# Integrating digital competencies of researchers into Ph.D. curricula: a case study on open science education

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### Abstract

The openness of science is gaining momentum in the digital era, prompting new visions, research methods, and innovations at universities. While the study of open science postulates and practices can expand the capabilities of future scholars, digital ones included, to provide a tentative action plan for research digitalization, foster cooperation, and transparency, improve research reproducibility, as well as enhance its visibility and significance, this issue, however, often remains overlooked when training specialists in higher education institutions. In an effort to combine the research practice of open science and the practice of training Ph.D. students in higher education institutions of Ukraine, we developed the elective training module "Digital technologies in modern scientific research: learning Open Science" in compliance with DACUM methodology. In our study, in terms of labor market requirements, we are guided by the need to train researchers capable of effective realization in the context of digital open science and explore the descriptors of researchers' digital competence (Jisc Researcher) as an expected outcome of postgraduate studies at universities. Results of experimental inspection of the developed module application in the process of master students learning at Borys Grinchenko Kyiv Metropolitan University have confirmed the relevance of its development and application while allowing to pinpoint certain problems. Accordingly, the prospects of further studies include bolstering the practical component of training and strengthening horizontal connections between universities and project teams in order for the Ph.D. students to gain the experience of scientific research digitalization and create the environment for Ph.D. students to form digital competencies in regards to digital proficiency, productivity, identity, and wellbeing.

### Keywords

open science, digital capabilities, digital competence of future researchers, Ph.D. student training, higher education, empirical research



## 1. Introduction

Recognition of open science [1] as one of the freedoms of the open world in European Research Area (ERA) and European Higher Education Area (EHEA) incentivizes European Universities to cooperate [2] and highlights the necessity of digital transformation of higher education institutions' scientific activity [3]. Herewith, one should regard the digital transformation of scientific activities as one of the interrelated dimensions (research, teaching, business process, human resource, curricula, infrastructure, administration, marketing, information) of digital transformation in higher education institutions [4].

Theoretical principles and practices of open digital science application in higher education institutions have been extensively studied. Generalized results regarding the application of open science in 272 institutions of higher education from 36 European countries are cited in [5]. Local studies are also worth exploring.

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Analysis of policy and application models of European Open Science Cloud (EOSC) as European Cloud University Platform are presented in integration research [6], particularly, the development of the digital innovation ecosystem of the university is identified as one of the core integration problems identified. The impact of digital technologies and open science principles in universities (i.e., open data sharing, open access publication, open repositories, open physical laboratories, common design and interdisciplinary research platforms) for sustainable development is explored in [7]. Design and reflection of Learning Open Science in education institutions in Germany are presented in [8]. A management aspect of this phenomenon also plays a major part. For example, finnish researchers present in [9] a generalized model of managing open science and innovation in universities in the digital world. While for Ukraine, this issue is pivotal in the context of post-war recovery [10].

As open science in the document by European Commission "Open innovation, open science, open to the world – a vision for Europe" [11] is regarded as a new approach to the scientific process based on cooperative work and new ways of diffusing knowledge by using digital technologies and new collaborative tools, the need to train competitive specialists in universities is emphasized considering that scientific research and its digitalization are coming to prominence [12]. Furthermore, in addition to building (or upgrading) digital institutional education environments [13], we should invest in the development of digital capabilities and competences, namely of young researchers (focus of the present study) [14]. With view of the above it is imperative to consider and cultivate digital capabilities both on individual and institutional level [15]. The latter is pursuant to Digital Education Action Plan (2021-2027) [16].

In this context, it is crucial to emphasize the role of two stakeholders: future researchers with high degree of preparedness to effective realization in the context of digital open science and university, compliant with requirements of European Research Area (ERA) and European Higher Education Area (EHEA).

Among other aspects, this involves a change in the learning model. The new model should focus on the cultivating digital capabilities of future researchers and the inclusion of digital competence in curricula [17].

Therefore, the objective of this study is to determine requirements to Ph.D. students' results and curricula in higher education (HE) in the context of the open science development and to field-test their effectiveness by the degree of formation of digital competence of researchers.

*Research questions:*

1. Is it feasible to determine the digital capabilities of researchers in institutions of higher education?
2. How are the digital capabilities of researchers integrated in the training programs for Ph.D. students in higher education institutions?
3. How does the learning model, focused on the development of digital capabilities of future researchers, impact the development of digital competence of Ph.D. students?

## 2. Theoretical background

### 2.1. Defining the digital competencies of future researchers

In this study, we relied on a phenomenological approach that reflects the requirements for digital competence of future researchers. For this purpose, an analysis of existing models of digital (information and communication) competences was carried out, in particular, the following documents and cases of their application in the process of training specialists were analyzed:

- The European Computer Driving License (ECDL, https://icdleurope.org/); ECDL certificate is recognized by all the European Union countries [18];
- The European e-Competence Framework (e-CF, https://ecfexplorer.itprofessionalism.org/) represents a structure that can be used both by companies that produce ICT services and products, and by institutions that use ICT in their core activities [19];

- Digital Competence Framework (DigComp, https://joint-research-centre.ec.europa.eu/digcomp_en) is an effective tool for implementing the Digital Education Action Plan in different countries (2021-2027) [16]; in this study we explore Digital Competence Framework for Citizens, namely, the updated version The Digital Competence Framework for Citizens: DigComp 2.2 [20];
- Digital profile of a researcher in higher education [21], as the structure element of digital capabilities Jisc (https://digitalcapability.jisc.ac.uk/what-is-digital-capability/), that focuses on digital capabilities relevant for both young and experienced scholars of higher education.

