Assessing the state of research e-infrastructures for open science in Ukrainian higher education institutions

Iryna I. Drach[1], Oleksandra V. Borodiyenko[1], Olha M. Petroye[1], Iryna Yu. Reheilo[1,2], Nataliia V. Bazeliuk[1], Olena M. Slobodianiuk[1] and Olena H. Kuzminska[3,4,5]

[1]*Institute of Higher Education of the NAES of Ukraine, 9 Bastionna Str., Kyiv, 01014, Ukraine*
[2]*National Academy of Educational Sciences of Ukraine, 52-A Sichovykh Striltsiv Str., Kyiv, 04053, Ukraine*
[3]*National University of Life and Environmental Sciences of Ukraine, 15 Heroyiv Oborony Str., Kyiv, 03041, Ukraine*
[4]*Kryvyi Rih State Pedagogical University, 54 Universytetskyi Ave., Kryvyi Rih, 50086, Ukraine*
[5]*Academy of Cognitive and Natural Sciences, 54 Universytetskyi Ave., Kryvyi Rih, 50086, Ukraine*

Abstract

The paper analyses the usage of research e-infrastructures in the realm of Open Science in Ukraine's higher education institutions (HEIs). Specifically, the study assesses the degree of organisational support for the research e-infrastructure dedicated to Open Science endeavours. This support encompasses providing unique tools, resources, and services tailored to facilitate specific HEIs' research activities. Additionally, the investigation scrutinises the functioning of the structural units and personnel responsible for developing and maintaining the research e-infrastructures. Furthermore, the paper delineates the salient features of utilising services that constitute the research e-infrastructures ecosystem for Open Science in HEIs of Ukraine. Notably, these services encompass mechanisms to ensure open access to publications, mechanisms for the storage and management of open research data, initiatives focused on the professional development of research and academic staff, endeavours aimed at enhancing research responsibility and integrity, systems for research performance evaluation, and efforts towards the advancement of citizen science. A comprehensive analysis of survey data, which aimed to examine the current state of organisational support for research e-infrastructure in Ukrainian HEIs, bases the research findings presented in this study. The survey involved a substantial sample size, with 1,502 participants representing over 110 HEIs. The analysis revealed that while there has been significant progress at the national level in promoting Open Science, there is still a notable fragmentation in implementing comprehensive Open Science policies, particularly concerning e-infrastructures, at the institutional level. The findings further highlight significant areas for improvement in the current state of organisational support for research e-infrastructure in Ukrainian HEIs. The authors propose several key recommendations from the study to address these challenges. First and foremost, there is a need to establish a pervasive culture of Open Science at the institutional level, whereby HEIs prioritise the integration of Open Science principles into their key normative documents. In addition, it is crucial to appoint highly competent professionals to administer and manage research e-infrastructures within HEIs. Developing a well-crafted communication policy that promotes awareness of available e-infrastructure resources and services and facilitates access to research infrastructures is essential to foster employee awareness and understanding. Furthermore, the active engagement of employees from IT departments and library workers is critical in operational and supportive aspects of research e-infrastructure. Continuous professional development and training initiatives are also crucial to elevate the proficiency of research and academic staff. Ultimately, creating an environment that fosters impactful research practices is paramount. By implementing these recommendations, HEIs can improve their organisational support for research e-infrastructure, strengthen their commitment to Open Science, and enhance their institutions' research capabilities and impact.

Keywords

Open Science, research infrastructure, higher education institutions (HEIs), Ukraine

CTE 2023: 11th Workshop on Cloud Technologies in Education, December 22, 2023, Kryvyi Rih, Ukraine
i.drach@ihed.org.ua (I. I. Drach); o.borodienko@ihed.org.ua (O. V. Borodiyenko); o.petroye@ihed.org.ual (O. M. Petroye); i.regeylo@ihed.org.ua (I. Yu. Reheilo); n.bazeliuk@ihed.org.ua (N. V. Bazeliuk); o.slobodianuk@ihed.org.ua (O. M. Slobodianiuk); o.kuzminska@nubip.edu.ua (O. H. Kuzminska)
0000-0001-7501-4122 (I. I. Drach); 0000-0001-9133-0344 (O. V. Borodiyenko); 0000-0003-2941-1455 (O. M. Petroye); 0000-0003-0512-2456 (I. Yu. Reheilo); 0000-0001-6156-1897 (N. V. Bazeliuk); 0000-0002-1927-3362 (O. M. Slobodianiuk); 0000-0002-8849-9648 (O. H. Kuzminska)

1. Introduction

The imperative for the development of research infrastructures in Ukraine has emerged in response to the tasks of "facilitating sustainable socio-economic progress and fostering scientific advancement", "fostering the enhancement of contemporary facilities and equipment, research infrastructure of scientific institutions and HEIs", "fostering scientific collaboration with foreign education institutions, while integrating into the European and global research areas", and "promoting scientific and technical cooperation through the exchange of scientific and technical knowledge, as well as the exchange of researchers and technicians" [1].

Nonetheless, the full-scale invasion of the Russian Federation into Ukraine on February 24, 2022, has markedly impeded the successful realisation of these goals. It has inflicted substantial devastation and impairment upon HEIs and research laboratories, necessitating the relocation of a considerable number of HEIs [2] (considerable challenges in the effective realisation of educational and research activities – authors), a notable depletion of the academic staff (attributable to the loss of employment opportunities, impediments in conducting professional activities, as well as restrictions on international mobility and collaboration) [3].

Under the present circumstances, preserving the nation's scientific and research capabilities hinges upon advancing digital transformation in education and science [4, 5]. These measures entail the realisation of comprehensive ecosystems comprising diverse digital solutions, including digital learning tools, online courses, electronic educational content, and various digital resources and services [6, 7]. Moreover, this paradigm necessitates the digitisation of processes and services, the increase in the level of digital competence among the educational process participants, and the automation of data collection and analysis [8, 9].

Significant in this context is the need to rethink the role and content of research activities of Ukrainian HEIs and their value, organisational, and functional transformation. HEIs have a crucial role in ensuring the processes of transition to the standards of Open Science through research, practical implementation of scientific results, and scientific education [10]. The proficient use of research e-infrastructures pertaining to Open Science constitutes an imperative prerequisite for augmenting the research capabilities of HEIs [11]. Moreover, adopting Open Science research e-infrastructures can confer many advantages upon HEIs amidst warfare and subsequent post-war reconstruction. These encompass enhanced scientific efficacy, primarily attributable to diminished redundancies and mitigating expenditures associated with data creation, transfer, and reuse.

Furthermore, expediting knowledge dissemination, facilitating transitions from research to innovation, and heightening the influence of research outcomes on the economy are of paramount significance as well [12]. Utilising resources, specifically applying sophisticated computational methodologies such as artificial intelligence (AI) [13, 14] and machine learning (ML) [15, 16], confers a distinct advantage beyond research activities. It encompasses the training of research staff and the augmentation of knowledge accessibility, particularly through the deployment of open educational resources [17].

For HEIs to fully capitalise on the benefits mentioned above, it is imperative to cultivate a culture of Open Science at the institutional level and engender motivation for its implementation. These issues necessitate promoting and adopting innovative practices in Open Science across various stages of the scientific process [18]. At the national level, a demand exists for suitable socio-cultural and technological transformations, coupled with advancing the Ukrainian segment within the global digital interoperable environment of scientific knowledge [19]. Furthermore, it is crucial to establish pertinent national policies that foster an environment conducive to innovative solutions for global and domestic challenges. These policies should encourage collaborative knowledge creation among scientists, scientific institutions, companies, governments, regulatory bodies, citizens, and international organisations [20, 21]. The aforementioned transformations necessitate systemic modifications encompassing research methodologies and the organisational systems spanning individual, institutional, national, and international levels [10].

Our analysis indicates the degree of progress made in formulating Open Science policies at the national level. Specifically, the inclusion in the Roadmap for Ukraine's Integration into the European

Research Area (ERA-UA) exemplifies this. One of the focal priorities entails implementing Open Science principles and using open access tools of the EU [22].

The National Plan for Open Science [23], established within the framework of the Ukraine Recovery Plan [24], not only demonstrates Ukraine's commitment to aligning with the European Open Science principles but also highlights the government's determination to establish the necessary regulatory, legal, and organisational foundations for the development of a comprehensive state policy on Open Science [25]. Equally significant for advancing Open Science is the Strategy for the Development of Higher Education in Ukraine for 2022-2032 [26]. Several essential areas guide the national-level implementation of the Open Science concept: i) facilitating open access to scientific findings, research data, and research infrastructure; ii) fostering science popularisation, promoting scientific knowledge dissemination, and engaging citizens in scientific and technical activities; iii) enhancing the quality evaluation system for scientific and technical endeavours; and iv) raising awareness and cultivating competencies in the realm of Open Science [24].

Implementing Open Science policies in Ukrainian HEIs remains fragmented and is primarily observed due to their engagement in international initiatives focused on this particular domain. Notably, participation in projects such as "Open Practices, Transparency and Integrity for Modern Academia, OPTIMA" [27] and "Open Science and Education in Europe: success stories for Ukrainian academia, OSEE" [28] has facilitated the introduction of innovative practices in Open Science. Despite the notable presence of Ukrainian HEIs in relevant project consortia, it is noteworthy that only one institution, namely the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", has succeeded in having its Open Science policy formally endorsed [29].

In leading Ukrainian HEIs, implementing Open Science policies revolves primarily around ensuring open access to publications. However, there is a lack of systematic efforts to inform and train academic staff and students on leveraging the opportunities of Open Science. Furthermore, HEIs websites do not consistently provide information on best practices in open research for promoting the Open Science policy and engaging citizens in research activities [10].

