

The Influence of the COVID-19 Pandemic on the Use of Digital Technologies by Scientists: A Comparison Between Poland and Abroad

Jolanta Wartini-Twardowska

Post PhD DSc, Department Business Economics and International Accounting,
University of Economics in Katowice, Poland
<https://orcid.org/0000-0001-7273-6357>

Dariusz Grabara

PhD DSc, Department Business Economics and International Accounting,
University of Economics in Katowice, Poland
<https://orcid.org/0000-0003-3695-9355>

Ewa Wanda Ziemia

Professor, Post PhD DSc, Department Business Economics and International Accounting,
University of Economics in Katowice, Poland
<https://orcid.org/0000-0002-1084-7497>

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Abstract

Purpose: Our research was performed to identify differences in the frequency of using digital technologies by scientists to support their research in the periods before, during, and after the COVID-19 pandemic. **Design/methodology/approach:** A survey questionnaire was used and data were collected from 467 scientists from Poland and abroad, which were statistically analyzed. The non-parametric Kruskal–Wallis test was applied to reveal the differences in the frequency of digital technologies use between scientists in Poland and abroad in three periods (before, during, and after the COVID-19 pandemic). The non-parametric Friedman rank test and the post-hoc Conover test with Benjamini-Hochberg adjustment were used to assess the significant differences between three paired periods: before-during, before-after, and during-after the COVID-19 pandemic. For these periods, the association between the use of digital technologies and the types of research (basic or applied) conducted by scientists in Poland and abroad was also measured using Spearman's rank correlation.

Correspondence address: Department Business Economics and International Accounting, University of Economics in Katowice, 1 Maja 50, 40-287 Katowice, Poland; e-mails: j.wartini_twardowska@ue.katowice.pl; dariusz.grabara@ue.katowice.pl; ewa.ziemia@ue.katowice.pl.

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Findings: Scientists from Poland and abroad differed in the use of all digital technologies before and after the COVID-19 pandemic. During the pandemic, the differences concerned only social media, owing to a similar increase in the use of both communication applications and e-learning platforms. The results demonstrated that there was a weak positive correlation between the use of all digital technologies and applied research by both groups of scientists for all paired periods. In Poland in particular, our research has confirmed a positive correlation between the use of communication applications and social media and basic research for two paired periods: before-during and during-after the pandemic.

Research limitation/implications: The limitations of this study were primarily related to the sample size, which did not allow the results to be generalized to the entire population. Another limitation was that all scientists from outside Poland were assigned to one group, without division into countries or regions of the world. This, however, enabled the research scope to be narrowed and resulted in stressing the differences between Poland and the rest of the world. A further limitation that may affect the research results is the adopted 5-point Likert scale, which determines the possibility of making an analysis.

Originality/value: This research contributes to knowledge about the adaptation of scientists in Poland and abroad to new conditions resulting from the COVID-19 pandemic regarding the frequency of digital technology use in basic and applied research. The significant differences found in the frequency of digital technology use between the three paired periods (before-during, before-after, and during-after the pandemic) have the potential to encourage research into their permanence.

Keywords: COVID-19 pandemic, digital technologies, scientific research, scientists.

JEL: D8, I23, O39

Wpływ pandemii COVID-19 na użycie technologii cyfrowych przez naukowców: Porównanie Polski z zagranicą

Streszczenie

Cel: nasze badanie zostało przeprowadzone w celu zidentyfikowania różnic w częstotliwości korzystania z technologii cyfrowych przez naukowców do wsparcia ich badań w okresach przed, podczas i po pandemii COVID-19.

Metodologia: wykorzystano kwestionariusz ankietowy i zebrano dane od 467 naukowców z Polski i zagranicy, które poddano analizie statystycznej. Zastosowano nieparametryczny test Kruskala–Wallisa, aby wykazać różnice między naukowcami w Polsce a za granicą w częstotliwości korzystania z technologii cyfrowych w trzech okresach (przed, podczas i po pandemii COVID-19). Nieparametryczny test rang Friedmana i test post-hoc Conovera z korektą Benjaminiego Hochberga wykorzystano do stwierdzenia istotnych różnic między trzema parami okresów: przed-podczas, przed-po i podczas-po pandemii COVID-19. Dla tych okresów zmierzono również, za pomocą korelacji rang Spearmana, związek między wykorzystaniem technologii cyfrowych a badaniami (podstawowymi lub stosowanymi) przeprowadzonymi przez naukowców w Polsce i za granicą.

Wyniki: naukowcy z Polski i zagranicy różnili się stopniem wykorzystania wszystkich technologii cyfrowych przed i po pandemii COVID-19. Podczas pandemii różnice dotyczyły jedynie mediów społecznościowych z powodu podobnego wzrostu wykorzystania zarówno aplikacji komunikacyjnych, jak i platform e-learningowych. Wyniki wykazały, że istnieje słaba pozytywna korelacja pomiędzy wykorzystaniem, przez obydwie grupy naukowców, wszystkich technologii cyfrowych a badaniami stosowanymi we wszystkich parach okresów. Zwłaszcza w Polsce nasze badania potwierdziły pozytywną korelację pomiędzy wykorzystaniem aplikacji komunikacyjnych i mediów społecznościowych a badaniami podstawowymi w dwóch parach okresów: przed-podczas i podczas-po pandemii.

