 177 users.

The researchers prefer MS Excel (figure 5) at the Analysis stage, and less use SPSS [19].

As of 2016, less than 20% of researchers use MATLAB (https://www.mathworks.com) and R (https://www.r-project.org/). However, since the R statistical programming language rose in 2021 to 8th place in the TIOBE (http://web.archive.org/web/20210805060025/https://www.tiobe.com/tiobe-index/) popularity index. Table 2 provides a comparative characterization of data analysis tools that, according to the survey (figure 5), had approximately the same popularity.

Analysis often requires harmonization of methods, discussion of models, or description of data for reuse. For these purposes, researchers use services for collective data processing for scientific purposes such as Open Science Framework (https://osf.io/), and general-purpose cloud

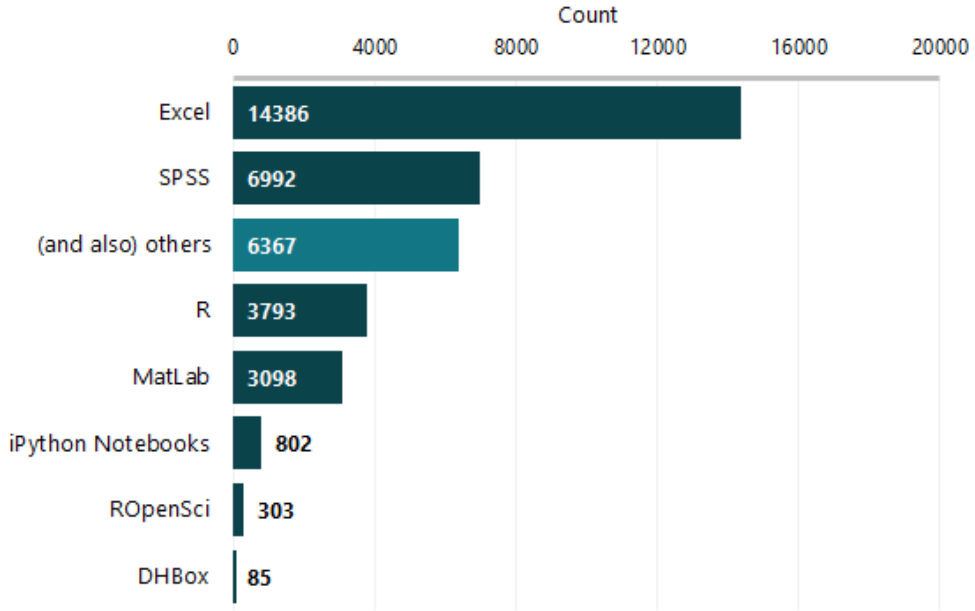

Figure 5: Fragment from the survey results demonstrating digital tools used for Analysis (source: https://101innovations.wordpress.com/survey-results/research-activities/analyze/).

Table 2
Comparative analysis of MATLAB and R (source: https://www.educba.com/matlab-vs-r/).

Characteristic	MATLAB	R
Open source	No, only for the paid version	Yes
Speed	MATLAB is faster than R	
Functionality	Engineering application: image processing, machine learning, signal processing, etc.	Statistical analysis, data processing
Availability of libraries	Most features are available as a toolboxes	A lot of packages with different functionality
Language type	High-level language	Interpreted language
Community support	The licensed package provides for technical support	Community support

services: Dropbox that Google Drive.

Though very likely, the early career researchers of Ukrainian higher educational institutions, supervised by representatives of traditional scientific schools, will give preference to Dropbox and Google Drive for some time.

Tools of the writing stage are divided into tools used for writing (preparing a manuscript) and tools used as bibliographic managers. To prepare manuscripts, researchers mostly use (figure 6)

MS Word (selected by 18,571 of 20,663 survey participants). Significantly fewer researchers (6,636 people) use Google Docs and Google Drive services to collaborate on the documents.