HEIs developed repositories to store and disseminate research results. Notable examples include eSSUIR at Sumy State University, eKMAIR at the National University of "Kyiv-Mohyla Academy", ELARTU at Ternopil Ivan Puluj National Technical University, eKhNUIR at V. N. Karazin Kharkiv National University, ARRChNU at Yuriy Fedkovych Chernivtsi National University, and ELAKPI at the National Technical University of Ukraine "Ihor Sikorsky Kyiv Polytechnic Institute" [18].

Several HEIs provide specialised courses to enhance participants' understanding and proficiency in various aspects of research methodologies, particularly within the digital context. For instance, National University of "Kyiv-Mohyla Academy" offers courses such as "Digital Science" and "Research Data Management" [30]. Similarly, Borys Grinchenko Kyiv University offers the "Digital Science" course [30]. Additionally, the Prometheus platform offers a course titled "Science Communication in the Digital Age" [31].

Conversely, examining international practices reveals that implementing Open Science policies is prominent in HEIs. Over 50% of HEIs have established dedicated Open Science policies, while 37% are actively developing such policies [32]. Notably, the prevailing practice in HEIs involves establishing specialised units or teams entrusted with overseeing, coordinating, and providing consultation on various facets of Open Science. HEIs websites serve as comprehensive information repositories and offer an array of educational activities to ensure wide-ranging awareness and proficiency among academic staff and students in utilising open access and research data management. These platforms facilitate dissemination of best practices in open research and contribute to popularising Open Science policies [33].

A range of legislative and regulatory instruments addresses the challenge of advancing the development of research e-infrastructures in the context of Open Science at the national level. The Law of Ukraine "On Scientific, Scientific and Technical Activities" serves as a foundational framework by governing the establishment of local, virtual, or distributed infrastructures, which can form part of international networks (Article 1) [34]. Moreover, the law emphasises the creation of a state research infrastructure aimed at optimising the use of diverse resources such as staff, materials, equipment,

computers, data storage, and knowledge banks. This infrastructure should facilitate the highest scientific, scientific and technical research, and development activities (Article 1) [34]. Furthermore, at the national level, a recognised need exists to align the national infrastructures with European research infrastructures (Article 66). This alignment underscores the importance of harmonising national efforts with the broader European agenda, ensuring strategic coordination and compatibility between national and European research infrastructure initiatives.

The State Target Programme for Development of Research Infrastructures in Ukraine for the period up to 2026 [1] seeks to establish favourable organisational, legal, and financial frameworks conducive to the advancement of research e-infrastructures in Ukraine while simultaneously facilitating researchers' access to the best European research e-infrastructures. Moreover, efforts are underway to formulate the Concept of the state policy for the development of e-infrastructures [24], foster collaborative use of research e-infrastructure [35], develop a research infrastructure dedicated to artificial intelligence and robotics [36], ensure access to European and global research e-infrastructure through international mobility of research staff [37], integrate HEIs ecosystems into regional innovation ecosystems and Industry 4.0 clusters, considering the SMART specialisation of regions [27], and create conditions for the professional development and global integration of Ukrainian researchers [38].

Despite the existing legislative and regulatory frameworks in Ukraine, there persists a systematic shortfall in budgetary allocations for supporting and modernising research infrastructure within HEIs, amounting to a mere 0.43% of the national GDP [39]. This insufficiency has had detrimental consequences, including the outflow of Ukrainian scientists to other countries. Notably, between 2014 and 2019, the number of researchers nearly halved, declining from 101,440 to 51,121 [39]. Inadequate funding for scientific activities, particularly on research e-infrastructure, has adversely affected the participation of Ukrainian researchers in the EU's research and innovation funding programme "Horizon 2020". The outcomes of competitive selections reflect a meagre 0.06% allocation of funding to Ukrainian teams compared to their counterparts from Turkey, who received seven times more, and Poland, who received eighteen times more [39]. These statistics witness the unsatisfactory state of research e-infrastructure, contributing to the need for more competitiveness in Ukrainian project proposals.

2. Theoretical framework

Developing research e-infrastructure within Open Science represents a pivotal facet of the digital transformation agenda and the Strategy of Human Development in Ukraine. This strategy emphasises the imperative of creating an enabling environment for the professional growth, advancement, and integration of Ukrainian scientists into the global scientific space. Developing research and innovation infrastructure and establishing a Unified Scientific Platform in Ukraine realise this objective. The latter encompasses a user-friendly, well-organised digital service system for scientific purposes, featuring interconnected networks and a centralised access point [40]. An important indicator of progress towards the objectives mentioned above involves the development of research infrastructure, including e-infrastructure, scientific data, and academic texts that are openly accessible or subject to transparent regulations [40].

The development of research e-infrastructure within the realm of Open Science assumes a crucial role in HEIs' pursuit of the "third mission", which entails serving the community through social responsibility and active engagement at global, regional, national, and local levels [41]. As part of a comprehensive digital transformation, implementing open practices, including Open Science, open access, and open data, enhances public trust in HEIs' educational and research activities and fosters a heightened appreciation for science [42, 43]. The framework of scientific communication with community representatives is evolving, as their active participation facilitates the dissemination of HEIs' scientific findings in society and enriches the interpretation of scientific conclusions by including diverse public perspectives [44].

Implementing digital transformation in higher education holds significant promise for fostering knowledge openness and innovation. It achieves this by ensuring the accessibility of information [45], facilitated through the establishment of appropriate technological infrastructure such as platforms,

services, and applications. The attributes of Open Science encompass several vital elements, including measurement and evaluation approaches that go beyond traditional research impact metrics, the provision of availability through open access, open data, and open codes, as well as a practical orientation that emphasises the effectiveness and target orientation of research [46].

The issue of Open Science has received significant attention both within domestic and international scientific communities. Extensive coverage has been dedicated predominantly to Open Science's conceptual framework and guiding principles [47, 10]. Following UNESCO's recommendations, the principles of Open Science encompass transparency, scrutiny, critique, verifiability; equal opportunities and access; respect, responsibility, and accountability; collaboration, participation, and inclusion; flexibility; and sustainability [48]. However, considering the specific national context, a somewhat distinct interpretation of these principles exists, particularly concerning open scientific knowledge, Open Science infrastructure, scientific communication, engagement of societal actors, and open dialogue with alternative knowledge systems [33].

The conceptual framework of Open Science has resulted in various approaches to delineating its components. For instance, Towards a 2030 Vision on the Future of Universities in Europe [49] highlights open research data, open academic communication, and open access to publications as integral components. Conversely, Yaroshenko et al. [30] propose a slightly different classification, identifying open data, open access, open peer review, open sources, open educational resources, and citizen science as distinct components of Open Science.

Research e-infrastructures play a pivotal role as a constituent element of Open Science, serving as essential components in generating, aggregating, processing, storing, and disseminating high-quality, certified scientific data following the FAIR principles. By adhering to these principles, research e-infrastructures facilitate the use of such data across diverse fields and on an international scale, thereby fostering the implementation of initiatives like the European Open Science Cloud (EOSC) and Open Science policies [50]. Research e-infrastructures, as foundational pillars of research and innovation ecosystems, offer researchers, innovators, and other stakeholders' invaluable access to unique knowledge and expertise, experimental facilities, technical resources, extensive datasets, and essential ICT and computing services. These resources are indispensable for conducting advanced fundamental and applied research [50].

Within the European Research Area (ERA), an intricate ecosystem of research infrastructures aims to foster synergies and coherence between research e-infrastructures. This ecosystem strives to align European, national, and regional research priorities and policies, facilitating the integration of research efforts across Europe and coordinating the support systems for national research infrastructures [51]. Implementing FAIR principles, which emphasise the need for scientific data to be findable, accessible, interoperable, and reusable, is crucial. Adhering to these criteria ensures data reproducibility and enables ESFRI (European Strategy Forum on Research Infrastructures) to uphold stringent quality control measures across all scientific domains [51].

The European Open Science Cloud (EOSC) initiative exemplifies a significant stride towards realising the objectives of Open Science. This forward-thinking endeavour aims to establish a virtual environment where researchers and professionals from diverse domains can seamlessly collaborate and access a wide array of services for data storage, management, analysis, and the reuse of research data. The EOSC achieves this by integrating existing infrastructures dispersed across disciplines and the EU member states, fostering a unified and accessible platform for knowledge exchange [49].

The transformation of HEI functions presents inherent challenges that warrant careful consideration. HEIs should be recognised as critical drivers of excellence and innovation, assuming the roles of both beneficiaries and enablers of research infrastructures. In this regard, HEIs play a crucial role in ensuring the sustainable operation of these infrastructures [52]. Their responsibilities include research and academic staff training, scientific, managerial, operational and support roles, researcher employment, securing funding, and facilitating transparent access to research e-infrastructures. Achieving the latter necessitates the development and effective administration of FAIR standards. However, it is worth noting that researchers have highlighted concerns regarding insufficient funding levels and limited collaboration between HEIs and companies concerning the shared use of research e-infrastructures

[52].

The design and development challenges of research e-infrastructures have garnered significant scholarly attention, particularly from foreign researchers focused on analysing their current state, administration, and provision of relevant services. Notably, scientific research conducted by scholars from various countries sheds light on the problems encountered in modern national research information systems. French researchers, for instance, have explored these issues [53], as have their counterparts in Germany [54, 55], Slovakia [56], China [57], and Finland [58].

One crucial area of research investigation is the financing models of e-infrastructures [59, 60]. Scholars have also evaluated such infrastructures [61, 62] and the evolutionary progression from essential services to self-sustaining research e-infrastructures [55].

Researchers have identified several distinctive features characterising research e-infrastructures. These include the provision of temporary data hosting for researchers and projects, often referred to as a "hotel" facility, and providing methodological support to facilitate research endeavours. Furthermore, research e-infrastructures are situated within internal and external network environments, ensuring connectivity and accessibility [53].