Ograniczenia/implikacje badawcze: ograniczenia tego badania dotyczyły przede wszystkim wielkości próby, co nie pozwoliło na uogólnienie wyników na całą populację. Kolejnym ograniczeniem było zakwalifikowanie wszystkich naukowców spoza Polski do jednej grupy, bez podziału na kraje lub regiony świata. Umożliwiło to jednak zawężenie zakresu badań i zaowocowało podkreśleniem różnic między Polską a resztą świata. Kolejnym ograniczeniem, które może mieć wpływ na wyniki badań jest przyjęta 5-stopniowa skala Likerta determinująca możliwość dokonania analizy.

Oryginalność/wartość: badania te przyczyniają się do poszerzenia wiedzy na temat adaptacji naukowców w Polsce i za granicą do nowych warunków wynikających z pandemii COVID-19 w zakresie częstotliwości wykorzystania technologii cyfrowych w badaniach podstawowych i stosowanych. Stwierdzone różnice dotyczące częstotliwości korzystania z technologii cyfrowej w trzech sparowanych okresach (przed-podczas, przed-po i podczas-po pandemii) mogą potencjalnie zachęcić do zbadania ich trwałości.

Słowa kluczowe: pandemia COVID-19, technologie cyfrowe, badania naukowe, naukowcy.

1. Introduction

The COVID-19 pandemic has disrupted traditional modes of scientific communication (Bottanelli et al., 2020), and digital technologies have aided in building new working conditions. Particularly, the pandemic has accelerated an unprecedented shift in the extent to which personal interactions have been replaced by virtual interactions (Fink, 2020). Scientists are no strangers to rapid digital evolution, but they did not anticipate the online revolution, where most interactions now take place (Fink, 2020). At the same time, opportunities and challenges have emerged that have created a naturally occurring research gap regarding the use of digital technologies by scientists. Since the success of scientists depends on the type of research conducted (Bekkers & Bodas Freitas, 2008), we attempted to determine the impact of the COVID-19 pandemic on the use of communication applications, e-learning platforms, and social media in regard to the work of scientists in the context of their research (basic and applied). Per OECD (1993), basic research is defined as “research carried out for the advancement of knowledge, without working for long-term economic or social benefits and with no positive efforts being made to apply the results to practical problems or transfer the results to sectors responsible for its application.” In turn, applied research is defined as “original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific practical aim or objective.” (OECD, 2012).

In our study, we attempted to answer the main research question (RQ1):

RQ1: Has the COVID-19 pandemic changed the use of digital technologies in scientific research by scientists in Poland and abroad?

Before the COVID-19 pandemic, exploiting new digital technologies was one of the greatest challenges faced by organizations and many did not keep up with the new digital reality (Hess et al., 2016). The pandemic has brought changes; our research highlights the differences in digital technology use by university researchers in three paired periods (before-during, before-after, and during-after the COVID-19 pandemic).

RQ1 was supported by three hypotheses, which are listed in the third section of this article. We have organized the rest of this article as follows: section 2 describes a systematic literature review; section 3 contains research methodology and data analysis; discovered changes in observed analysis periods are described in section 4; section 5 includes discussion and conclusions.

2. Systematic Literature Review

We conducted a qualitative analysis of publications dating from 2019 to 2020 to investigate the impact of the current COVID-19 pandemic on scientific research and scientists (researchers). The download of data from the Web of Science Core Collection database was completed on November 1, 2020. Based in part on Centre for Reviews and Dissemination (CRD) (2008) and qualitative meta-synthesis of publications, we proposed the following five steps for the process of systematic review:

- (1) Preparation of research topics that included issues from the widest to the narrowest of the following: researcher AND Covid-19; scientists AND Covid-19 AND effects; academic* AND research* AND Covid-19* AND digital*; academic AND research AND Covid-19 AND media; academic* AND staff AND activit* AND Covid-19.
- (2) Searches of the Web of Science Core Collection citation and chemical indexes of all publications (949 in total) that included the following issues: researcher AND Covid-19 (842); academic* AND staff AND activit* AND Covid-19 (14); scientists AND Covid-19 AND effects (45); academic* AND research* AND Covid-19* AND digital* (20); academic AND research AND Covid-19 AND media (28). The indexes used were as follows: Science Citation Index Expanded (SCI-EXPANDED), 1900–present; Social Sciences Citation Index (SSCI), 1900–present; Arts & Humanities Citation Index (A&HCI), 1975–present; Conference Proceedings Citation Index-Science (CPCI-S), 1990–present; Conference Proceedings Citation Index-Social Science & Humanities (CPCI-SSH), 1990–present; Book Citation Index-Science (BKCI-S), 2010–present; Book Citation Index-Social Sciences & Humanities (BKCI-SSH), 2010–present; Emerging Sources Citation Index (ESCI) 2015–present; Current Chemical Reactions (CCR-EXPANDED), 1985–present (includes Institut National de la Propriete Industrielle structure data from 1840); Index Chemicus (IC), 1993–present.
- (3) Exclusion of publications that were duplicated, discussions, editorials, letters, book reviews, posters, or did not explicitly fulfill the following criteria: English language, existing abstract, usage of one of the above-named terms; academic nature of peer review, and access to a complete publication.