At the same time, it should be noted that today an increasing number of researchers and practicing educators are turning to the application of the DigComp framework for the formation of educational policies, planning of training and assessment of the formation of digital skills [22, 23]. There are also recommendations for the correlation of the mentioned frames: ECDL and DigComp [24] as well as e-CF and DigComp [25]. This helps, for example, to determine the continuity and enhancing effect of ECDL and DigComp when planning the curriculum or the correlation of general requirements for the digital competence of citizens (DigComp) and IT professionals (e-CF). The latter permits to demonstrate the continuity of certain skills when moving from the competencies expected of citizens to the competencies that IT professionals should possess. Since none of the 30 profiles of IT specialists identified by e-CF as of 2018, which are used for drawing up educational programs [19], corresponds to the target audience (Researchers) identified in this study, it is not worthwhile to use the profiles of these specialists.

Therefore, taking DigComp 2.2 [20] as a basis, we continued our research on the description of the profiles of subjects acquiring these competencies: by analogy with e-CF, [19], we compared the groups of competencies of the DigComp 2.2 framework and the Jisc researcher profile (figure 1).

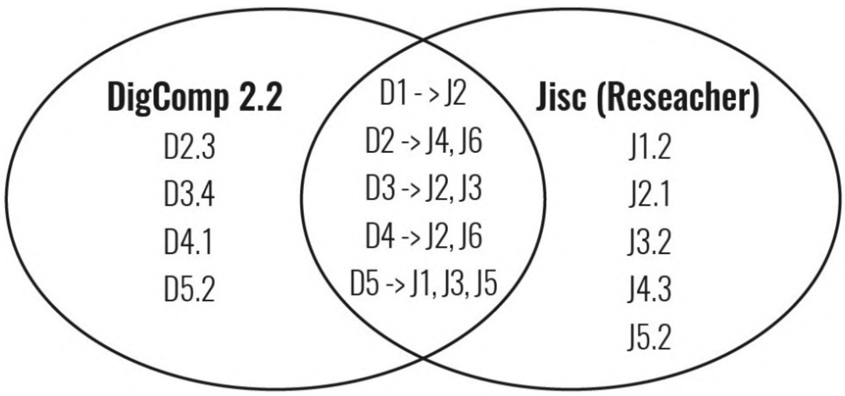



**Figure 1:** DigComp 2.2 and Jisc Researcher comparison.

This mapping showed that at the highest level of generalization, Jisc Researcher follows DigComp 2.2, as each of the 5 groups of competencies of DigComp 2.2 can be cross-referenced to the six groups of Jisc Researcher. Full or partial similarity of the defined competencies (marked with the same color) is shown in figure 2.

At the same time, it should be noted that the requirements for the digital competence of researchers have a specialized focus and a wider scope (15 detailed descriptors – a total of 64, against 21 in DigComp 2.2). That is why correlation shown in figure 2 is a certain generalization, since the decomposition of the Jisc Researcher descriptors and conducting additional analysis constitute the basis for determining the specific requirements for researchers that follow the basic ones. For example, Information literacy of the researcher (J2.1) is an extension of the equivalent category DigComp 2.2 (D1.3), in particular, in terms of the development of a personal digital environment adapted to scientific interests and needs (J2.1.5).

As Jisc Researcher focuses on the digitization of research, specific descriptors are also highlighted, in particular:

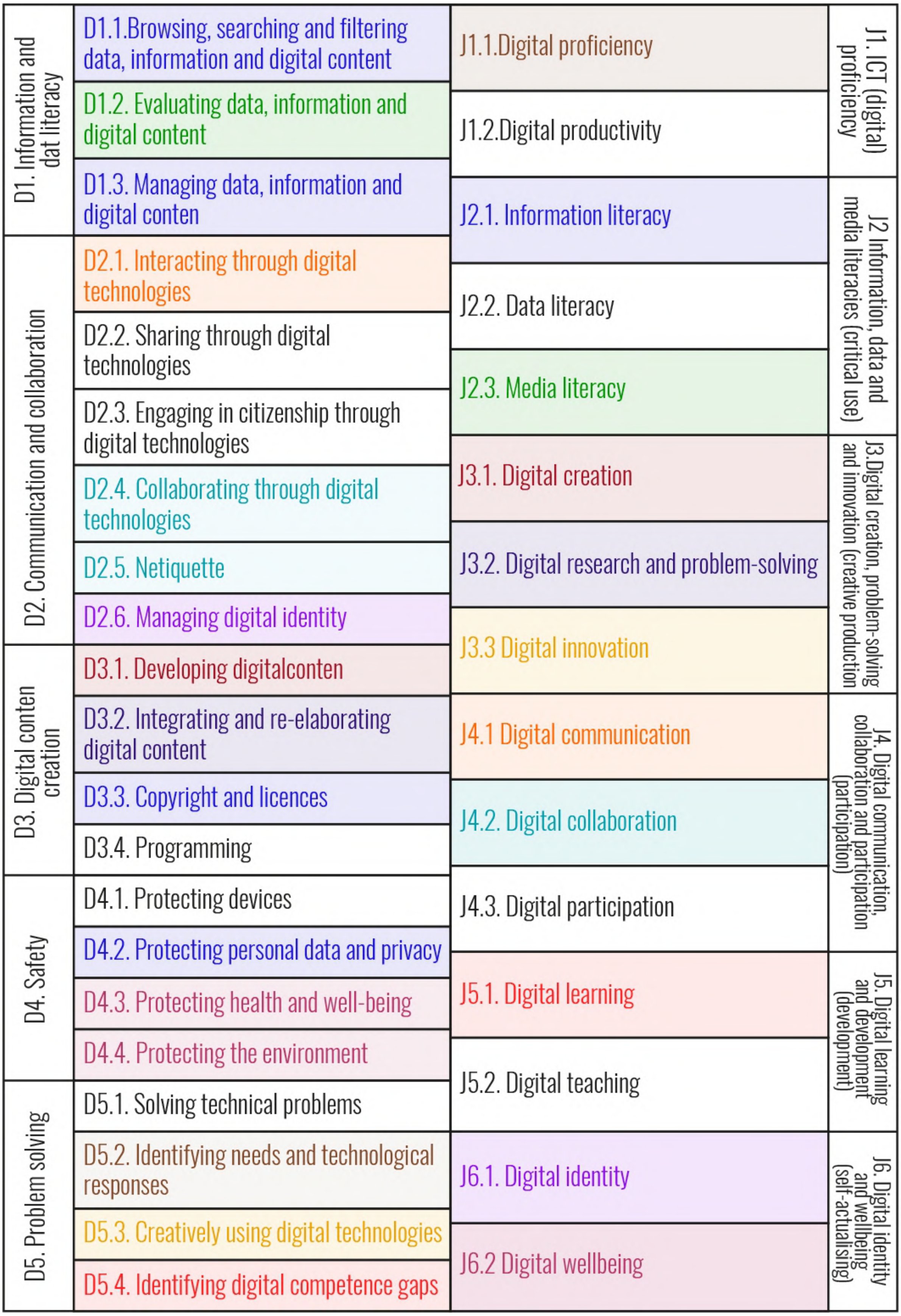



**Figure 2:** Cross references DigComp 2.2 and Jisc Researcher.

J1.2. Digital productivity, containing requirements related to the quality and productivity of scientific research;

J2.2. Data literacy as a proven ability to manage research data;

J3.2. Digital research, in particular in the part of solving problems (full name of the descriptor – Digital research& problem-solving), which correlates with the corresponding descriptor DigComp 2.2, since the ability to solve problems belongs to key competencies;

J5.2. Digital teaching is understood primarily as digital mentoring, which is clarified through the decomposition of descriptors.

However, the researcher's digital profile does not specify requirements for solving problems related to setup, safe use, and technical support for research, programming, and community outreach. These competencies should be formed at the basic level in every citizen pursuant to the DigComp 2.2 framework.

Therefore, the presented analysis is a reason to adopt the Jisc Researcher profile as a basis for determining the requirements for digital competence (following the DigComp 2.2 framework) of future researchers.

## 2.2. A curriculum development using DACUM

Since the integration of digital and professional competences into educational curricula is most extensively studied in the training programs of future IT specialists, in this study we will try to scale the developed methods, in particular [17, 19], to the design of programs for the training of future researchers at universities.

In this context, attention should be drawn to the use of a systematic approach as DACUM (Development of the curriculum) to integrate the pragmatic perception of industry practitioners and strict prescriptions of instructors in academic curriculum [26]. In our research, in terms of labor market requirements, we focus on the training needs of researchers capable of effective implementation in the conditions of digital open science, and we consider the descriptors of the digital competence of researchers (Jisc Researcher) as the expected results of postgraduate studies at universities. It should also be noted that the definition of learning objectives and expected results, for example, using e-CF profiles [19], for the design of educational programs, individual courses or modules requires further modifications and (or) the introduction of sub-competencies. In this process, it is advisable to use the recommendations of DACUM both regarding the selection of experts and the algorithm of their activities [27].

Therefore, in order to achieve the goals of our research, namely, to determine the requirements for the results and training programs of Ph.D. students in higher education (HE) in the context of the development of open science, as well as to confirm the effectiveness of their application in accordance with the level of formation of the digital competence of researchers, we formulated the following tasks:

1. Determine the feasibility of using the Jisc Researcher profile as a basis for determining the requirements (in terms of competencies) for the learning outcomes of Ph.D. students in higher education (HE) as future digital researchers (*corresponds to the Job/task analysis stage of the DACUM process implementation)*;
2. Analyze the educational programs of the university (on the example of Borys Grinchenko Kyiv Metropolitan University) regarding the formation of digital competencies of researchers and to develop a training module to ensure their formation (*corresponds to the Education /training program development stage of the DACUM process implementation*);
3. To determine the effectiveness of the application of the author's educational module through the Assessment of digital researcher level of Ph.D. students of the 2nd year of study based on the Jisc Researcher profile and compare the results of the experimental (undergoing training according to the author's module) and control groups *(corresponds to the Validation stage of the DACUM process implementation*).