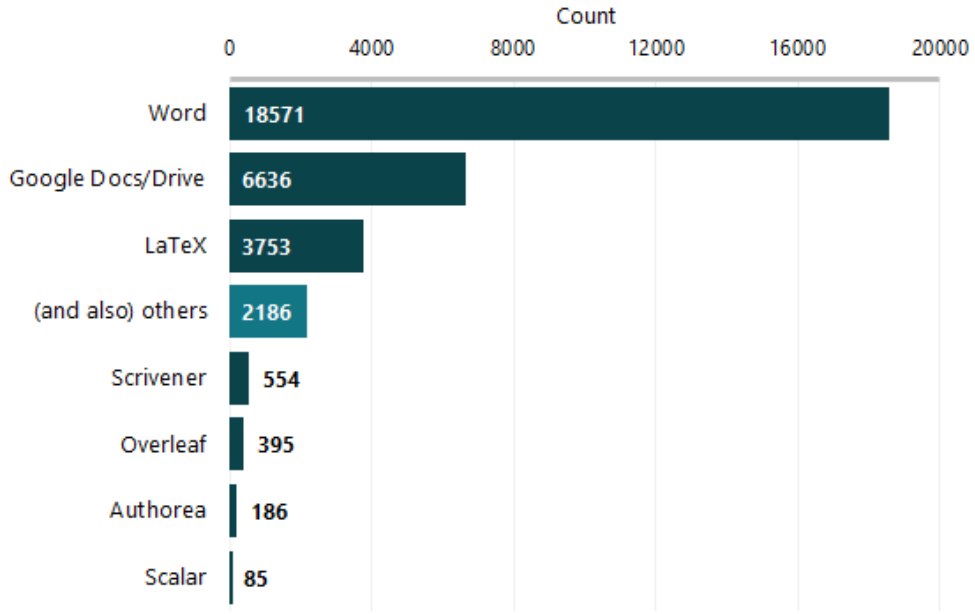

Figure 6: Fragment from the survey results demonstrating the tools for the Writing stage (source: https://101innovations.wordpress.com/survey-results/research-activities/write/).

Free software such as LibreOffice (https://www.libreoffice.org/discover/libreoffice/) and OpenOffice (https://www.openoffice.org/) has significantly fewer users (267 and 215 users respectively).

We should emphasize the LaTeX document preparation system for high-quality layout (https://www.latex-project.org/about/) which is popular among scientists (figure 6): de facto this is a standard for scientific documents exchange and publication. That is why we would recommend young scientists to gain experience with this software.

At this stage, researchers also use bibliographic managers software to save bibliographic data, complete texts, create personal and collective bibliographic collections, create links and lists of used sources. The most popular tools on this stage include EndNote, Zotero, and Mendeley (figure 7). Though the popularity itself is doubtful: only 15,956 out of 20,663 respondents answered this question, and the majority of users who voted (for EndNote) does not exceed 50% (7,540 users).

Due to the importance of bibliographic managers in the study process, table 3 presents the comparative characteristics of free bibliographic managers. The free EndNote package is only available in the online version of the EndNote program. At the same time, these services are expanding their functionality, thus increasing the number of users. For example, today the Mendeley social network is integrated with the Scopus scientometric database, therefore, it is difficult to predict the growth of the popularity for these tools [1].