- (4) Qualification of data after having reviewed the remaining 914 papers. We excluded 905 that did not relate to researchers or scientists and their research, and those with inadequate content. We retained papers that included the use of digital technologies for research purposes, except for research on the spread of the COVID-19 virus or other related medical issues.
- (5) Analysis and (narrative) synthesis using the full text of the final set of extracted publications, and a comparison of the extracted publications using a synthetic description (see Table 1). Based on in-depth analysis, we concluded that four of the nine extracted articles related directly to the usage of digital technologies, while the remaining articles only tangentially referred to it. Byrnes et al. (2020) compiled a list of video conferencing technologies, software, and online platforms to support anatomists' communication and collaboration, which highlighted the advantages and disadvantages of video conferencing technology in teaching and research. In turn, according to Davison (2020), using digital technologies to collect data during the COVID-19 pandemic is merely replication, and a more effective way to meet respondents is required in the context of social science research realization. In the opinion of Kligler-Vilenchik et al. (2020), social media has become a way of spending time during the COVID-19 pandemic for most (non-scientist) respondents. However, Schwarz et al. (2020) explored digital formats of interaction between research community members that became part of a new regime of academic exchange. Interactions between scientists due to digital technologies have increased the integrity of knowledge exchange, and have reduced the time and costs of organizing interactions that are geographically and temporally differentiated (Trogisch et al., 2020). A somewhat similar research direction was chosen by Bottanelli et al. (2020) suggesting a set of practices for creating a series of effective online seminars, and Weissberger et al. (2020) provided ideas for organizing virtual conferences with live video, chats, and social media.

Author (year)	Research method	Field of sciences	Period of research	Context or formulated key research questions	Findings or recommended research questions
1	2	3	4	5	6
Bottanelli et al. (2020)	Multi-case research	Natural Sciences	During COVID-19	Virtual research seminars: adoption of new ways to communicate science and build scientific relationships within a digital environment	<ol style="list-style-type: none"> (1) Set of practical suggestions to create an online seminar series for research communities such as: <ol style="list-style-type: none"> (i) confirm interest in the topics of seminars based on surveying social media as well as through national or international scientific societies (ii) synergize with organizers of other seminars without competing with an existing seminar series (iii) consider a brand for seminars (iv) develop the content of seminars based on safe speakers (v) promote speakers (2) Find new ways to communicate science and build scientific relationships in the context of a digital environment (3) Provide advice on formats and tools, security, spreading the word, and creating a diverse, inclusive or collegial space online
Byrnes et al. (2020)	Narrative review	Medical and Health Sciences	During COVID-19 and after	The utility of communication technologies, social media, and three-dimensional digital animation technology in supporting effective communication and professional activities of anatomists	Highlighted the need for further improvements in communication technologies to improve dependability, costing, and audio-visual quality
Davison (2020)	Narrative review	Social Sciences	During COVID-19	The nature of COVID-19's disruption and ways a researcher, teacher, administrator, and editor deal with it	Data collection through IT technology during COVID-19 is only replication
Fink (2020)	Literature review	Social Sciences	During COVID-19	<ol style="list-style-type: none"> (1) Opportunities and challenges for information systems research areas and methodologies (2) The current landscape of the research community 	<ol style="list-style-type: none"> (1) The suggestion of investigating research areas such as: <ol style="list-style-type: none"> (i) remote work (particularly from home) (ii) virtual collaboration (the digitization of physical collaboration), especially the effects of more varied contingencies on performance in collaborative settings (iii) distance learning: its efficiency and variance, as well as new avenues (iv) digital infrastructure (evolution of digital infrastructure and streaming quality) (2) Difficulties, due to COVID-19 disruption, for social scientists in using pre-pandemic findings when formulating hypotheses and making predictions, or developing new conceptualizations
Kligler-Vilenchik et al. (2020)	Two waves of the 10-day survey of salient Twitter users in Jerusalem (March 9–March 19, N = 34; March 23–April 2, N = 25) Online questionnaire-based survey Mixed-methods analysis	Social Sciences	During COVID-19	<ol style="list-style-type: none"> (1) The methodological challenges of adapting ongoing academic survey studies to a changing environment (2) How social media use—and academic research—evolve during times of global pandemic 	The increased use of Twitter as a way to pass time — a phenomenon rather uncommon in “traditional” crises such as natural disasters
Schwarz et al. (2020)	Narrative review	Social Sciences	During COVID-19	Digital workplaces for researchers	Digital interaction formats: <ol style="list-style-type: none"> (i) increase the inclusivity of knowledge exchange, reduce time and costs of organizing academic interactions (ii) enable more diverse workspaces with geographical and temporal flexibility (iii) struggle to reproduce social interactions such as informal discussions (iv) raise new concerns on data security (v) could induce higher stress levels

Table cont.

Author (year)	Research method	Field of sciences	Period of research	Context or formulated key research questions	Findings or recommended research questions
1	2	3	4	5	6
Trogisch et al. (2020)	Single-case research: Sino-German international research training group dedicated to early-career researchers	Natural Sciences	During COVID-19 and after	The Sino-German international collaborative research program	Five pillars for the resilience of large international collaborative research programs: (i) flexible funding and reporting deadlines (ii) a guarantee of the continuation of research through a fallback plan adaptation and its implementation (iii) innovation in teaching and the supervision or mentoring, as well as promoting learning motivation (iv) intensification of assurances about continuous support and help in case of mental health problems (v) intensification and integration of team members thanks to regular online meetings and virtual seminars for creative and successful teamwork (2) Opportunities and threats of international collaboration
Utoft (2020)	Narrative review Single-case research	Social Sciences	During COVID-19	(1) Myth about “the single woman” as an academic—a future spurious star in pandemic times and her academic productivity (2) Research questions: (i) when does work–life balance mean work–family balance? (ii) can there be a “life” for “the single, childfree female academic” if work is the only thing left?	Proposed activities to prevent disclusion: (i) great solidarity and encouragement thanks to online communities and writing groups with strangers; (ii) daily, virtual 11-o’clock coffee break with colleagues; (iii) inspiration coming from the radically honest, unapologetic, active writers who tell unpolished stories of their struggles and overcoming them during the COVID-19 pandemic
Weissgerber et al. (2020)	Narrative review	Medical and Health Sciences, Natural Sciences	During COVID-19	Repercussions of a lockdown on work and wellbeing for UK doctoral students and early-career researchers	(1) Seven recommendations to mitigate the unintended consequences of conference and travel cancellations (2) A list of ideas for virtual conferences