In addition, scholars have defined various types of research e-infrastructures. These encompass immediate physical infrastructures consisting of server and network equipment. Electronic infrastructures are data repositories catering to the needs of a limited user base within a single institution. Digital infrastructures, on the other hand, encompass network and/or distributed computing resources that extend across multiple institutions and/or countries. Such infrastructures offer services for performing GRID calculations, computing clusters, fog computing, and other cloud technologies, facilitating distributed computing and the management of large datasets, including the formation of data lakes. Lastly, meta-infrastructures represent conglomerates of independent digital research infrastructures operating across different institutions and countries united within transnational virtual data archives [63].

The fundamental constituents of research e-infrastructures in the social and humanities domains encompass critical services dedicated to documenting, preserving, and sharing primary and raw data acquired by individual researchers or research groups [63]. These services facilitate primary data processing and prepare them for subsequent use by researchers. Platforms built upon these foundations contain international survey findings, enabling comparative studies and acquiring comparative outcomes. Additionally, research e-infrastructures encompass services tailored for data documentation, archiving, anonymisation, access provisioning, and data dissemination. Complementing these functionalities are services designed to actively train researchers, acquainting them with contemporary research methodologies, procedures, and opportunities.

The development of e-infrastructures within the realm of Open Science is a topic that has attracted the attention of Ukrainian researchers. Notably, the authors has created a model for the ecosystem of research e-infrastructures in Ukrainian universities. This model aims to ensure the effective functioning of each component and the overall ecosystem of Open Science. Within this model, each component of Open Science, including open research data, open access to publications, citizen science, education and skills, research responsibility and integrity, and research performance evaluation, is represented by corresponding services (see figure 1) [64].

The services encompassed within this ecosystem include communication and networking services, platforms for content sharing, data processing and storage facilities, and learning management systems [65]. The model reflects the primary directions of policy formulation and development of the research e-infrastructure ecosystem for Open Science in Ukrainian universities. It creates opportunities for researchers to actively engage in Open Science processes at all stages of their research endeavours.

We perceive the research e-infrastructure ecosystem as a distinct subsystem within the broader ecosystem of Open Science. It encompasses electronic tools that furnish resources and services to research and academic staff, students, and other participants within the Open Science research communities. These e-tools facilitate research activities and foster an environment conducive to innovation [64].

Figure 1: The model of research e-infrastructures ecosystem in Ukrainian universities.

3. Research methodology

The reliability of the obtained research results hinges on the appropriateness and relevance of the employed research methods. During the theoretical phase of this study, a range of theoretical research methods, such as systematic literature review, bibliometric analysis methodologies, structuring, grouping, generalisation, and abstraction were utilised. These methods served the purpose of identifying the research problem, analysing the theoretical framework, and assessing the current state of research on the identified problem within both foreign and domestic scientific domains. A comprehensive array of sources, including national legal and regulative acts on the development of Open Science and research e-infrastructures within the realm of Open Science, underpinned the study. Additionally, programme documents from the European Union were analysed to provide insights into European policies relating to the focal subjects. Furthermore, data was sourced from reputable databases such as Scopus, Web of Science Core Collection, and the Directory of Open Access Journals, etc. to augment the research's evidential foundation.

This study's empirical phase involved surveying to gather insights into critical research inquiries. Specifically, the survey aimed to investigate the current state of organisational support for research e-infrastructure within the realm of Open Science at the institutional level and to discern the distinctive characteristics associated with utilising research e-infrastructure services in Ukrainian HEIs. This survey was integral to the broader study titled "Increasing the Research Capacity of Ukrainian Universities in the Context of War and Post-War Reconstruction through Implementing the "Open Science" Concept" (registered under the state registration number 0122U200775), conducted by the Department

of Universities Research Activities at the Institute of Higher Education of the National Academy of Educational Sciences of Ukraine.

An online questionnaire titled "Open Science in Higher Education Institutions of Ukraine" was developed to gather data from higher education professionals. The questionnaire comprised both closed-ended questions, offering predefined answer options with the possibility of either single or multiple choice, and open-ended questions allowing participants to provide detailed responses. The formulation of the questionnaire was based on previous research findings [64] and on the research methodology for studying Open Science practices employed in European universities [12].

The research programme encompassed an examination of key aspects of implementing Open Science in HEIs of Ukraine. Four distinct blocks organise these aspects: (1) the current state of Open Science development in HEIs; (2) the state of research e-infrastructure within HEIs and its role in fostering Open Science; (3) the evaluation of research activities in the context of Open Science; and (4) the potential opportunities and threats associated with the use of AI in scientific research within the realm of Open Science. Additionally, respondents were requested to provide general information, including institutional specifics of their respective HEIs (such as location, scale, ownership, subject profile), as well as socio-demographic and professional characteristics (including age, gender, position, scientific degree, academic title, research performance, and publication record). The theoretical model of the research e-infrastructure ecosystem in Ukrainian HEIs, which the authors of this study substantiated [64], predicated the questionnaire.

Empirical data collection took place from March 21 to April 3, 2023. A target sample type was used – employees (heads of institutions and structural units, academic and research staff, library and IT workers) of HEIs to conduct the survey. The source base for the target sample was the Register of Subjects of Educational Activity – Higher Education Institutions of the Unified State Electronic Database on Education, Ukraine [66]. The following types of HEIs were selected from the Register: universities, academies, and institutes that conduct research activities, carry out research and provide training to research staff. Official e-mails were sent to these HEIs inviting heads of institutions and structural units, academic and research staff, library workers, and IT workers to participate in the survey.

The survey engaged participants from over 110 HEIs spanning various regions of Ukraine, except for the occupied territories of Crimea and Donbas. The study encompassed Ukraine's Eastern, Western, Southern, Northern, and Central regions, comprehensively representing the country's higher education landscape (figure 2). Notably, HEIs in the Kyiv region had the highest participation rate, with 17 institutions, including 7 from Kyiv. Other well-represented regions included Kharkiv (12 institutions), Odesa (10 institutions), Lviv (9 institutions), and Dnipropetrovsk (8 institutions) regions.

The total number of respondents was 1,517. The most significant number of respondents represented HEIs of Kyiv (409 persons, 27.2%), Kharkiv (225 persons, 15.0%), Cherkasy (169 persons, 11.3%) and Dnipropetrovsk (144 persons, 9.6%) regions. All participants were informed about the objectives of the study. The survey was anonymous: the received information was used only in a generalised form.

A thorough quality check was conducted on the completed questionnaires before commencing the analysis to ensure the integrity and credibility of the data obtained. As a result, 15 questionnaires were excluded from the dataset. These exclusions pertained to respondents whose affiliation to specific HEIs could not be determined or who were employees of colleges not part of the target sample. Consequently, the aggregated responses of 1,502 participants using Microsoft Excel (PivotTables, math and statistical functions, etc.), descriptive and mathematical-statistical methods, base the analysis and interpretation of the collected data. The visual diagrams, accompanied by their corresponding interpretations, present the findings derived from the data analysis. The qualitative data analysis method was employed to analyse responses to open-ended questions.

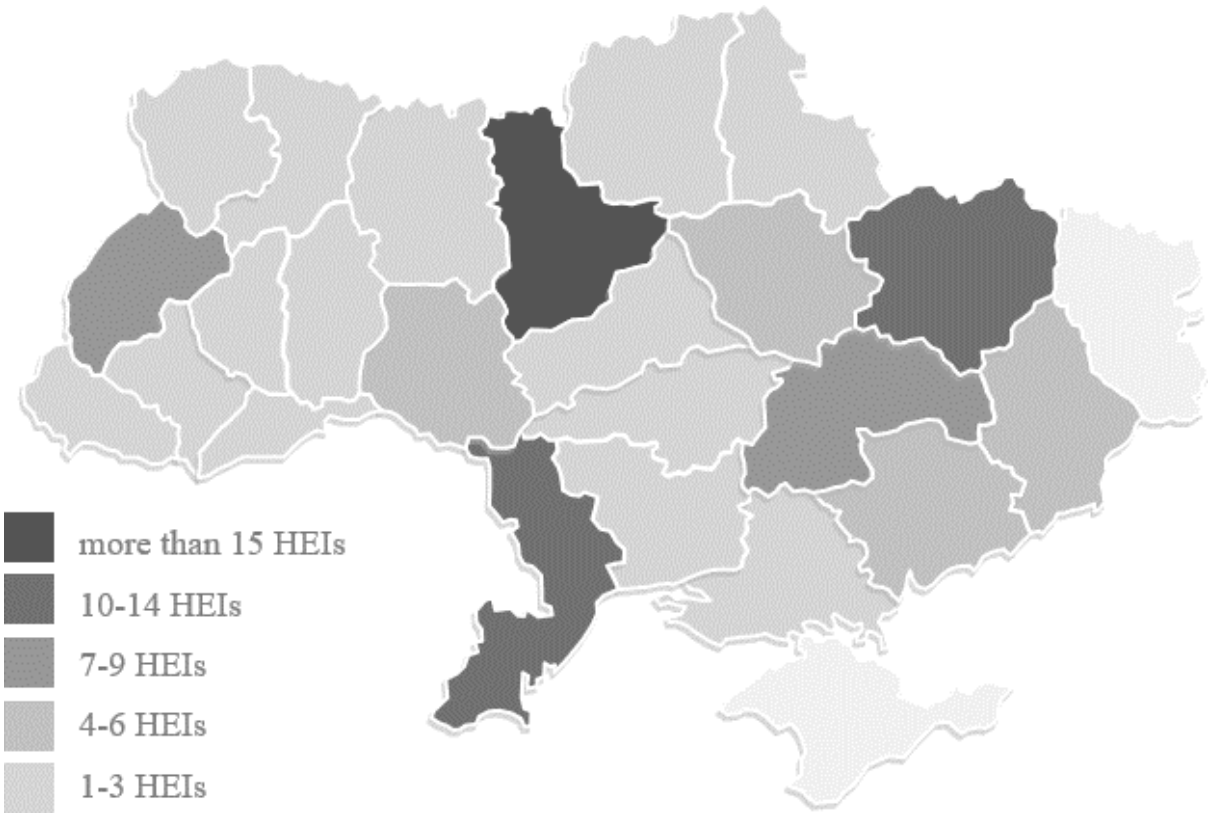

Figure 2: Geographical distribution of HEIs whose representatives participated in the survey.