It should be noted that the results of the stages of the DACUM process [27] are presented in sections: 2.1 – preparation for job analysis, 4.1 – task analysis, 4.2 – education/training program development, 4.3 – validation/verification of the effectiveness of the developed program.

## 3. Research design

The undertaken study can be classified as empirical, therefore it is based on the methods of empirical research, namely: observation, survey (conversation, interview, questionnaire), expert assessment, content analysis, study and generalization of pedagogical experience.

As a basis, we employed the DACUM methodology, which is used to determine the competencies that should be integrated in the training program of specialists of a specific profession [27]. The effectiveness of this technique is based on three premises: (I) Experienced workers can describe their work better than anyone else; (II) Any job can be effectively described in terms of the competencies or tasks performed by successful workers in that profession; (III) It is appropriate to describe the specific knowledge, skills, attitudes, and tools that employees need to perform their tasks properly. Accordingly, it is necessary to select two main groups of experts:

- 5-9 specialists, in our case, they are experts in digital open science and communication, from the number of scientific and pedagogical workers of higher education institutions and research institutions (I group, engaged for the implementation of the I and II tasks of the research);
- PhD students of a higher education institution (II group) who are involved in determining the effectiveness (implementation of the III research task) of educational solutions proposed by experts.

Therefore, in order to determine the most significant criterion indicators for evaluating the digital competence of a Ph.D. Student based on the Jisc Researcher (*I research task*), 9 international experts were involved, in particular, among the participants of the European project called IRNet, whose cooperation is ongoing [14]. The selection of experts was carried out in accordance with the task of the research and the object of evaluation. The main criterion for the selection of experts was professional competence in the field of expert assessment, which was determined by their ability to adequately assess the digital competences of researchers in accordance with the field of professional activity, as well as the educational curricula created for their formation.

The experts were sent questionnaires to evaluate each of the 15 defined Jisc Researcher criterion indicators (figure 2) on a four-point significance scale (1 – not significant, 2 – slightly significant, 3 – significant, 4 – highly significant). The indicator was considered important if the value of the average rank was more than 2. The consistency of the opinions of the group of experts was checked according to the Kendall rank correlation coefficient.

To fulfill the *second task* of the research, content analysis was used to compare curricula for the inclusion of digital competencies of researchers in the training plans of Ph.D. students of Ukrainian higher education institutions, DACUM method – for Curriculum Design [27], and expert evaluation method – for evaluating the content and expected results (in terms of competencies) of the author's module "Digital technologies in modern scientific research: learning Open Science". Expert evaluation will be carried out by the same 9 experts who volunteered to work on the 1st task of the research.

To implement the *third task* of the research, we conducted a statistical survey. The Google form, developed in the process of implementing the previous study [14], was reused (https://docs.google.com/forms/d/e/1FAIpQLSdrO8MYhVJNvh72cqjZhyH9VQMl1kPBiFiHkORM7_o70JkfiQ/viewform) to determine the difference in the level of formation of digital competence of researchers according to the level of intervention at the level of training programs in accordance with the Jisc recommendations [21].

89 Ph.D. students of the second year of study at the Borys Grinchenko Kyiv Metropolitan University took part in the survey, 46 of them studied the author's module (II group, experimental), 43 did not (I group, control). The homogeneity of the groups prior to specialized training (conducted according to

the methodology and materials presented in [15]) is confirmed by the criteria of the Chi-Square Test of Independence and Mann-Whitney U Test regarding the similarity of distributions by gender, areas of study and age [28]. The processing and analysis of the results of the study involved the use of the Likert scale. Non-parametric methods of data analysis using SPSS statistical data processing tools were used for data processing [29].

# 4. Results of research

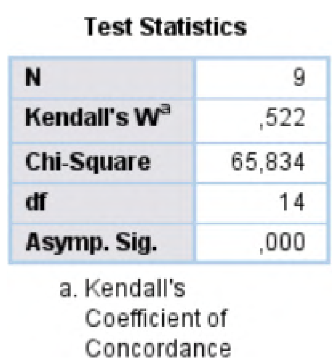
## 4.1. Expert evaluation of criterion indicators for evaluating the digital competence of Ph.D. students based on Jisc Researcher

As a result of the expert evaluation of the criterion indicators for evaluating the digital competence of Ph.D. Students based on Jisc Researcher, the importance of the selected criteria (indicators) turned out to be varied. But all the determined criterion indicators (table 1) turned out to be significant, which indicates the correctness of the application of the Jisc Researcher model for determining the level of digital competence of Ph.D. students.