Tab. 1. Literature about the impact of the COVID-19 pandemic on scientists and their scientific research. Source: The authors' elaboration.

3. Research Methodology

The research problem described in this paper is part of broader research that aims to collect opinions on how the COVID-19 pandemic has changed scientific research and educational processes, especially regarding the adoption of different digital technologies. A quantitative research approach was adopted and a questionnaire survey was conducted in this study. The research process is documented in detail below, with a focus on addressing the main research problem of this paper, answering the specific research questions posed, and testing the hypotheses formulated.

3.1. Research Instrument

A survey questionnaire written in English was developed for collecting empirical data from academics in Poland and abroad. We used the same version of the survey questionnaire in all countries. We decided not to design or translate the questionnaire in Polish (or other languages) to avoid inconsistencies and inaccuracies in some expressions due to translation.

The survey questionnaire aimed to collect opinions on how the pandemic has changed educational processes and scientific research, especially regarding the use of different forms of digital technologies. It was composed of four parts. We began by explaining the research aims and informed respondents that their participation in completing the survey was voluntary. It was also guaranteed that all responses would be kept confidential. The first section of the questionnaire included questions on demographic information (gender, age, citizenship), professional information (position type, research discipline), and type of university (traditional, online). The second section contained questions on how respondents' work hours were allocated to different activities before, during, and after the COVID-19 pandemic, and the predicted changes in future publication and funding related to spending on research, teaching, and writing before, during, and after the pandemic. The third section was related to the teaching process, regarding the quality and support of digital technologies, before, during, and after the COVID-19 pandemic. The final section included questions on scientific works and the quality and support of digital technologies before and during the pandemic, as well as its implications on these issues in the future. At the end of the questionnaire, we asked respondents about their forecasts for the future of research and education after the COVID-19 pandemic.

The survey respondents answered the following five questions (QQ):

- QQ1:** How much is your research focused on basic research in science, before, during, and after the coronavirus pandemic?
- QQ2:** How much is your research focused on applied research in science, before, during, and after the coronavirus pandemic?

- QQ3:** How do you assess the frequency of usage of any communication apps in your research, before, during, and after the coronavirus pandemic (e.g., Skype, WhatsApp, Messenger, MS Teams)?
- QQ4:** How do you assess the frequency of usage of any e-learning platforms in your research before, during, and after the coronavirus pandemic (e.g., Moodle, Google Classroom, Zoom, Docebo, Wizz IQ, ATutor)?
- QQ5:** How do you assess the frequency of usage of any social media in your teaching and education, before, during, and after the coronavirus pandemic (e.g., Facebook, Twitter, LinkedIn, YouTube, Instagram, blog sites)?

We used a 5-point Likert scale for the respondents' assessments. They answered the first two questions as follows: (1) never, (2) seldom, (3) sometimes, (4) often, and (5) very often. For the next three questions, respondents could choose one of five responses: (1) definitely unimportant, (2) rather unimportant, (3) neither important nor unimportant, (4) rather important, and (5) definitely important.

To verify the draft version of the survey questionnaire, a pilot study was conducted with 17 academics from Poland and abroad (two from the UK and United States each, one each from Slovakia, Germany, and Nigeria, and 10 from Poland) at the end of May 2020. As a result, a few questions were deleted, and minor changes of a formal, technical, or language nature were made to others. An improvement in the questionnaire layout was made but no substantive amendments were required.

3.2. Research Subjects

Selecting a sample is a fundamental element of a quantitative study (Collis & Hussey, 2003). Stratified sampling was used to obtain the sample, which can be taken to be true for the whole population. The strata were identified based on country, age, gender, position type, and research discipline. To gather a substantial number of respondents, snowball sampling was pursued, which involved daily and routine distribution (social media and email posting) of an introduction e-letter and survey link requesting participation in the research. To increase response rates, the following methods described by Nulty (2008) were used: involving academics (encouraging colleagues), pushing the survey (providing respondents with the survey URL in emails sent directly to them), publishing the project with a link to the basic questionnaire on the ResearchGate website (www1) and Facebook fan pages, and providing frequent reminders.