4. Results and discussion

4.1. Organisational support provided for the research e-infrastructure within the realm of Open Science

The concept of organisational support for research e-infrastructure within the realm of Open Science encompasses a comprehensive array of tools, resources, and services dedicated to facilitating the effective organisation, support, and use of research e-infrastructure.

Based on the comprehensive analysis of survey data, the findings reveal that most HEIs have taken steps towards establishing dedicated structural units (72.6% of respondents) or appointing personnel responsible for developing and maintaining the research e-infrastructures (71.2% of respondents). However, it is noteworthy that a considerable proportion of respondents (35.0%) expressed a need for more organised efforts, indicating that academic and research staff rely on publicly available tools, resources, and services for their research activities (figure 3). Notably, respondents from HEIs in the Kyiv region demonstrated the lowest level of satisfaction with the organisation of such initiatives, with 60.1% of representatives expressing dissatisfaction. Conversely, the situation appears comparatively better in HEIs located in the Chernihiv, Sumy, Zaporizhzhia, and Volyn regions, as only 11.1%, 12.5%, 12.5%, and 18.8% of representatives, respectively, noted the absence of systematic efforts towards the establishment and development of research e-infrastructure

Survey data reflect conflicting results regarding evaluating organisational support of research e-infrastructure within the realm of Open Science by different categories of respondents. So, the overwhelming majority are research staff (76.5%), academic staff (73.6%), employees of IT departments (71.4%), heads and deputy heads of structural units, and library workers (69.6%, respectively) believe that there is a *specialised unit responsible for the development of research e-infrastructure at HEIs.* At the same time, only 22.8% of heads and deputy heads of HEIs confirm the presence of relevant units. The identification of such a discrepancy in results requires further research. In general, the high share

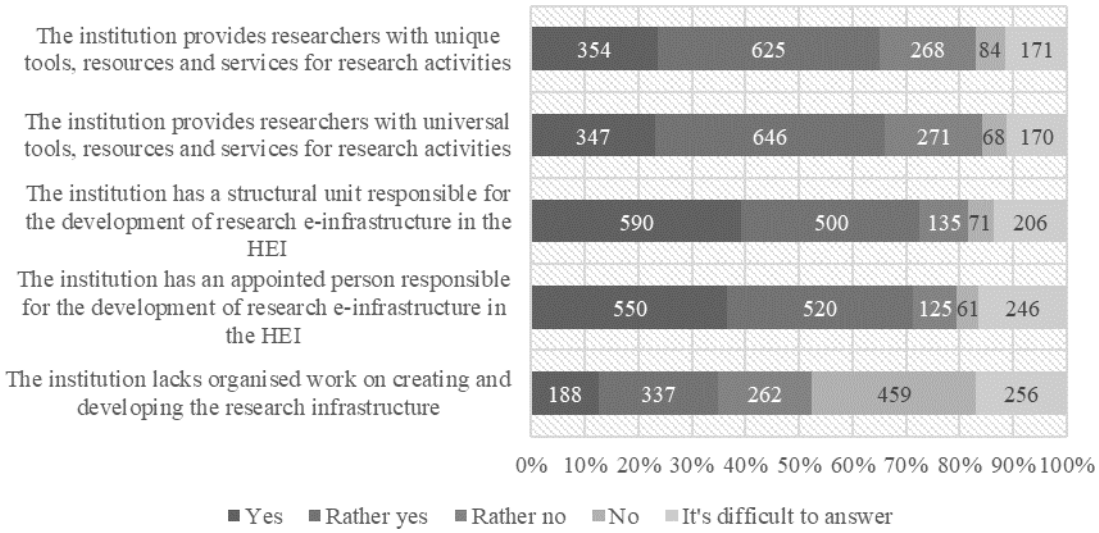

Figure 3: Organisational support provided for the research e-infrastructure within the realm of Open Science.

of survey participants who are not aware of this issue draws attention, and it is the largest among employees of IT departments (28.6%), heads and deputy heads of structural units (22.2%), and library workers (21.7%).

The findings regarding the geographical distribution of structural units responsible for the development of research e-infrastructure reveal exciting variations. According to the respondents, the most minor presence of such structural units was reported in the Chernivtsi (33.3%) and Zhytomyr regions (50.0%). Conversely, all representatives from the HEIs of the Rivne region who participated in the survey indicated the existence of such units. Notably, the proportion of respondents representing HEIs in the Zakarpattia (88.2%) and Sumy (87.5%) regions reported a relatively high presence of these structural units. Furthermore, it is worth highlighting the differences in responses based on the ownership status of the HEIs. Among the respondents, 65.2% of representatives from private HEIs, 71.6% from municipal HEIs, and 72.7% from state-owned HEIs affirmed the presence of these structural units.

The survey results revealed that a significant proportion of respondents identified the *appointment of staff responsible for developing research e-infrastructure* within their institutions. Specifically, 55.6% of HEIs heads and their deputies and 78.3% of library workers reported the presence of designated staff. However, many respondents indicated the absence of such responsible persons, including 33.3% of HEIs heads and their deputies, 21.0% of heads of structural units and their deputies, 12.2% of research staff, and 10.7% of academic staff. Interestingly, the IT department workers (28.6%) and library workers (23.5%) exhibited the lowest awareness regarding such responsible persons. Additionally, 16.9% of research and 12.2% of academic staff could not respond to this question, warranting further investigation into the underlying factors influencing these discrepancies. Moreover, notable regional differences were observed, with 100% of respondents representing HEIs in the Rivne region, 87.5% in the Sumy region, and 86.7% in the Kirovohrad region reporting the presence of responsible staff. In contrast, the lowest percentage of respondents indicating the presence of responsible persons was found in the Chernivtsi region, at 33.3%.

The evaluation of the *provision of unique tools, resources, and services tailored to facilitate specific HEIs' research activities* is of particular interest. Notably, differences in evaluations were observed among employees holding various managerial, research, academic, and support positions, particularly those within IT departments and libraries. The survey results demonstrated a nearly unanimous level of assessment across different categories of positions, with 64.0% of academic staff, 72.0% of research staff, and 88.2% of respondents from other categories expressing similar evaluations. These findings held regardless of the geographical distribution and ownership of HEIs.

Simultaneously, a notable proportion of respondents indicated a need for more unique means, resources, and services for researchers within their institutions. The mentioned included 25.7% of heads

and deputy heads of structural units, 22.2% of heads or deputy heads of HEIs, and 23.9% of academic staff. Notably, the highest proportion of non-response to this question was observed among employees of IT departments (28.6%) and library workers (26.1%). Moreover, respondents from privately-owned HEIs reported a lower level of provision of such resources (56.5%) compared to those from municipal (70.3%) and state-owned institutions (66.0%). Regional disparities were also apparent, with lower indicators of provision observed in Chernivtsi (33.3%), Mykolaiv (40.8%), Vinnytsia (41.3%), and Kyiv (43.3%) regions. Conversely, higher levels were reported in Kherson (100%), Sumy (87.5%), and Poltava (80.9%) regions. Additionally, noteworthy discrepancies were observed within individual HEIs. For instance, among the 144 representatives surveyed from one institution, 65.28% believed that researchers were provided unique means, resources, and services tailored to their research needs. In contrast, 26.39% held the opposite opinion, and 8.33% did not respond to this question.

The analysis of respondents' answers highlights substantial variations in the perception of the available research e-infrastructure in the realm of Open Science within the higher education community in Ukraine. Respondents with different characteristics, such as scientific degrees, academic titles, and research performance, demonstrated divergent views that deviated significantly from the average values observed in the sample. Notably, PhDs and respondents without a scientific degree displayed less awareness of the investigated aspects, with a higher proportion facing difficulties in answering related questions (18.1% among PhDs, 18.6% among respondents without a scientific degree), compared to DScs (11.7%). Similar patterns emerged when examining respondents with different academic titles. For instance, among those with the academic title of Professor, the percentage of individuals unable to answer relevant questions was considerably lower (9.1%) compared to respondents with the titles of Associate Professor and Senior Researcher (14.3%) and those without an academic title (15.4%). Notably, respondents with no research performance exhibited a significantly higher percentage of difficulty in answering questions about the level of available research e-infrastructure (20.2%). This indicator was 14.8% among individuals with up to 1 year of experience, 12.6% among those with 2 to 5 years of experience, 13.6% among those with 6 to 20 years of experience, and 15.4% among those with over 20 years of research experience to provide a comparative perspective.

4.2. Use of services that constitute the research e-infrastructures ecosystem within the realm of Open Science in HEIs of Ukraine

Studying the current state of development of e-infrastructure within the realm of Open Science in HEIs was conducted utilising a comprehensive six-component model of the research e-infrastructures ecosystem in Ukrainian universities, as proposed [64].