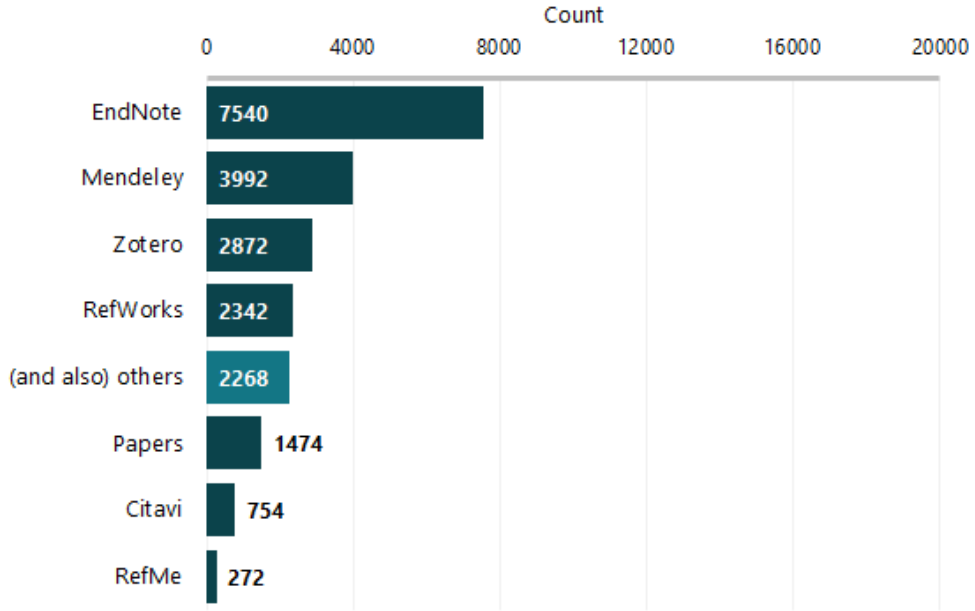

Figure 7: Fragment from the survey results demonstrating the tools for Reference management (source: https://101innovations.wordpress.com/survey-results/research-activities/reference-management/).

Table 3
Comparative analysis of bibliographic managers (source: https://www.library.yorku.ca/web/research-learn/citing-your-work-academic-integrity/citations/zotero-vs-mendeley-comparison/).

Characteristic	**Zotero** https://www.zotero.org/	**Mendeley** https://www.mendeley.com/
Key offers	Work as a Firefox extension or as a standalone version with a connector to Chrome, Safari, Firefox and Opera	Includes a desktop version and web version compatible with all major web browsers
Cost	Basic software is free. Charges for adding additional storage space	
Storage	The free version provides 300 MB of cloud storage	The free version provides 2 GB of cloud storage
Operating system	Mac OS, Windows, Linux, and any otherss where Firefox runs	Mac OS, Windows, Linux
Citation styles	Both Mendeley and Zotero use Citation Style Language, which offers over 7,000 free CSL citation styles.	

The publication stage includes tools for archiving and hosting publications, data, and code, selecting a journal, and publishing. Although scientists still prefer traditional scientific publications (13,542 respondents out of 15,253), open-access platforms offer an alternative publication model that allows everyone to distribute their scientific works for free. Thus, most scientists post their publications in institutional repositories and the ResearchGate social scientific network.

To share their code and data, researchers use GitHub, Figshare, though there are still many users who prefer to archive their scientific works and data and upload them on Dropbox and Google Drive under restricted access. Among the publication tools, researchers use journals indexed in scientometric databases, catalogs of open electronic journals, archives of scientific publications, and scientific social networks (table 4).

Table 4
Comparing the tools for publishing scientific articles.

Characteristic	**Scopus** (abstract and citation database)	**DOAJ** (list of open access journals)	**ResearchGate** (social network service for scientists)	**arXiv** (open-access repository of e-prints)
Commercial	Yes	No	No	No
Publishing individual articles	No	No	Yes	Yes
Citation tracking	Yes	No	Yes	Yes
Advanced article search	Yes	No	No	Yes
Access to the article	Defined by publisher	Free	Defined by author	Free
Articles control	Yes	Yes	No	Yes

Though we should mention that it is quite difficult for early career researchers to publish their work in publications indexed in scientometric databases, even in collaboration with their research supervisors. Electronic journals present new challenges for the Ukrainian educational institutions, since they are not ready to set and maintain the platforms for internal communication, and also some research supervisors deny the idea of digital communication itself.

The scientific work results outreach and research popularization stage includes services for archiving and sharing posters, presentations, research popularization, and creating the researchers' profiles. The posters and presentations archiving services are the least in demand (by a survey conducted in 2016: according to opinions of 6,576 out of 20,663 users). Among those 6,576 respondents: 3,295 researchers use SlideShare, 969 researchers use Vimeo, and 864 users prefer Figshare. Here we should note that the survey did not suggest YouTube, which will probably be more popular among young Ukrainian researchers.

Approximately 50% of researchers (10,744 of 20,663 respondents) consider it necessary to popularize their research works. These respondents mostly use Twitter (5,601 users), Wikipedia (3,516 users), WordPress (3,024 users), Research Blogging (798 users).