3.3. Data Collection

Based on several analyses showing that surveys conducted over the internet provide results that are as valid as more "traditional" methods

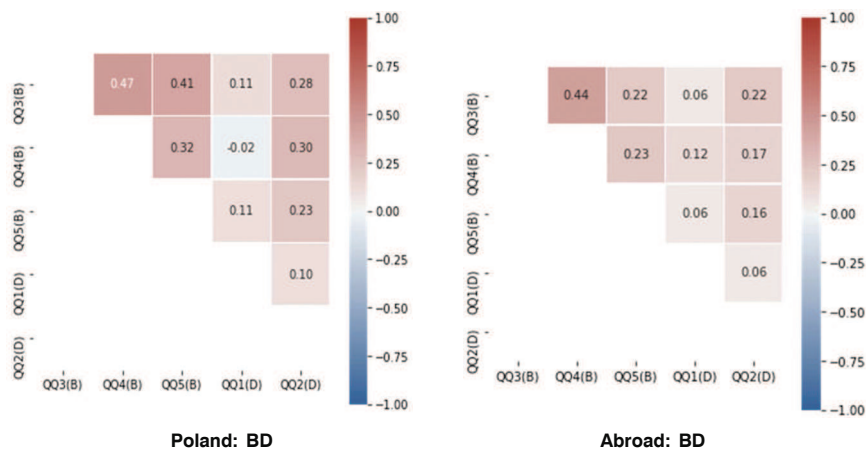
(Shatz, 2017), and due to social distancing because of the pandemic, we used the Computer Assisted Web Interview method for recruiting respondents and collecting data. The LimeSurvey tool was employed for recruiting reliable samples. The data were collected during two months of work, from June 11 to August 18, 2020. This led to 982 responses. After screening the responses and excluding outliers, 476 usable, correct, and complete responses were collected and subjected to further analysis. The demographic analysis of the research sample is presented in Table 2.

Characteristics	Demographic factors	Number of respondents	Percentage of respondents
Gender	Females	238	50.0
	Males	231	48.5
	Unspecified	7	1.5
Age	20–34	86	18.1
	35–49	228	47.9
	50–68	146	30.7
	>69	16	3.4
Country	Poland	278	58.4
	Abroad	198	41.6
Position type	Graduate student in doctoral program	52	10.9
	Lecturer	53	11.1
	Assistant Professor	143	30.0
	Associate Professor	123	25.8
	Professor	86	18.1
	Retired	4	0.8
	Other: Assistant and researcher	15	3.2
Research discipline	Social sciences	382	80.3
	Engineering and technology	65	13.7
	Humanities	13	2.7
	Natural sciences	14	2.9
	Medical and health sciences	1	0.2
	Agricultural sciences	1	0.2

Tab. 2. Demographic statistics of survey respondents. Source: The authors' research.

3.4. Data Analysis

The data were stored in different formats, for example, CSV, MS Excel, XML. We employed MS Excel to extract the relevant data. Using PS Imago Pro 6.0. (SPSS Statistics 26) and RStudio, the data were statistically analyzed. Firstly, Cronbach's coefficient alpha was used to conduct reliability analysis. For the five analyzed questions on the questionnaire, Cronbach's alpha was 0.840, which indicated high internal consistency and reliability (Hinton, Brownlow, McMurray, & Cozens, 2004). Secondly, descriptive statistical analysis was employed to assess the frequency of digital technology use. The following statistics were calculated: median; mode; coefficient of variance; skewness; and kurtosis using SPSS. Figure 1 was created using Python (version 3.7.0) (Twardowska, 2021). Thirdly, the Kruskal–Wallis test was applied to identify differences in the frequency of digital technology use in the research of scientists in Poland and abroad during the following periods: before (B), during (D), and after (A) the COVID-19 pandemic. Fourthly, the non-parametric Friedman rank test and Conover's multiple comparison test were used to identify significant differences between the three paired periods BD, BA, DA. Fifthly, Spearman's rank correlation coefficients were used to identify the association between the frequency of digital technology use and the type of research in both groups of scientists for the paired periods BD, BA, DA. Correlation coefficient values <0.3 were classified as weak; from 0.3 to 0.7 as moderate; and from 0.7 to 1 as strong correlations (Bland & Altman, 1995).