Our study's findings reveal that most respondents rely on institutional and subject repositories (84.5%) and the National Repository of Academic Texts (84.2%) to facilitate open access to publications. Notably, popular subject repositories include the Digital Library of the National Academy of Educational Sciences of Ukraine, as well as university repositories such as eSSUIR, eKMAIR, ELARTU, eKhNUIR, ARRChNU, and ELAKPI. It is worth mentioning that a smaller proportion of HEIs use international services such as Open Research Europe (24.5%) and the Directory of Open Access Journals, DOAJ (17.2%). Additionally, a few respondents reported the use of other services, including the Directory of Open Access Books, DOAB (6.7%), OpenAIREValidator (4.4%), Figshare (2.9%), Zenodo (4%), and Episciences (1.7%) (figure 4).

The comprehensive analysis of the survey data reveals a notable level of consistency in respondents' answers regarding the provision of open access to publications, irrespective of their scientific degree, academic title, or research performance. However, there are significant variations in the responses of different positions. Notably, employees of IT departments demonstrate a considerably lower rating (28.6%) in terms of the state of institutional and industry provision of open access to publications in HEIs, compared to other respondent groups. This finding highlights IT staff's limited involvement in shaping and developing research e-infrastructure for Open Science. Notably, among the 2.3% of respondents who indicated uncertainty in their answers within this category, a substantial proportion comprises IT department employees (14.3%).

The respondents highlighted the use of Open Journal Systems (OJS) as a platform for publishing

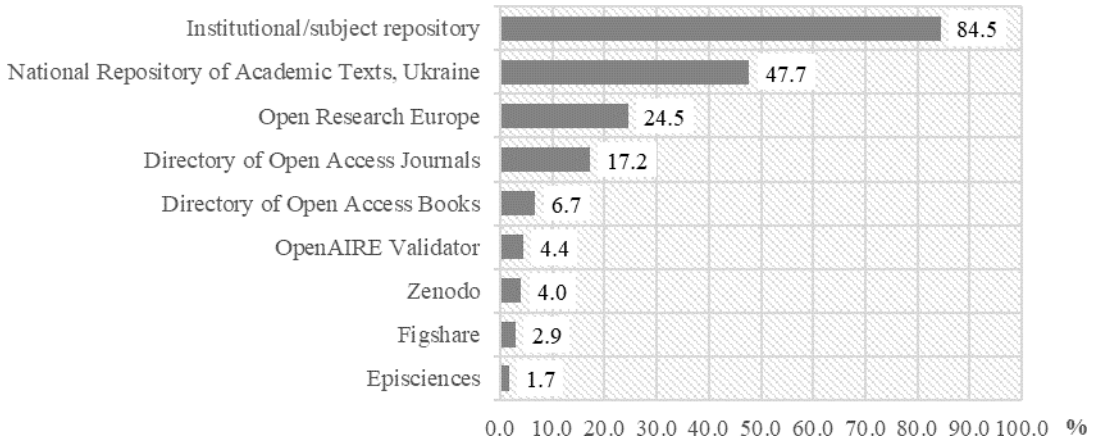

Figure 4: Use of services for open access to publications.

scientific periodicals. Additionally, they mentioned the inclusion of institutional repositories in the directories of OpenDOAR (Directory of Open Access Repositories) and ROAR (Registry of Open Access Repositories). A small proportion of respondents (2.3%) indicated a need for more information. Notably, respondents' answers shed light on the challenges faced by servers hosting institutional repositories, which have suffered damage due to military actions. These challenges underscore the urgency of providing informational, educational, and advisory support to staff members in HEIs, particularly young researchers, to enhance their effective use of existing international services.

In the context of storage and management of *open research data*, HEIs predominantly rely on using Open Science Framework (38.5%). Additionally, a lesser proportion of institutions make use of Mendeley Data (15.2%), Figshare (13.1%), and Zenodo (9.7%) (figure 5). It is worth noting that some respondents also highlighted the use of Discuss Data as part of their data management practices.

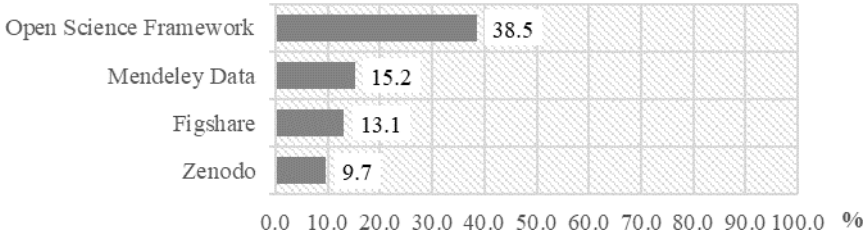

Figure 5: Use of services for storage and management of open research data.

Our analysis revealed that various factors, such as job position, publication record, research performance, the field of knowledge, institution location, and institutional scope, notably influenced the survey results. Notably, library workers demonstrated a preference for Mendeley Data (43.5%), while research staff leaned towards Open Science Framework (32.9%) and Figshare (19.5%). Academic staff, as well as heads and deputy heads of structural units and institutions, expressed a higher affinity for Open Science Framework (40.7%, 35.0%, and 33.3%, respectively) and Mendeley Data (14.0%, 20.2%, and 11.1% respectively). IT personnel predominantly utilised the Open Science Framework (57.1%) and Mendeley Data (14.3%). DScs displayed a greater level of engagement with the Open Science Framework (42.1%) and Mendeley Data (22.6%) compared to other groups, with a difference of 5-8%. PhDs showed less usage of Zenodo (8.4%) and Figshare (11.8%), while individuals without a scientific degree preferred Mendeley Data (11.6%). Notably, among PhDs and respondents without a scientific degree, a significant proportion utilised other services (16.6% and 5.5%, respectively), while among DScs, only 1.5% reported doing so.

A detailed examination of the findings concerning utilising e-infrastructure services for storing and managing open research data revealed striking disparities among respondents with different research

performance levels. Specifically, individuals with up to 1 year of research performance demonstrated higher usage rates (approximately 5% higher) of Open Science Framework (44.4%) and Figshare (19.4%) services compared to other groups.

One significant observation that requires particular attention is the limited awareness among respondents regarding open data storage and management services. Nearly 30.3% (455 individuals) responded, such as "It is difficult to answer", "I cannot say", "I did not get information", or "Lack of information". This proportion is considerably higher than the corresponding evaluation of services for open access to publications. Respondents offered explanations for their lack of knowledge, including statements such as "You should consult the HEI management", "I do not get reliable information", or "Inquire with library workers about Open Science services".

The professional development of research and academic staff, specifically in terms of *education and skills*, primarily relies on utilising various services. Our findings indicate that the most commonly employed platforms for this purpose include Moodle (85.7%), YouTube (50.5%), and to a lesser extent, edX (9.5%) (figure 6).

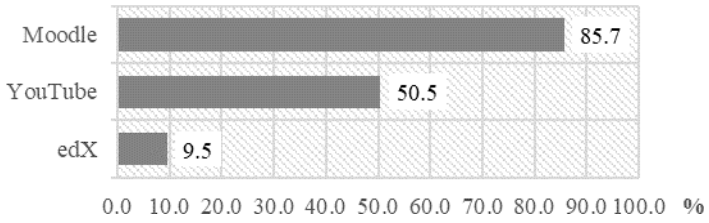

Figure 6: Use of services for professional development of research and academic staff.

A notable proportion of respondents (34.7%) could not answer the question regarding services for the professional development of research and academic staff within Open Science. Moreover, it is evident that the characteristics of the respondents, such as their position, scientific degree, academic title, and research performance, influenced their assessments.

In terms of YouTube usage, DScs indicated a higher level of use (59.8%) compared to PhDs (49.3%) or individuals without a scientific degree (46.4%). Professors also reported a higher level of YouTube usage (60.6%) in comparison to Associate Professors (49.6%) and persons without an academic title (48.1%). Conversely, respondents without an academic title expressed a higher level of Moodle usage (89.2%) compared to Professors (84.4%).

Furthermore, variations in evaluations were observed among respondents with varying research performance levels. Respondents with over 20 years of experience provided the highest ratings for YouTube usage (55.4%), while those without such experience reported the lowest levels (39.8%). However, no significant differences were identified in the responses concerning using Moodle and edX among respondents with different research performance levels. Furthermore, 2.3% of respondents could not identify the pertinent services. This notable discrepancy between respondents' awareness of services, such as those utilised for storing and managing open research data by their institution (30.3% of respondents), warrants further research.

Unicheck (65.2%) and StrikePlagiarism (25.4%) emerged as the primary tools to enhance research *responsibility and integrity*. Relatively less prevalent were CrossRef Similarity Check (6.1%), Wcopyfind (4.7%), and Anti-Plagiarism (0.4%) (figure 7). Respondents in the comments section underscored using these services primarily to scrutinise students' qualification papers. Notably, one respondent highlighted the presence of a specialised commission within their HEI responsible for conducting an expert evaluation of programme outcomes.

Considering the responders' job positions, analysing their answers reveals notable discrepancies in evaluations on utilising Unicheck. Despite the overall high popularity of this service among HEIs, estimates range from a minimum of 28.6% among employees of the IT department to a maximum of 80.5% among heads and deputy heads of structural units. On the other hand, the distribution of responses regarding the use of StrikePlagiarism is more evenly spread, with ratings ranging from a

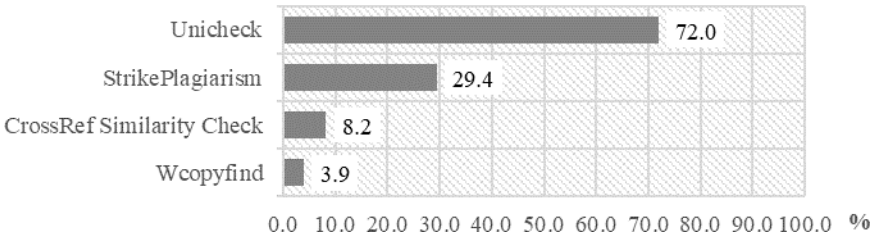

Figure 7: Use of services to enhance research responsibility and integrity.

low of 22.2% among heads and deputy heads of institutions to a highest of 33.5% among heads and deputy heads of structural units. The similarity of responses between research and academic staff is notable, with Unicheck garnering ratings of 71.1% and 63.6%, respectively, StrikePlagiarism receiving ratings of 28.7% and 30.4% respectively, and CrossRef Similarity Check receiving ratings of 7.8% and 7.3% respectively. These results demonstrate that the responses from those directly involved in research activities provide the most objective reflection of the situation regarding using services to enhance research responsibility and integrity.