**Table 1**
Determination of the importance of Jisc Researcher indicators for evaluating the digital competence of Ph.D. students.

| Expert | J1.1 | J1.2 | J2.1 | J2.2 | J2.3 | J3.1 | J3.2 | J3.3 | J4.1 | J4.2 | J4.3 | J5.1 | J5.2 | J6.1 | J6.2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| exp1 | 3 | 4 | 2 | 3 | 4 | 4 | 2 | 3 | 4 | 3 | 4 | 4 | 3 | 3 | 4 |
| exp2 | 4 | 4 | 3 | 4 | 4 | 3 | 1 | 3 | 3 | 4 | 3 | 4 | 3 | 3 | 4 |
| exp3 | 3 | 4 | 2 | 3 | 4 | 3 | 2 | 3 | 4 | 4 | 4 | 4 | 3 | 3 | 4 |
| exp4 | 3 | 4 | 3 | 3 | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 4 |
| exp5 | 4 | 4 | 3 | 3 | 4 | 4 | 2 | 4 | 4 | 3 | 4 | 3 | 2 | 4 | 4 |
| exp6 | 4 | 4 | 2 | 3 | 4 | 4 | 3 | 4 | 3 | 4 | 4 | 4 | 3 | 4 | 3 |
| exp7 | 4 | 4 | 3 | 3 | 4 | 4 | 2 | 4 | 2 | 4 | 4 | 4 | 2 | 3 | 4 |
| exp8 | 4 | 3 | 3 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 |
| exp9 | 3 | 3 | 1 | 4 | 4 | 4 | 3 | 4 | 3 | 4 | 3 | 4 | 3 | 4 | 4 |
| Sum | 32 | 34 | 22 | 30 | 36 | 34 | 21 | 33 | 31 | 33 | 34 | 35 | 25 | 32 | 35 |
| Mean rank | 3.6 | 3.8 | 2.4 | 3.3 | 4.0 | 3.8 | 2.3 | 3.7 | 3.4 | 3.7 | 3.8 | 3.9 | 2.8 | 3.6 | 3.9 |

We used Kendall's Coefficient of Concordance for estimating the degree of agreement among experts when rating items (figure 3). These results were obtained using SPSS. A value of 0.522 indicates moderate agreement among the 9 experts in ranking the importance of competence in the given scale and level of agreement observed among the experts is statistically significant (p-value<0.05). The Chi-Square value of 65.834 with 14 degrees of freedom indicates that there is a significant association among the ranked items, suggesting that the experts' rankings are not likely to be random.


**Test Statistics**

| | |
|---|---|
| N | 9 |
| Kendall's W[a] | ,522 |
| Chi-Square | 65,834 |
| df | 14 |
| Asymp. Sig. | ,000 |

a. Kendall's Coefficient of Concordance

**Figure 3:** Results of calculating Kendall's Coefficient of Concordance in SPSS.

### 4.2. Integration of digital capabilities of researchers into training programs for Ph.D. students in institutions of higher education as examplified by Borys Grinchenko Kyiv Metropolitan University

Taking the experience of Integrating Digital Competence in Higher Education Curricula as a basis [17], we carried out a comparative analysis of educational programs for Ph.D. students in Ukrainian institutions of higher education in general and at Borys Grinchenko Kyiv Metropolitan University in particular.

As a result, it should be noted that the digital capabilities of future doctors of philosophy are purposefully formed by teaching the mandatory subject "Scientific Research Strategies". In accordance with the II task of the research, the module "Digital technologies in modern scientific research: learning Open Science" (2 credits, 60 hours) was additionally developed, it is mainly aimed at the formation of the ability to use digital technologies in modern scientific research, starting from their formulation and the construction of appropriate information models and ending with the interpretation of the results obtained with the help of a computer. The main content of the module, examples of digital tools studied by Ph.D. students, and a list of Jisc Researcher competencies that are formed when studying each topic are shown in table 2.

**Table 2**
General presentation of the module "Digital technologies in modern scientific research: learning Open Science".

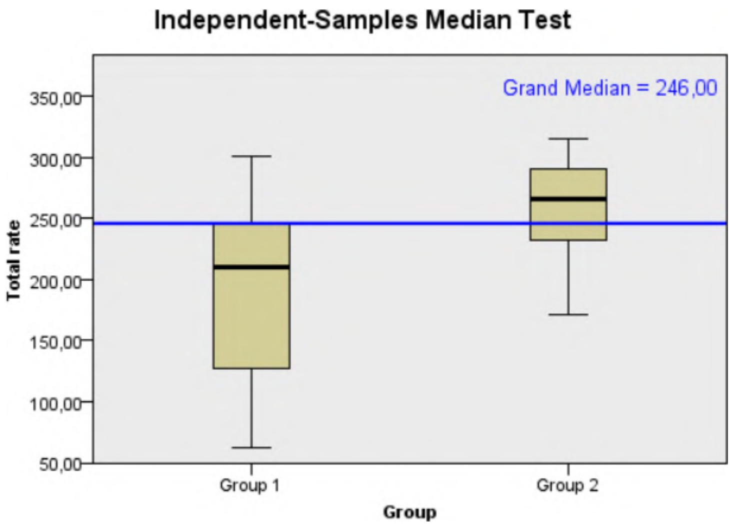
| № | Content | Tools (examples) | Competencies Jisc Researcher (figure 2) |
|---|---|---|---|
| 1 | Open science and digital capabilities of researchers | FOSTER (https://www.fosteropenscience.eu/foster-taxonomy/open-science-tools) | J3.3, J4.3, J5.1, J6.1, J6.2, J1.1 |
| 2 | Open access to scientific information | arXiv, Directory of Open Access Repositories (OpenDOAR), Directory of Open Access Journals (DOAJ) | J2.1, J4.1, J4.3 |
| 3 | Open data practices. Research data management | Open Access Repositories (ROAR) Base, Zenodo; re3data.org; Figshare | J2.2, J4.2 |
| 4 | Using open source tools | SPSS, MATLAB, R, MS Excel, iPylton, ROpenSci Statistica, MS Power BI | J2.2, J3.2, J3.1, J5.1 |
| 5 | The practice of using social networks to support scholarly communication | Academia.edu, Reseachgate.net, Google Scholar; Mendeley Scientific Social Community | J4.2, J6.1, ; J2.1, J4.3 |
| 6 | Selecting tools to support the life cycle of scientific research | An overview and comparative characteristics are presented in [30] | J2.2, J2.3, J3.1, J3.2, J3.3, J4.1, J4.2, J4.3, J5.1, J5.2 |
| 7 | Interdisciplinary research platforms | EOSC Services [31] | J2.2, J4.1, J4.2, J4.3, J5.2 |
| 8 | Academic Integrity and Ethics of Scientific Publications in the Digital Environment | Advego Plagiatus, Etxt Antiplagiat, StrikePlagiarism, PlagScan, Unichek, ChatGPT, SCImago Journal Rank (SJR) | J2.1, J4.2 |
| 9 | Expanding the possibilities of PhD students | E-conference tools, Sherpa Romeo, ScienceOpen, ORCID, Web of Science Clarivate Analytics, Publons, Erasmus+ | J4.1, J4.2, J6.1, J1.2, J1.1, J6.2, J1.2 |