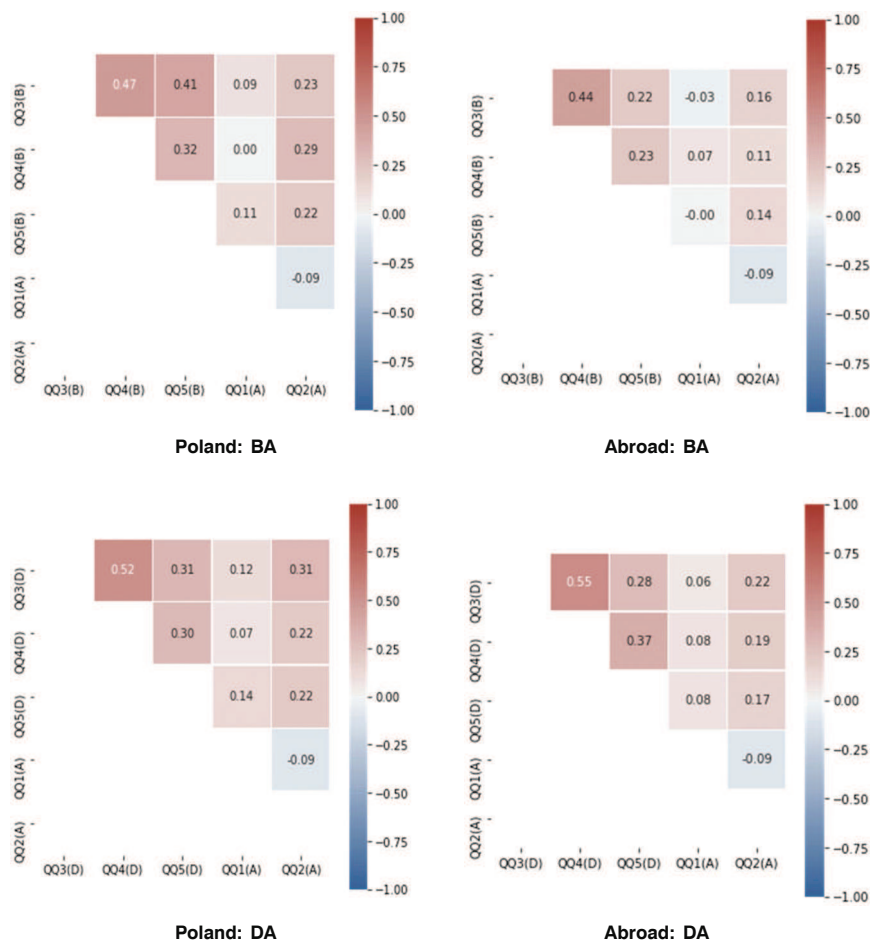


Fig. 1. Spearman's rho correlation coefficients between digital technologies and scientific research for the paired periods BD, BA, DA. Source: The authors' research.

Three hypotheses were formulated:

- H1:** There were significant differences in the frequency of digital technology usage by scientists in Poland and abroad to support their basic research for the paired periods: BD, BA, DA;
- H2:** There were significant differences in the frequency of digital technology usage by scientists in Poland and abroad to support their applied research for the paired periods: BD, BA, DA;
- H3:** There is a positive correlation between the frequency of digital technology usage by scientists and scientific research in Poland and abroad for the paired periods: BD, BA, DA.

4. Statistical Analysis

4.1. Reliability Measurement

The first stage of the analysis was the calculation of the internal consistency reliability of five dependent variables (QQ1–QQ5) for three periods B, D, A. It was based on Cronbach's coefficient alpha. The test results are presented in Table 3.

Cronbach's Alpha	Cronbach's Alpha based on standardized items	No. of items
0.84	0.84	15

Tab. 3. Reliability statistics. Source: The authors' research.

According to George and Mallery's rules of thumb (George & Mallery, 2003), Cronbach's $\alpha > 0.8$ indicated good internal consistency of the five assessed questions.

4.2. Descriptive Statistics

Table 4 shows the analysis outputs of survey questionnaires from SPSS involving three questions about digital technologies (QQ3–QQ5). Computed descriptive statistics included: median, mode, variance, skewness, and kurtosis. Respondents in Poland and those abroad were analyzed separately.

Items		Questions	QQ3	QQ3	QQ3	QQ4	QQ4	QQ4	QQ5	QQ5	QQ5
			B	D	A	B	D	A	B	D	A
Poland	N	Valid	278	278	278	278	278	278	278	278	278
		Missing	0	0	0	0	0	0	0	0	0
	Median	2.00	4.00	4.00	2.00	4.00	3.00	2.00	2.00	2.00	
	Mode	2	5	4	1	5	4	1	1	1	
	Variance	1.21	1.50	1.09	1.49	2.29	1.64	1.21	1.88	1.67	
	Skewness	0.54	-1.07	-0.54	1.01	-0.73	-0.37	1.03	0.58	0.49	
	Kurtosis	-0.44	0.13	-0.15	-0.01	-1.00	-0.91	0.18	-0.98	-0.97	
Abroad	N	Valid	198	198	198	198	198	198	198	198	198
		Missing	0	0	0	0	0	0	0	0	0
	Median	3.00	4.00	4.00	2.00	4.00	4.00	3.00	3.00	3.00	
	Mode	3	5	4	2	5	4	3	4	4	
	Variance	1.04	1.39	0.90	1.54	1.90	1.41	1.24	2.04	1.76	
	Skewness	0.18	-1.23	-0.79	0.37	-0.96	-0.66	0.15	-0.10	-0.18	
	Kurtosis	-0.53	0.65	0.54	-0.92	-0.41	-0.40	-0.99	-1.34	-1.17	

Tab. 4. Descriptive statistics. Source: The authors' research.

QQ3: How do you assess the frequency of usage of any communication apps in your research (e.g., Skype, WhatsApp, Messenger, MS Teams)?

The median of the frequency of communication application usage by scientists in Poland changed from two (seldom) before the pandemic to four (often) during and after the COVID-19 pandemic. A similar increase of median occurred for scientists abroad over the same periods, but before the COVID-19 pandemic, the median was higher at three.

Most frequently, both groups of respondents used communication applications equally often during (Mode = 5: very often) and after the pandemic (Mode = 4: often), as opposed to before the pandemic (Mode = 2 for PL or Mode = 3 for abroad). The highest growth was during the pandemic. In the analyzed period, the variance was higher for Polish scientists than for scientists abroad, while it fluctuated in both groups of respondents.

Respondents in Poland and abroad were the most diverse in relation to communication application usage during (Variance = 1.50 for PL, Variance = 1.39 for abroad), and after the pandemic, the variance was the lowest. The skewness of communication application usage by scientists in Poland and abroad varied. During and after the pandemic, left-asymmetric skewness was observed, while right-asymmetric values were detected before the pandemic. Before and after the pandemic, the kurtosis for Poland was below zero (i.e., extreme values were greater), with a slightly higher variety before the pandemic. During the pandemic, the kurtosis focused on a positive value. For scientists abroad, the kurtosis was negative before the pandemic (B), whereas during and after the pandemic, a lower spread of values was observed.

QQ4: How do you assess the frequency of usage of any e-learning platforms in your research (e.g., Moodle, Google Classroom, Zoom, Docebo, Wizz IQ, ATutor)?