There is a consensus among respondents with different scientific degrees regarding using StrikePlagiarism services, with ratings of 32.0% among DScs, 28.3% among PhDs, and 30.1% among individuals without a scientific degree. A similar agreement is observed for CrossRef Similarity Check, with ratings of 10.2% among DScs, 7.0% among PhDs, and 9.9% among individuals without a scientific degree. For Wcopyfind, there is also alignment in evaluations, with ratings of 3.0% among DScs, 3.4% among PhDs, and 6.1% among individuals without a scientific degree. However, significant differences emerge in respondents' assessments of the use of Unicheck, with ratings of 80.5% among DScs, 73.5% among PhDs, and 61.4% among individuals without a scientific degree.

The survey participants' research performance influenced their responses regarding utilising services to enhance research responsibility and integrity at HEIs. Respondents with over 20 years and 6-20 years of research performance provided similar ratings for all services (Unicheck – 74.7% and 73.4%; StrikePlagiarism – 32.5% and 30.2%; Wcopyfind – 8.8% and 7.7%, respectively). Likewise, respondents with 2-5 years and less than 1 year of research performance also displayed nearly identical ratings (StrikePlagiarism – 25.8% and 27.8%; Wcopyfind – 4.9% and 5.6%, respectively). In contrast, respondents without research performance exhibited somewhat distinct ratings (Unicheck – 57.7%, StrikePlagiarism – 24.4%, CrossRef Similarity Check – 8.1%, Wcopyfind – 6.5%). Notably, respondents with less than 1 year of research performance provided significantly higher ratings for using CrossRef Similarity Check. Regarding publication records, significant differences were observed in evaluations of the Unicheck service, with 77.7% of respondents with over 50 publications, 73.4% with 11-50 publications, 68.1% with 1-10 publications, and 54.1% without any publication record.

It is noteworthy that a significant proportion of respondents (7.7%) demonstrated a limited level of awareness regarding the services employed by HEIs to promote research responsibility and integrity, as evidenced by their responses such as "I do not know", "It is difficult to say", or "I cannot say".

In HEIs of Ukraine, various services are utilised to *evaluate research performance*. The predominant services include ORCID (82.2%) and Google Scholar (78.1%), which are widely adopted for this purpose. Additionally, institutional/subject repositories are commonly employed, with a usage rate of 72%. The Bibliometrics of Ukrainian Science is also utilised significantly, with a usage rate of 40.3% (figure 8). Other services that contribute to research performance evaluation in these institutions include the Open Ukrainian Citation Index, OUCI (26.4%), Directory of Open Access Journals, DOAJ (12.9%), ImpactStory (8%), Directory of Open Access Books, DOAB (4.5%), Altmetric (3.8%), Open Science Observatory (3.7%), Datacite (1.5%), and PLUMx (1.3%).

The analysis of responses revealed variations in the use of ORCID and Google Scholar services among respondents with different job positions. The highest adoption rates were observed among heads and deputy heads of institutions (88.9% each), heads and deputy heads of structural units (86.0% and 86.8%, respectively), and academic staff (82.7%). Conversely, employees of IT departments and library workers

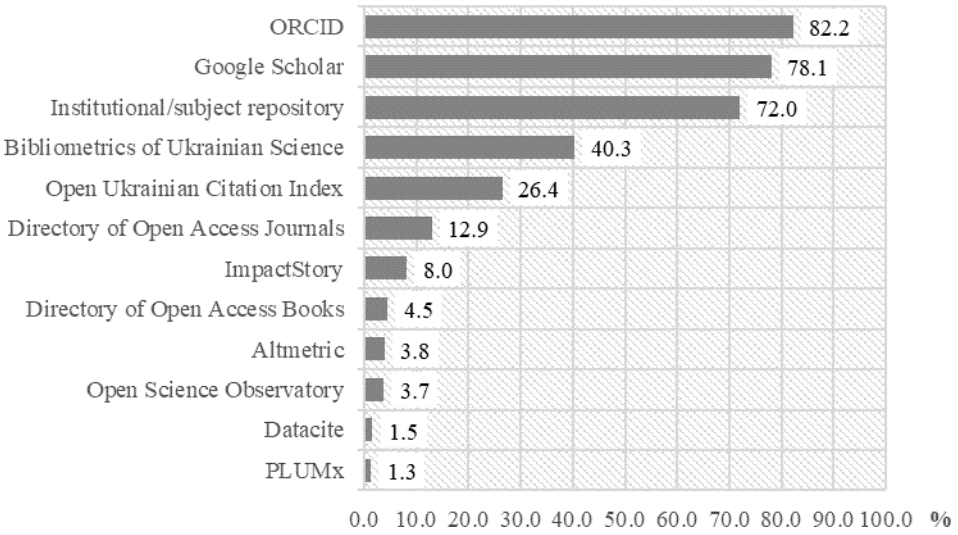

Figure 8: Use of services for evaluation of research performance.

demonstrated lower usage rates, with figures of 42.3% and 28.6%, respectively. When considering the use of institutional/subject repositories, the highest adoption rates were reported by library workers (91.3%) and heads and deputy heads of institutions (88.9%). On the other hand, employees of IT departments showed the lowest adoption rate at 42.9%.

Regarding the use of the Bibliometrics of Ukrainian Science, responses indicated that 69.6% of library workers, 50.6% of heads and deputy heads of structural units, and only 28.6% of IT departments' employees reported its use. For OUCI, 30.4% of heads and deputy heads of structural units and library workers noted its usage. In contrast, only 14.3% of IT department employees reported its use. Lastly, the DOAJ was cited by 28.8% of heads and deputy heads of institutions and 22.2% of library workers as being employed within HEIs.

No notable variations were discovered in the evaluations provided by respondents when categorised based on different attributes such as their position, scientific degree, academic title, and research performance. As anticipated, respondents without a scientific degree or academic title, lacking research performance, and without publication records tended to provide lower estimates (up to 20% variance for certain positions) regarding the use of relevant services.

In the context of *citizen science* development, HEIs in Ukraine use various services. The most prevalent among them is Science to Business (S2B), an online platform facilitating communication and effective interaction between the scientific community and business representatives, with a usage rate of 36.9%. Other notable services include ImpactStory (14.8%), OpenAIRE CONNECT Dashboard (13.2%), Altmetric (8.5%), Datacite (5.5%), and PLUMx (3.9%) (figure 9). It is worth mentioning that a minority of respondents (less than 0.4%) indicated unfamiliarity with the concept of "citizen science".

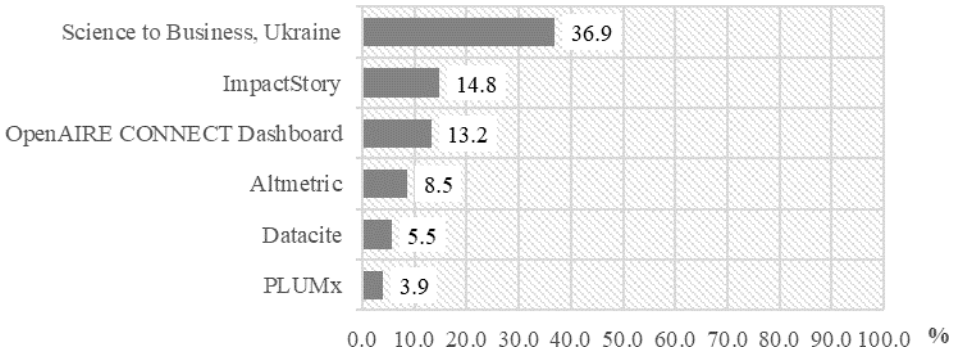

Figure 9: Use of services for citizen science development.

Among the respondents, academic staff (38.5%), heads and deputy heads of structural units (34.6%), and heads and deputy heads of institutions rate the use of the S2B service higher compared to employees of IT departments (28.6%), research staff (26.8%), and library workers (26.1%). Notable disparities were observed in the OpenAIRE CONNECT Dashboard service assessments, with 23.2% of research staff indicating its use. At the same time, none of the employees from IT departments and library workers reported utilising this service in their respective HEIs.

No significant differences were found between participants' responses with different scientific degrees, academic titles and those without any. However, the results revealed that respondents with less than 1 year of research performance more frequently indicated the use of S2B (47.2%), Altmetric (15.3%), and Datacite (9.7%) in their respective HEIs. Furthermore, it was identified that among respondents without any research performance, the most significant proportion indicated the use of the PLUMx service (6.5%).

5. Conclusions

The full-scale invasion of Ukraine by the Russian Federation on February 24, 2022, has had a detrimental impact on advancing research infrastructures in Ukraine, spanning the national, regional, and institutional levels. Nevertheless, the establishment, management, and efficient use of Open Science research e-infrastructures remain essential prerequisites for bolstering the research capabilities of Ukrainian HEIs.

Despite the considerable progress made in national-level Open Science policies, the institutional landscape reveals a certain fragmentation in implementing comprehensive Open Science policies, including policies regarding e-infrastructures. Many HEIs need more relevant policies within their development strategies. Notably, efforts are underway to establish repositories that facilitate open access to publications through initiatives such as the Higher Education and Research Centre, alongside the provision of research competency development courses [10]. In contrast, the leading EU universities prioritise implementing Open Science policies and operationalising organisational, advisory, and informational support systems for researchers.