The importance of the Jisc Researcher indicators from the point of view of inclusion in the curriculum of the author's module was confirmed by the results of the expert evaluation, similar to section 4.1. Kendall's Coefficient of Concordance is equal to 0.714, which indicates strong agreement among the 9 experts in ranking the importance of inclusion in the curriculum in the given scale. The level of agreement observed among the experts is statistically significant ($p$-value$<0.05$).

At the same time, it should be noted that, according to experts (corresponds to [8]), the formation of digital individual components of a researcher's digital competence, primarily in terms of scientific proficiency and productivity (indicators of group J1) and identity and well-being (indicators of group J6), also requires the involvement of Ph.D. students in real scientific research and projects. Therefore, these and some others, for example J3.2, J3.3 and J4.3, competences within the optional module can be formed only at the basic level.

## 4.3. Experimental verification of the effectiveness of the proposed decision

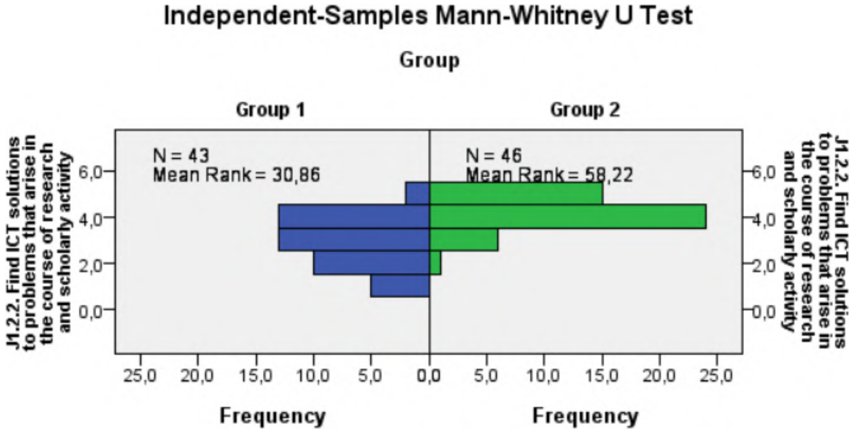
Comparing the results of the survey of the participants of the experimental group (46 students who studied the author's module) and the control group (43 students who did not study the author's module), it should be noted that the students of the experimental group showed better results overall (figure 4). We used the Independent-Sample Median Test to compare the medians of two independent groups (Group 1 – control group and Group 2– experimental group), because this test allows us to compare two independents group with non-normal distributions of rates. The test statistics value = 20.9 indicates that we have a substantial difference in the medians of the two groups and this difference in medians is statistically significant (p-value<0.05) (figure 4). So, we reject the null hypothesis. The likelihood of observing such a significant difference due to random chance alone is extremely low.




| | | |
|---|---|---|
| Total N | | 89 |
| Median | | 246,000 |
| Test Statistic | | 20,921 |
| Degrees of Freedom | | 1 |
| Asymptotic Sig. (2-sided test) | | ,000 |
| Yates's Continuity Correction | Chi-Square | 19,024 |
| | Degrees of Freedom | 1 |
| | Asymptotic Sig. (2-sided test) | ,000 |

**Figure 4:** Independent-Sample Median Test of total rates for control (Group 1) and experimental (Group 2) groups of Ph.D. students.