The median frequency of e-learning platform usage for scientists in Poland changed from the value of two (seldom) before, to four (often), and three (sometimes) after the pandemic. The median for scientists abroad also increased to four (often) during the pandemic and was sustained after the pandemic. In Poland and abroad, e-learning platforms were used more often during (Mode = 5: very often) and after (Mode = 4: often), than before the COVID-19 pandemic (Mode = 1 for PL or Mode = 2 for abroad), with the highest increase during the pandemic.

In the analyzed periods, the variance was higher for scientists in Poland than abroad, except for the period before the pandemic. The variance fluctuated positively for scientists in Poland compared to the period before the pandemic. During the pandemic, scientists in Poland and abroad were the most diversified in terms of the use of e-learning platforms (Variance = 2.29 PL, Variance = 1.90 abroad). In the post-pandemic period, the variance was even lower for scientists abroad than

before the pandemic. The skewness of the use of e-learning platforms for Polish scientists fluctuated. During and after the pandemic, left-asymmetric skewness was observed, as opposed to the right-asymmetric values that were viewed before the pandemic. Kurtosis values for scientists in Poland and abroad in all three periods B, D, and A were below zero, that is, extreme values increased in frequency, although they decreased gradually abroad.

QQ5: How do you assess the frequency of usage of social media in your research (e.g., Facebook, Twitter, LinkedIn, YouTube, Instagram, blog sites)?

The median frequency of social media use by scientists was the same throughout the analyzed periods B, D, A. The median frequency for scientists in Poland was lower (Median = 2, i.e., seldom) than for abroad (Median = 3, i.e., sometimes).

Most frequent respondents in Poland did not use and do not intend to use social media after the pandemic (Mode = 1, i.e., never). The most frequent response from respondents abroad regarding before the pandemic was „sometimes” (Mode = 3), and during and after the pandemic a positive change was observed (Mode = 4, i.e., often). In the analyzed periods, the variance was higher for scientists abroad than for Polish scientists.

Social media use fluctuated positively in Poland and abroad compared to the period before the pandemic. Scientists differed mostly on the use of social media during the pandemic (Variance = 1.88 for PL; 2.04 for abroad), although after the pandemic, the variance was still higher than before the pandemic. In the analyzed periods B, D, A, the skewness for scientists in Poland and abroad systematically decreased. However, in Poland the left-asymmetry of values above the mean in periods D and A decreased, while abroad the skewness was higher than zero before the pandemic, and due to the systematic decline of values in periods B, A turned into a negative skew. The kurtosis for Poland before the pandemic changed from right-asymmetry in the period B to left-asymmetry, and in period A it was almost the same as period D. The kurtosis for abroad was negative in all three periods, that is, extreme values increased in frequency, and the abundance curve was systematically flattening in periods B, D, A.

4.3. Analysis of the Differences Between Scientists in Poland and Abroad

The results for the Kruskal–Wallis test in Table 5 showed that:

(a) before the COVID-19 pandemic, scientists in Poland and abroad were significantly different in:

- the use of communication applications in scientific research, QQ3 supported H1;
- the use of e-learning platforms in scientific research, QQ4 also supported H1;

- (b) during the pandemic, scientists in Poland and abroad did not differ significantly in the use of communication applications and e-learning platforms in scientific research, QQ3, QQ4 did not support H1 for this period;
- (c) after the pandemic, scientists in Poland and abroad significantly differed in:
- the use of communication applications in scientific research, QQ3 supported H1;
 - the use of e-learning platforms in scientific research, QQ4 supported H1;
- (d) in all analyzed periods, Polish scientists were significantly different from scientists abroad in terms of the frequency of social media use, QQ5 supported H1.

Polish scientists and scientists abroad differed in most of the analyzed periods in the frequency of specified digital technologies use.

Questions	Significance*	Decision	Questions	Significance*	Decision
QQ3 B	0.00	Reject the null hypothesis	QQ4 A	0.00	Reject the null hypothesis
QQ3 D	0.54	Accept the null hypothesis	QQ5 B	0.00	Reject the null hypothesis
QQ3 A	0.01	Reject the null hypothesis	QQ5 D	0.00	Reject the null hypothesis
QQ4 B	0.00	Reject the null hypothesis	QQ5 A	0.00	Reject the null hypothesis
QQ4 D	0.42	Accept the null hypothesis			

* Asymptotic significances are displayed.

Tab. 5. Non-parametric Kruskal-Wallis test (*k* independent samples). Source: The authors' research.

4.4. Analysis of the Differences Between Scientists in Poland and Abroad in Inter-Period Comparisons

The difference identified in the frequency of digital technologies use in each paired period (BD, BA, DA) was based on values in Table 6 involving (a) Friedman chi-squared; (b) df (number of points of freedom); and (c) p-value (the probability that the Friedman test accepts the value of F). The Conover test identified the significant differences between specific paired periods (BD, BA, DA) and included the Conover's statistics; p-value (probability of accepting the value of the test statistic by the Conover test); adj. p-value (equal probability of accepting the test statistic by the Conover test); the Benjamini-Hochberg method to counteract group risk.

Nationality	Item	QQ3	QQ4	QQ5	Item	QQ3	QQ4	QQ5	Nationality
Poland	N	278	278	278	N	198	198	198	Abroad
	Friedman Chi-Squared	358.91	301.97	111.24	Friedman Chi-Squared	234.45	210.92	109.56	
	df	2	2	2	df	2	2	2	
	p-value	0.00*	0.00*	0.00*	p-value	0.00*	0.00*	0.00*	

Note: * p-value $\leq \alpha$.