The current state of organisational support for research e-infrastructure in Ukrainian HEIs needs to be improved. The provision of researchers with unique tools, resources, and services tailored to facilitate the specific research needs of each institution still needs to be completed. While some HEIs have established dedicated structural units or appointed responsible individuals to oversee the development of research e-infrastructure, many HEIs need more organised efforts. Consequently, research and academic staff in these institutions rely on publicly available facilities, resources, and services for their research activities.

The level of awareness and engagement in developing research e-infrastructure is relatively low among employees of IT departments and library workers, noticeably lower compared to other categories of staff. Furthermore, there is a notable discrepancy in the perception of the existing research e-infrastructure within the realm of Open Science among individuals within the educational community of Ukrainian HEIs, based on their characteristics such as scientific degree, academic title, and research performance. The findings indicate that individuals with higher scientific degrees tend to possess more comprehensive knowledge across all aspects of research.

The respondents overwhelmingly rely on institutional/subject and national repositories to facilitate open access to publications. However, the use of international services remains significantly limited. The unfortunate damage inflicted upon servers hosting institutional repositories due to military operations emphasises the necessity for comprehensive measures to provide informational, educational, and consulting support to personnel within HEIs. Notably, young scientists require guidance on maximising the potential of existing international Open Science services to ensure their effective use.

The limited level of awareness among respondents regarding services related to the storage and management of open data, the promotion of research responsibility and integrity, and the professional development of research and academic staff within the realm of Open Science present a distinct challenge.

There is a need for initiatives to enhance awareness and understanding among respondents on these crucial aspects of Open Science.

A notable observation pertains to the limited use of services to enhance research responsibility and integrity. These services predominantly scrutinise students' qualification papers, with few HEIs exhibiting the presence of a dedicated committee that conducts expert evaluations of programme outcomes. The mentioned indicates a need for more effective implementation and integration of such services across the higher education landscape to foster a culture of research integrity and enhance scholarly practices.

The results of our study support the imperative for establishing a pervasive culture of Open Science at the institutional level, necessitating a concerted effort to drive its implementation [18]. There is an urgent need to enhance the key normative documents of HEIs, including strategies, plans, and roadmaps, explicitly articulating the mission, goals, and objectives of integrating Open Science principles to achieve this. Furthermore, the systematic functioning of research e-infrastructures and relevant resources and services must be substantiated and ensured for effective operation. It is crucial to prioritise appointing highly competent professionals to administer and manage research e-infrastructures within HEIs. This appointment will facilitate the seamless functioning and optimisation of these vital structures supporting Open Science endeavours.

A well-crafted communication policy adopted by HEIs is pivotal in elevating employees' awareness concerning Open Science policies and procedures and facilitating access to research infrastructures. Moreover, it is prudent to actively engage employees from IT departments and library workers in the operational and supportive aspects of research e-infrastructure. In view of these considerations, we emphasise the importance of instituting proactive measures within institutions to enhance the research competence of research and academic staff consistently. By adopting a constructive approach, HEIs can continuously elevate the proficiency of their academic staff, fostering an environment conducive to impactful research practices.

The present study has shed light on several promising directions for future research in the field. These directions include exploring the challenges and successful approaches in building national research information systems within the European Union countries. Additionally, investigating various financing models for Open Science e-infrastructures holds potential for further exploration. Evaluating the effectiveness and impact of e-infrastructures at the national, regional, and institutional levels is another area that warrants attention. Finally, examining the preparedness of research and academic staff in Ukrainian HEIs to leverage e-infrastructures within the realm of Open Science for fundamental and applied research needs to be investigated.

References

[1] Cabinet of Ministers of Ukraine, On Approval of the Concept of the State Target Programme for Development of Research Infrastructures in Ukraine for the period up to 2026, 2021. URL: https://zakon.rada.gov.ua/laws/show/322-2021-%D1%80.

[2] Education in emergency, 2023. URL: https://saveschools.in.ua/en/.

[3] O. Borodiyenko, Y. Malykhina, Y. Protopopova, K. Kim, V. Malykhina, Social and Economic Prerequisites of Strategic Development of Universities in the Conditions of War and Post-War Period, Financial and Credit Activity Problems of Theory and Practice 3 (2022) 26–268. doi:10.55643/fcaptp.3.44.2022.3762.

[4] V. Kremen, V. Bykov, O. Liashenko, S. Lytvynova, V. Lugovyi, Y. Malovanyi, O. Pinchuk, O. Topuzov, Scientific and methodological provision of digitalisation of education in Ukraine: status, problems, prospects: Scientific report to the general meeting of the National Academy of Educational Sciences of Ukraine "Scientific and Methodological Support for the Digitalisation of Education in Ukraine: State, Problems, Prospects", November 18-19, 2022, Herald of the National Academy of Educational Sciences of Ukraine 4 (2022) 1–49. doi:10.37472/v.naes.2022.4223.

[5] T. Sych, Y. Khrykov, O. Ptakhina, Digital transformation as the main condition for the development

of modern higher education, Educational Technology Quarterly 2021 (2021) 293–309. doi:10.55056/etq.27.

[6] V. I. Kovalchuk, S. V. Maslich, L. G. Movchan, V. V. Soroka, S. H. Lytvynova, O. H. Kuzminska, Digital transformation of vocational schools: problem analysis, CTE Workshop Proceedings 9 (2022) 107–123. doi:10.55056/cte.107.

[7] O. V. Ovcharuk, A. M. Gurzhii, I. V. Ivaniuk, L. A. Kartashova, O. O. Hrytsenchuk, T. A. Vakaliuk, M. P. Shyshkina, The use of digital tools by secondary school teachers for the implementation of distance learning in the context of digital transformation in Ukraine, CTE Workshop Proceedings 9 (2022) 16–27. doi:10.55056/cte.96.

[8] O. P. Pinchuk, O. M. Sokolyuk, O. Y. Burov, M. P. Shyshkina, Digital transformation of learning environment: aspect of cognitive activity of students, CTE Workshop Proceedings 6 (2019) 90–101. doi:10.55056/cte.370.

[9] Ministry of Education and Science of Ukraine, Digital Transformation of Education and Science, 2024. URL: https://mon.gov.ua/ua/tag/cifrova-transformaciya-osviti-ta-nauki.

[10] V. Lugovyi, I. Drach, O. Petroye, V. Zinchenko, Y. Mielkov, I. Zhyliaiev, I. Reheilo, V. Kamyshyn, N. Bazeliuk, Analysis of leading domestic and foreign experience in increasing the research capacity of universities of Ukraine in the conditions of war and post-war reconstruction in the context of implementation of the "Open Science" concept, Institute of Higher Education of NAES of Ukraine, Kyiv, 2022.

[11] M. P. Shyshkina, M. V. Marienko, Augmented reality as a tool for open science platform by research collaboration in virtual teams, Educational Dimension 1 (2019) 147–158. doi:10.31812/educdim.v53i1.3838.

[12] European Commission, Open Science, 2024. URL: https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/our-digital-future/open-science_en.

[13] S. O. Semerikov, A. M. Striuk, H. M. Shalatska, AI-assisted language education: critical review, Educational Dimension 4 (2021) 1–7. doi:10.31812/ed.623.

[14] K. S. Tarisayi, Strategic leadership for responsible artificial intelligence adoption in higher education, CTE Workshop Proceedings 11 (2024) 4–14. doi:10.55056/cte.616.

[15] L. O. Fadieieva, Enhancing adaptive learning with Moodle's machine learning, Educational Dimension 5 (2021) 1–7. doi:10.31812/ed.625.

[16] N. Melek, Responding to challenge call for machine learning model development in diagnosing respiratory disease sounds, Journal of Edge Computing (2024). doi:10.55056/jec.679.

[17] H. E. Pence, Will Open Science Succeed in Higher Education?, Journal of Educational Technology Systems 51 (2023) 261–270. doi:10.1177/00472395231153957.

[18] T. Yaroshenko, Open Access, Open Science, Open Data: How It Was and Where We Are Going (To the 20th Anniversary of the Budapest Open Access Declaration), Ukrainian Journal on Library and Information Science (2021) 10–26. doi:10.31866/2616-7654.8.2021.247582.

[19] V. O. Kopanieva, L. Y. Kostenko, O. V. Novytskyi, V. A. Reznichenko, The Task of Digital Transformation of the Scientific and Informational Environment, Problemy prohramuvannia (2023) 3–10. doi:10.15407/pp2023.01.003.

[20] R. Vicente-Saez, R. Gustafsson, L. Van den Brande, The dawn of an open exploration era: Emergent principles and practices of open science and innovation of university research teams in a digital world, Technological Forecasting and Social Change 156 (2020) 120037. doi:10.1016/j.techfore.2020.120037.

[21] R. Vicente-Saez, R. Gustafsson, C. Martinez-Fuentes, Opening up science for a sustainable world: An expansive normative structure of open science in the digital era, Science and Public Policy 48 (2021) 799–813. doi:10.1093/scipol/scab049.

[22] Ministry of Education and Science of Ukraine, On approval the Roadmap for Ukraine's Integration into the European Research Area (ERA-UA), 2021. URL: https://tinyurl.com/3ccvhu24.

[23] Cabinet of Ministers of Ukraine, On approval of the National Plan for Open Science, 2022. URL: https://zakon.rada.gov.ua/laws/show/892-2022-%D1%80.

[24] Ukraine Recovery Plan, 2022. URL: https://recovery.gov.ua/en.