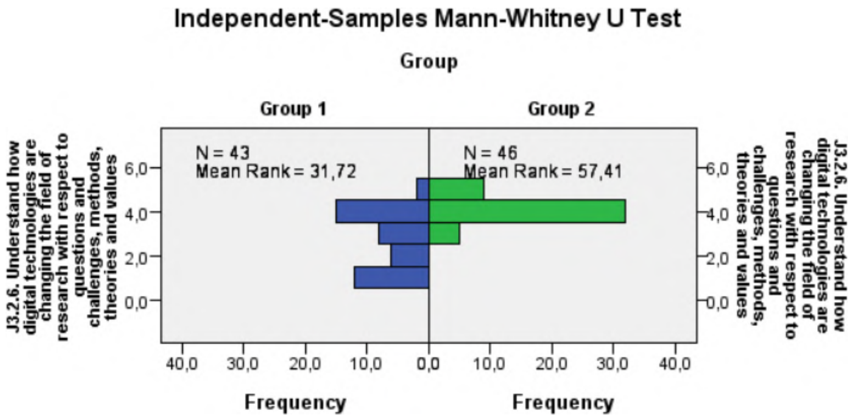
If we take into account the lack of formation of certain groups of indicators of digital competence of future researchers, defined in [14], in order to confirm the influence of the author's methodology (design and application in the process of training Ph.D. students of the selective module "Digital technologies in modern scientific research: learning Open Science") on the formation of a certain competence in the experimental group, an additional comparison of competencies was carried out, according to research related to digitization, in particular, in terms of finding ICT solutions to problems that arise in the course of research and scholarly activity (J1.2.2); understanding how digital technologies are changing the field of research with respect to questions and challenges, methods, theories and values (J3.2.6), developing and projecting a positive digital identity or identities as a researcher (J6.1.1) and academic integrity J2.2.3 (apply to the relevant ethical bodies for permission to collate and use research data). For this comparison, we used Independent-Samples Mann-Whitney U test, which allows for comparison of differences between two independent groups when the dependent variable is either ordinal or continuous but not normally distributed, what we had in our cases. Therefore, the self-assessment of the Ph.D. students experimental and control groups for component J1.2.2 Jisc Researcher shows us that we have a significant difference between rates (p-values<0.05) for Mann-Whitney test statistic =1597.0. The experimental group have a higher mean rank of rates (58.22) than the control group (30.86) (figure 5).




| | |
|---|---|
| Total N | 89 |
| Mann-Whitney U | 1 597,000 |
| Wilcoxon W | 2 678,000 |
| Test Statistic | 1 597,000 |
| Standard Error | 116,157 |
| Standardized Test Statistic | 5,234 |
| Asymptotic Sig. (2-sided test) | ,000 |

**Figure 5:** The self-assessment results of the J1.2.2 Jisc Researcher component formation of the Ph.D. students experimental and control groups.

We have similar results with differences between experimental and control group for J3.2.6 Jisc Researcher component. This test also found a significant difference (p-value = 0.000) for Mann-Whitney test statistic =1560.0 The experimental group have a higher mean rank of rates (57.41) than the control group (31.72) (figure 6).




| | |
|---|---|
| Total N | 89 |
| Mann-Whitney U | 1 560,000 |
| Wilcoxon W | 2 641,000 |
| Test Statistic | 1 560,000 |
| Standard Error | 111,967 |
| Standardized Test Statistic | 5,100 |
| Asymptotic Sig. (2-sided test) | ,000 |

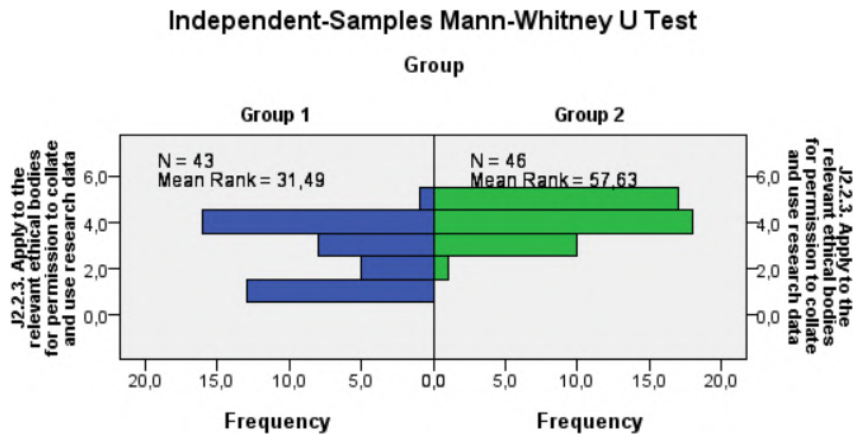
**Figure 6:** The self-assessment results of the J3.2.6 Jisc Researcher component formation of the Ph.D. students experimental and control groups.

For J2.2.3 Jisc Researcher component experimental group of Ph.D. students shows us higher results too, and this result is statistical significant (p-value = 0.000) for Mann-Whitney test statistic =1570.0 (figure 7). Mean rank for experimental group = 57.63, for control group – 31.49.

The difference between group in direction of self-assessment of the J6.1.1 Jisc Researcher component formation is significant too. We found Mann-Whitney test statistic =1536.0 (p-value = 0.000) (figure 8). Mean rank for experimental group = 56.90, for control group – 33.27.