For early career researchers, Facebook is a potentially attractive network to support scientific communication: it allows young researchers to popularize their work, for instance at open events like scientific conferences, webinars, presenting results, etc. Scientific profiles will be useful for masters during their research and while looking for an expert or a consultant in their field. Though, for that, young scientists should create and manage their profiles. According to a survey, the researchers are interested in building their brand, all 20,663 respondents replied positively to

this question. The opinions on the preferred tooling (figure 8) differ: about 50% of respondents have personal profiles in ResearchGate and Google Scholar; 25% use Academia.edu and ORCID; 4,974 claims they use institutional resources and tools. Also, the number of user profiles in Scopus and Web of Science should grow according to the growing number of publications in these databases.

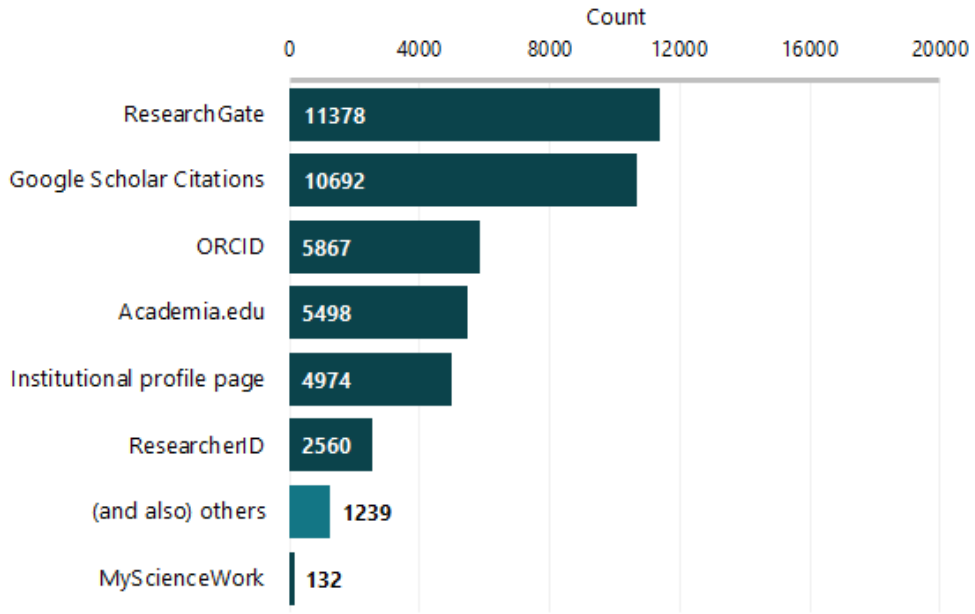

Figure 8: Fragment from the survey results for Researcher profiles (source: https://101innovations.wordpress.com/survey-results/research-activities/profiles/).

As for the expert assessment of scientific research (assessment), it is difficult for early career researchers to compete with experienced scientists. Though, the scientists do not support that activity either. Only 3,312 of 20,663 respondents answered this question positively, which is the lowest activity for the life cycle stages.

A completely different situation is with assessing the influence of their scientific achievements: 12,750 out of 20,663 respondents answered this question positively. Most researchers use the scientometric databases of Web of Science (6,797 users) and Scopus (5,673 users), much less prefer Google scholar (611 users) and ResearchGate (175 users).

At the same time, we cannot play down the importance of creating profiles by early career researchers and managing their research results in Google Scholar and ResearchGate.

3. Conclusion

The following conclusions are based on an analysis of the results of a global survey conducted in accordance with the tasks of implementing the “101 Innovations in Scholarly Communication”

project, modern trends in the digitalization of scientific communication, and features of the implementation of the life cycle of scientific research:

- Despite the large number of digital tools available to promote scientific communication, utilization of these technologies at various stages of the scientific research life cycle is uneven as of 2016. Given the lack of integration of Ukrainian scientists into the global scientific community, it is reasonable to expect a similar trajectory in Ukrainian science in 2021.
- The majority of researchers use digital technologies to find and access scientific literature, analyze research data, produce articles, and create their own image. At the same time, it should be noted that scientists prefer publication in printed professional journals, that MS Word is used for manuscript preparation, that MS Excel is used for data analysis, research materials, and data search, and that Google Scholar and ResearchGate services are also used to build the researcher's image.
- Scientists are least interested in tools that aid in the distribution, popularization, and evaluation of their own research. The latter demonstrates not only a "break" in the life cycle of scientific research, but also a certain closeness of scientific activity and isolation from the global scientific area, which is undergoing digital transformation.
- Understanding the irreversibility of scientific and scientific communication digitalization, as well as assisting young scientists in integrating into the global scientific space, it is recommended to conduct specialized training and educational activities to popularize open access initiatives and open science. One of the responsibilities for providing scientific support for the scientific activity of young scientists, particularly masters of Ukrainian institutions of higher education, is the formulation of suggestions for the use of digital instruments at various stages of conducting scientific research.

The research is still ongoing as evidenced by the repeated surveying of members of the scientific community with the goal of confirming the hypotheses advanced and elucidating the current usage of scientific communication tools by researchers. It will be possible to determine the directions of their collaboration and the integration of Ukrainian scientists into the larger scientific community by conducting a comparative analysis of the landscape of digital scientific communications of researchers from various career levels, particularly postgraduate students and their scientific supervisors.

References

[1] 101 Innovations, 2016. Academic social networks – the Swiss Army Knives of scholarly communication. Available from: https://tinyurl.com/3kzhhvfj.

[2] Bezjak, S., Clyburne-Sherin, A., Conzett, P., Fernandes, P., Görögh, E., Helbig, K., Kramer, B., Labastida, I., Niemeyer, K., Psomopoulos, F., Ross-Hellauer, T., Schneider, R., Tennant, J., Verbakel, E., Brinken, H. and Heller, L., 2018. *The Open Science Training Handbook.* Available from: https://www.fosteropenscience.eu/content/open-science-training-handbook.

[3] Bielikov, O., 2020. Scientific communication as a component of pedagogical science. *Bulletin of the Cherkasy Bohdan Khmelnytsky National University. Series "Pedagogical Sciences"*, (1). Available from: https://ped-ejournal.cdu.edu.ua/article/view/36-41.

[4] Bronnikova, L.V., 2015. Communication in science: New tools for the production of knowledge. *Naukovi pratsi. Filosofiia*, 257(245), pp.38–42.

[5] Brünger-Weilandt, S., 2007. E-science - advancing new ways of scientific communication. *Information Services & Use*, 27(4), pp.161–166. Available from: https://doi.org/10.3233/ISU-2007-27406.

[6] Canet, F., 2019. Changing times for scholarly communication: The case of the academic research video and the online video journal. *Profesional de la información*, 28(4). Available from: https://doi.org/10.3145/epi.2019.jul.06.

[7] Castelvecchi, D., 2018. Google enters data ecosystem: Dataset Search could be especially helpful to cross-disciplinary researchers. *Nature*, 561(7722), pp.161–162.

[8] Crouzier, T., 2013. Digital tools for researchers. Available from: http://web.archive.org/web/20200118101419/http://connectedresearchers.com/online-tools-for-researchers/.

[9] Davis, M.J., Coppock, E. and Vowell, L., 2012. Science-Forums.net A Platform for Scientific Sharing and Collaboration. *Grey Journal (TGJ)*, 8(1), pp.5–13.

[10] Dostup za koshty biudzhetu do Scopus ta WoS dlia vyshiv ta naukovykh ustanov Ukrainy bude prodovzheno – nakaz MON, 2020. Available from: https://tinyurl.com/ynyca4dn.

[11] Hayashi, K., 2021. How Could COVID-19 Change Scholarly Communication to a New Normal in the Open Science Paradigm? *Patterns*, 2(1), p.100191. Available from: https://doi.org/10.1016/j.patter.2020.100191.

[12] Higgs, A., 2018. The new dimension in scholarly communications: How a global scholarly community collaboration created the world's largest linked research knowledge system. *Information Services & Use*, 38(1-2), pp.85–89. Available from: https://doi.org/10.3233/ISU-180002.

[13] Horbenko, Y.O., 2009. Tendentsii rozvytku naukovykh komunikatsii v suchasnii Ukraini. *Visnyk Kharkivskoho natsionalnoho universytetu im. V.N. Karazina*, (881), pp.167–174. Available from: http://dspace.univer.kharkov.ua/handle/123456789/4853.