[25] Draft Sections of the Recovery Plan for the post-war reconstruction and development of Ukraine promulgated and offered for commenting and proposals, 2022. URL: https://www.kmu.gov.ua/en/news/opryliudneno-dlia-komentuvannia-rozdily-planu-vidnovlennia-ukrainy.
[26] Cabinet of Ministers of Ukraine, On approval of the Strategy for the Development of Higher Education in Ukraine for 2022-2032, 2022. URL: https://zakon.rada.gov.ua/laws/show/286-2022-%D1%80.
[27] Lviv Polytechnic National University, Open Practices, Transparency and Integrity for Modern Academia (OPTIMA), 2023. URL: https://lpnu.ua/en/optima.
[28] Sumy State University, SumDU implements a project for introducing the best EU open experience into education and science, 2023. URL: https://news.sumdu.edu.ua/en/en-news/12889.
[29] On Approval and Implementation of the Open Science Policy at the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", 2022. URL: https://ela.kpi.ua/handle/123456789/51235.
[30] T. Yaroshenko, O. Serbin, O. Yaroshenko, Open Science: the Role of Universities and Libraries in Modern Changes in Scientific Communication, Digital Platform: Information Technologies in Sociocultural Sphere 5 (2022) 277–292. doi:10.31866/2617-796X.5.2.2022.270132.
[31] Science Communication in the Digital Age, 2020. URL: https://courses.prometheus.org.ua/courses/course-v1:UKMA+SCDA101+2020_T1.
[32] R. Morais, B. Saenen, F. Garbuglia, S. Berghmans, V. Gaillard, From principles to practices: Open Science at Europe's universities: 2020-2021 EUA Open Science Survey results, Technical Report, European University Association, Brussels, 2021. URL: https://eua.eu/resources/publications/976.
[33] I. I. Drach, S. H. Lytvynova, O. M. Slobodianiuk, Experience of implementating insitutional policicies on open science in European universities, Information Technologies and Learning Tools 90 (2022) 173–190. doi:10.33407/itlt.v90i4.4945.
[34] Verkhovna Rada of Ukraine, Law of Ukraine "On Scientific, Scientific and Technical Activities", 2015. URL: https://zakon.rada.gov.ua/laws/show/848-19.
[35] Cabinet of Ministers of Ukraine, On Approval of the Regulation on the National Electronic Research Information System, 2022. URL: https://zakon.rada.gov.ua/laws/show/1067-2022-%D0%BF.
[36] Verkhovna Rada of Ukraine, On Approval of the Tasks of the National Informatisation Programme for 2022-2024, 2022. URL: https://zakon.rada.gov.ua/laws/show/2360-20.
[37] Cabinet of Ministers of Ukraine, On Amendments to Certain Decrees of the Cabinet of Ministers of Ukraine on the Regulation of Academic Mobility Issues, 2022. URL: https://zakon.rada.gov.ua/laws/show/599-2022-%D0%BF.
[38] Cabinet of Ministers of Ukraine, On Approval of the Action Plan for the Implementation of the Human Development Strategy for 2021-2023, 2021. URL: https://zakon.rada.gov.ua/laws/show/1617-2021-%D1%80.
[39] Cabinet of Ministers of Ukraine, On Approval of the National Economic Strategy for the Period up to 2030, 2021. URL: https://zakon.rada.gov.ua/laws/show/179-2021-%D0%BF.
[40] President of Ukraine, On the Decision of the National Security and Defence Council of Ukraine of 14 May 2021 "On the Human Development Strategy", 2021. URL: https://zakon.rada.gov.ua/laws/show/225/2021.
[41] UNESCO European Centre for Higher Education, The Bucharest Declaration concerning Ethical Values and Principles for Higher Education in Europe, Higher education in Europe XXIX (2004) 503–507. URL: https://unesdoc.unesco.org/ark:/48223/pf0000139478.
[42] H. Song, D. M. Markowitz, S. H. Taylor, Trusting on the shoulders of open giants? Open science increases trust in science for the public and academics, Journal of Communication 72 (2022) 497–510. doi:10.1093/joc/jqac017.
[43] T. Rosman, M. Bosnjak, H. Silber, J. Koßmann, T. Heycke, Dataset for: Open Science and public trust in science: Results from two studies. Public Understanding of Science, 2022. doi:10.23668/psycharchives.6495.
[44] H. Akin, Overview of the Science of Science Communication, in: K. H. Jamieson, D. M. Kahan, D. A. Scheufele (Eds.), The Oxford Handbook of the Science of Science Communication, Oxford

University Press, New York, 2017, pp. 24–33. doi:10.1093/oxfordhb/9780190497620.013.3.
[45] T. Shenkoya, E. Kim, Sustainability in Higher Education: Digital Transformation of the Fourth Industrial Revolution and Its Impact on Open Knowledge, Sustainability 15 (2023) 2473. doi:10.3390/su15032473.
[46] B. Fecher, S. Friesike, Open Science: One Term, Five Schools of Thought, in: S. Bartling, S. Friesike (Eds.), Opening Science: The Evolving Guide on How the Internet is Changing Research, Collaboration and Scholarly Publishing, Springer International Publishing, Cham, 2014, pp. 17–47. doi:10.1007/978-3-319-00026-8_2.
[47] European Research Area and Innovation Committee, European Research Area (ERA) Roadmap 2015-2020, 2015. URL: https://data.consilium.europa.eu/doc/document/ST-1208-2015-INIT/en/pdf.
[48] UNESCO Recommendation on Open Science, 2021. URL: https://unesdoc.unesco.org/ark:/48223/pf0000379949.
[49] Towards a 2030 Vision on the Future of Universities in Europe, Policy Report, Luxemburg, 2020. doi:10.2777/510530.
[50] Council of the European Union, Council Conclusions on Research Infrastructures, 2022. URL: https://data.consilium.europa.eu/doc/document/ST-15429-2022-INIT/en/pdf.
[51] Roadmap 2021: Strategy Report on Research Infrastructures, Dipartimento di Fisica – Università degli Studi di Milano, 2021. URL: https://roadmap2021.esfri.eu/media/1295/esfri-roadmap-2021.pdf.
[52] R. Bertacco, I. Bolliger, L. Börjesson, M. Bugel, O. Hradil, R. Migueis, M. Wallquist, Universities of S&T as Engines of Excellence, Talent and Innovation: Roles in Research and Innovation Infrastructures, White Paper, Leuven, 2019. URL: https://www.cesaer.org/content/5-operations/2019/20190313-white-paper-rii.pdf.
[53] R. Fabre, D. Egret, J. Schöpfel, O. Azeroual, Evaluating the scientific impact of research infrastructures: The role of current research information systems, Quantitative Science Studies 2 (2021) 42–64. doi:10.1162/qss_a_00111.
[54] I. Spang-Grau, Research information in the selection process of germany's universities of excellence, in: EuroCRIS Strategic Membership Meeting, Münster, Germany, 2019. URL: http://hdl.handle.net/11366/1230.
[55] B. Fecher, R. Kahn, N. Sokolovska, T. Völker, P. Nebe, Making a Research Infrastructure: Conditions and Strategies to Transform a Service into an Infrastructure, Science and Public Policy 48 (2021) 499–507. doi:10.1093/scipol/scab026.
[56] D. Zendulková, G. Gavurníková, J. Turňa, Map of Research Infrastructure as a tool of the Information System for Research, Development, and Innovation, Procedia Comput. Sci. 211 (2022) 47–56. doi:10.1016/j.procs.2022.10.175.
[57] L. Zhang, J. Li, P. F. Uhlir, L. Wen, K. Wu, Z. Luo, Y. Liu, Research e-infrastructures for open science: The national example of CSTCloud in China, Data Intelligence 5 (2022) 355–369. doi:10.1162/dint_a_00196.
[58] H.-M. Puuska, W. Rydman, Linking funding to research output and facilities through the Finnish Research Information Hub, in: CRIS2018: 14th International Conference on Current Research Information Systemsg, Umeå, Sweden, 2018. URL: http://hdl.handle.net/11366/637.
[59] P. de Castro, The role of Current Research Information Systems (CRIS) in supporting Open Science implementation : the case of Strathclyde, ITlib. Informačné technológie a knižnice (2018) 21–30. doi:10.25610/itlib-2018-0003.
[60] M. Stocker, L. Darroch, R. Krahl, T. Habermann, A. Devaraju, U. Schwardmann, C. D'Onofrio, I. Häggström, Persistent Identification of Instruments, Data Science Journal (2020). doi:10.5334/dsj-2020-018.
[61] S. Vancauwenbergh, Analyzing the research data infrastructure in Europe, in: Autumn 2019 euroCRIS Strategic Membership Meeting (WWU Münster, Germany, Nov 18-20, 2019), euroCRIS, Germany, 2019. URL: http://hdl.handle.net/11366/1225.
[62] J. Schöpfel, O. Azeroual, G. Saake, Implementation and user acceptance of research information systems: An empirical survey of german universities and research organisations, Data Technologies and Applications 54 (2019) 1–15. doi:10.1108/dta-01-2019-0009.

[63] A. Duṣa, D. Nelle, G. Stock, G. G. Wagner, Facing the Future. European Research Infrastructures for the Humanities and Social Sciences, SCIVERO Verlag, Berlin, 2014.

[64] I. Drach, O. Petroye, N. Bazeliuk, O. Borodiyenko, O. Slobodianiuk, Modelling the Universities' E-Infrastructure for the Development of Open Science in Ukraine, in: E. Faure, O. Danchenko, M. Bondarenko, Y. Tryus, C. Bazilo, G. Zaspa (Eds.), Information Technology for Education, Science, and Technics, Springer Nature Switzerland, Cham, 2023, pp. 275–298. doi:10.1007/978-3-031-35467-0_19.

[65] What Are Infrastructure Services?, 2020. URL: https://stefanini.com/en/insights/news/what-are-infrastructure-services.

[66] Register of Subjects of Educational Activity – Higher Education Institutions, 2023. URL: https://registry.edbo.gov.ua/.