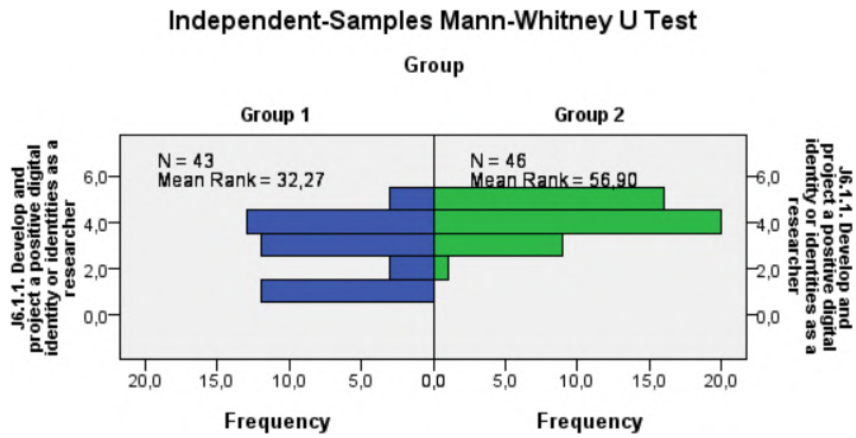
The comparisons drawn (figures 5-8) speak in favor of the application of the developed methodology for the competence enhancement of educational programs or, as in this case, the development of the selective module "Digital technologies in modern scientific research: learning Open Science". At the same time, based on the results of additional in-depth interviews with the students of the experimental group, the need was detected (corresponds to the results of the expert evaluation (section 4.2 of the study) and similar training practices for using Open Science [8]) to develop modules for expanding skills in digitalization of conducting scientific research This can be implemented by enhancing (competence and technology-wise) courses available in the training program for Ph.D. students or introducing into the educational program a scientific research practicum similar to the programs of European universities, within the framework of which Ph.D. students join real projects implemented in universities.

However, taking into account the sufficient level of digital skills and capabilities of students of this




| | |
|---|---|
| Total N | 89 |
| Mann-Whitney U | 1 570,000 |
| Wilcoxon W | 2 651,000 |
| Test Statistic | 1 570,000 |
| Standard Error | 117,104 |
| Standardized Test Statistic | 4,961 |
| Asymptotic Sig. (2-sided test) | ,000 |

**Figure 7:** The self-assessment results of the J2.2.3 Jisc Researcher component formation of the Ph.D. students experimental and control groups.




| | |
|---|---|
| Total N | 89 |
| Mann-Whitney U | 1 536,500 |
| Wilcoxon W | 2 617,500 |
| Test Statistic | 1 536,500 |
| Standard Error | 117,062 |
| Standardized Test Statistic | 4,677 |
| Asymptotic Sig. (2-sided test) | ,000 |

**Figure 8:** The self-assessment results of the J6.1.1 Jisc Researcher component formation of the Ph.D. students experimental and control groups.

higher education institution, which is confirmed by previous studies [15], the prospects for further research include the development of horizontal scientific connections, the organization of projects and research, including international ones. This will help the true inclusion of future researchers in the European Research Area for the effective realization of Open Science principles.

## 5. Conclusions

Recognition of open science postulates promotes new visions, principles and methods of conducting research and implementing innovations at universities, consequently bringing the need of the high-quality training of future researchers to the foreground.

Analysis of research results and practical cases is basis for determining some key benefits of studying open science for Ph.D. students:

- *access to knowledge*: open science promotes the unrestricted sharing of research findings, datasets, and methodologies;
- *collaboration and networking opportunities*: open science encourages collaboration among researchers from different institutions and disciplines;
- *enhanced reproducibility and transparency*: Ph.D. students can ensure the reproducibility of their own research and contribute to the credibility of the scientific community as a whole; transparent research practices also allow for better peer review, and validation of findings, which strengthens the overall scientific rigor;

- *increased visibility and impact*: publishing research openly can significantly enhance its read, and cited by other researchers, attract potential collaborators and funding opportunities, and ultimately increase the impact of their research

Among the ways to ensure realization of the specified benefits is the learning model orientation towards cultivation of digital capabilities of future researchers and inclusion of digital competence in the curriculum.

Following the analysis of the source database with the subsequent expert evaluation via engaging international experts, we:

- substantiated the expediency of applying descriptors Jisc Researcher to determine the requirements to digital competence of the future researchers;
- determined the need (the practice of implementing open science is impossible without the formation of digital skills) for inclusion of digital competencies of researchers in the curricula for Ph.D. students and developed the training module “Digital technologies in modern scientific research: learning Open Science”;
- completed experimental examination of effectiveness of this module application (as elective) when training PhD students at Borys Grinchenko Kyiv Metropolitan University.

Results of self-assessment of the level of formation of the digital competence of researchers among Ph.D. students who studied under the module “Digital technologies in modern scientific research: learning Open Science” confirm the effectiveness of the education solution proposed by the authors while isolating certain issues regarding modelling or reproducing of open science practices in the training process of Ph.D. students. The latter paves way for determining the areas for further studies, which include:

- expanding horizontal connections between universities and project teams for the Ph.D. students to gain the experience of scientific research digitalization and creating the environment for them to form digital competencies regarding digital proficiency, productivity, identity and wellbeing;
- management of changes on the level of monitoring and updating curricula as well as development of digital ecosystem of a university, while also ensuring that the Ph.D. students are trained to be digital scholars;
- exploration of innovations, in particular those linked to the development of artificial intelligence in combination with adhering to the principles of academic integrity and ethics of conducting scientific research.

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