Tab. 6. Friedman rank test for differences between the paired periods BD, BA, DA. Source: The authors' research.

Statistically significant differences were found between the frequency of the use of communications applications and e-learning platforms in the paired periods BD, BA, DA, hence supporting the H2 hypothesis. However, owing to the lack of differences concerning the use of social media by Polish scientists in the period DA (Table 7), the H2 hypothesis was only partially supported. Scientists in Poland and abroad also differed in terms of the correlation between (basic or applied) research and the frequency of digital technologies use (Figure 1).

Nationality	QQ	Item	BD	BA	DA	Item	BD	BA	DA	QQ	Nationality
Poland	QQ3	N	278	278	278	N	198	198	198	QQ3	Abroad
		Conover's statistics	26.13	18.26	-7.88	Conover's statistics	20.64	16.07	-4.57		
		p-value	0.00*	0.00*	0.00*	p-value	0.00*	0.00*	0.00*		
		adj. p-value ¹⁾	0.00*	0.00*	0.00*	adj. p-value ¹⁾	0.00*	0.00*	0.00*		
	QQ4	N	278	278	278	N	198	198	198	QQ4	
		Conover's statistics	23.81	17.26	-6.55	Conover's statistics	19.51	15.41	-4.10		
		p-value	0.00*	0.00*	0.00*	p-value	0.00*	0.00*	0.01*		
		adj. p-value ¹⁾	0.00*	0.00*	0.00*	adj. p-value ¹⁾	0.00*	0.00*	0.01*		
	QQ5	N	278	278	278	N	198	198	198	QQ5	
		Conover's statistics	12.39	13.47	1.08	Conover's statistics	12.96	12.79	-0.17		
		p-value	0.00*	0.00*	0.73	p-value	0.00*	0.00*	0.99*		
		adj. p-value ¹⁾	0.00*	0.00*	0.73	adj. p-value ¹⁾	0.00*	0.00*	0.99*		

Note: QQ – questionnaire question; BD – before, during the COVID-19 pandemic; BA – before, after the COVID-19 pandemic; DA – during, after the COVID-19 pandemic; ¹⁾ p adjustment method – Benjamini-Hochberg method; * statistically significant value.

Tab. 7. Conover's test. Source: The authors' research.

4.5. Analysis of the Correlation Between Digital Technologies and Scientific Research

H3 was fully supported by the results of the analysis based on Spearman's rank correlation coefficients for Poland:

- (a) for the paired periods BD, BA: weak positive correlation between the frequency of the use of communication applications and social media, and applied research;
 - (b) for the paired period DA: (i) moderate positive correlation between the frequency of the use of communication applications and applied research, and (ii) weak positive correlation between the frequency of the use of e-learning platforms and social media, and applied research; and (iii) weak positive correlation between the frequency of the use of communication applications and social media, and basic research;
- Moreover, for scientists abroad:
- (a) for the paired periods BD, BA, DA: weak positive correlation between the frequency of the use of all digital technologies and applied research,
 - (b) for the paired period BD: weak positive correlation between the frequency of the use of e-learning platforms and basic research.

5. Conclusions and Discussion

The destructive nature of the pandemic has prompted scientists to frequently use digital technologies to solve research problems (Byrnes et al., 2020). Our research has confirmed that during and after the COVID-19 pandemic, scientists in Poland and abroad used digital technologies in their research more frequently than earlier.

Firstly, the examined scientists from Poland and abroad differed in the frequency of digital technologies use before the pandemic—more often digital technologies were used by the scientists from abroad. However, we did not find such differences between scientists in Poland and abroad in the use of communication applications and e-learning platforms during the COVID-19 pandemic. Moreover, their use during the pandemic increased to a similar level in both groups of scientists. Subsequently, we observed large differences in the use of social media by scientists in Poland and abroad—scientists from abroad used social media much more often during the pandemic and intend to continue after the pandemic.

Secondly, our research has confirmed that there were significant differences in the frequency of digital technology use by scientists in Poland and abroad in their research. Therefore, our research contributed toward identifying differences between the use of digital technologies in three paired periods: before-during, before-after, and during-after the pandemic. It also shows that we are getting closer to the next stage, that is, the permanence of these differences rather than a long-term adoption of modern communication tools, as concluded by Byrnes et al. (2020).

Thirdly, in the case of scientists abroad, we did not find a positive correlation between the use of the majority of digital technologies and basic research. Nevertheless, the correlation between the use of social media and applied research for scientists abroad was weaker than for Polish scientists, although in each of the analyzed periods, scientists abroad often or very often used social media.

In each paired period, a moderate correlation between the use of some digital technologies and application research was discovered only in Poland. We also identified a weak correlation between the use of communication applications (for two paired periods: before-during, and during-after the pandemic) and social media (for each paired period), and the basic research of scientists in Poland.

Overall, the results of our research support Ahmad's (2020) conclusion that the COVID-19 pandemic would change the world, and scientists should accept the permanent changes that allow them to reimagine themselves in a new reality (Utof, 2020).

Owing to the influence of the COVID-19 pandemic on an increase in the frequency of digital technology use, future research could focus on how digital technologies help to integrate research teams and establish collaboration, which in turn, might translate into the higher quality and a greater quantity of basic or applied research.

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