[14] Hurd, J.M., 2000. The Transformation of Scientific Communication: A Model for 2020. *Journal of the American Society for Information Science*, 51(14), pp.1279–1283. Available from: https://doi.org/10.1002/1097-4571(2000)9999:9999<::AID-ASI1044>3.0.CO;2-1.

[15] Kramer, B. and Bosman, J., 2015. 101 Innovations in Scholarly Communication - the Changing Research Workflow. Available from: https://doi.org/10.6084/m9.figshare.1286826.v1.

[16] Kruesi, L.M., Tanner, K.J. and Burstein, F.V., 2018. Knowledge Management Theory and the Evidence-Based Healthcare Model to Guide the Design for an Australasia Open Biomedical Repository. *IFLA WLIC 2018 – Kuala Lumpur, Malaysia – Transform Libraries, Transform Societies*. Available from: http://library.ifla.org/id/eprint/2184.

[17] Kuzminska, O., 2020. *Theoretical and methodical principles of design and application of digital educational environment of scholarly communication of masters of research*. The thesis for the degree of Doctor of Pedagogical Science, in specialty 13.00.10 – Information and Communication Technologies in Education. State Institution «Taras Shevchenko National University of Luhansk», Starobilsk. Available from: http://dspace.luguniv.edu.ua/xmlui/handle/123456789/6375.

[18] Kuzminskaia, E.G., 2014. Informatcionnye tekhnologii i nauchnaia kommunikatciia: instrumenty i modeli vnedreniia v usloviiakh universiteta. *Obrazovatelnye tekhnologii i*

obshchestvo, 17(1), pp.447–456. Available from: https://tinyurl.com/2p9f4ymp.

[19] Levesque, R., 2005. *SPSS Programming and Data Management: A Guide for SPSS and SAS Users*. 2nd ed. SPSS Inc. Available from: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.370.2036&rep=rep1&type=pdf.

[20] Manca, S., 2018. ResearchGate and Academia.edu as networked socio-technical systems for scholarly communication: a literature review. *Research in Learning Technology*, 26. Available from: https://doi.org/10.25304/rlt.v26.2008.

[21] Mayer, K., 2015. From science 2.0 to open science – turning rhetoric into action? *STCSN E-Letter*, 3(1). Available from: http://stcsn.ieee.net/e-letter/stcsn-e-letter-vol-3-no-1/from-science-2-0-to-open-science.

[22] Nicholas, D., Jamali, H.R., Herman, E., Watkinson, A., Abrizah, A., Rodríguez-Bravo, B., Boukacem-Zeghmouri, C., Xu, J., Świgoń, M. and Polezhaeva, T., 2020. A global questionnaire survey of the scholarly communication attitudes and behaviours of early career researchers. *Learned Publishing*, 33(3), pp.198–211. Available from: https://doi.org/10.1002/leap.1286.

[23] Riehle, C.F. and Hensley, M.K., 2017. What Do Undergraduate Students Know about Scholarly Communication?: A Mixed Methods Study. *portal: Libraries and the Academy*, 17(1), pp.145–178. Available from: https://doi.org/10.1353/pla.2017.0009.

[24] Tammaro, A.M., 2017. Digital Scholarship Innovation and Digital Libraries: A Survey in Italy. In: M. Agosti, M. Bertini, S. Ferilli, S. Marinai and N. Orio, eds. *Digital Libraries and Multimedia Archives*. Cham: Springer International Publishing, pp.31–43. Available from: https://doi.org/10.1007/978-3-319-56300-8_4.

[25] White, E. and King, L., 2020. Shaping scholarly communication guidance channels to meet the research needs and skills of doctoral students at Kwame Nkrumah University of Science and Technology. *The Journal of Academic Librarianship*, 46(1), p.102081. Available from: https://doi.org/10.1016/j.acalib.2019.102081.

[26] Yaroshenko, T. Naukovi komunikatsii XXI stolittia: elektronni resursy dlia nauky ta osvity Ukrainy [Scientific communications of the 21 century: electronic resources for Ukrainian science and education]. Available from: http://dspace.nbuv.gov.ua/handle/123456789/938.