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TRENDS OF THE LATEST PHASE OF SCIENCE AND SCIENTIFIC RESEARCH DEVELOPMENT IN UKRAINE

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Methods. The results are obtained through the use of methods of analysis – when studying basic theoretical, methodological approaches to the emergence of science and understanding of it as a concept; abstraction – in determining the essential features of scientific research; generalization – in determining the European trends in the development of e-science and the latest achievements of Ukraine in this direction.

Results. It is proved that the rapid development of scientific processes, modernization of science as a concept in general, the ability to predict and analyse events lay the groundwork for further development of organizational processes of scientific research. It is pointed out that in the process of evolutionary transformations, the views on the origin of science and approaches to understanding this concept have changed. It is emphasized that the development of science is in direct relationship to the development of scientific research, whereas socio-economic, political, and cultural development is impossible without their active implementation. It is substantiated that in the course of historical development, there takes place the transformation of a traditional society into an information society, in which the information infrastructure is formed. Under the influence of a rapid increase in the amount of information, its socio-economic significance, drastic changes are taking place, in particular in scientific and scientific-practical activities. Science acquires new significance and is considered in its dynamics, movement, and development. The latest phase of science development has been supplemented and characterized.

It is noted that the issues of e-science and Ukrainian e-infrastructures remain relevant and unresolved, as the overall problem is the lack of a unified state policy in Ukraine regarding e-science and Ukrainian e-infrastructures. The necessity of specifying the newest phase of science development is stressed, as well as systematization and structuring of the basic European trends and achievements of Ukraine in developing e-science and e-infrastructures.

Novelty. The basic approaches and views on the emergence of science, which are reflected in modern scientific publications, have been improved. A structural management system of EOSC is offered taking into account achievements of domestic scientists and researchers.

Practical value. The authors systematize the European trends in the development of e-science and the latest achievements of Ukraine in this direction. E-infrastructures in Ukraine are visualized according to the Concept of development of Ukrainian research infrastructures.

Keywords: science, scientific research, e-science, Ukrainian e-infrastructures, EOSC management system, digital science.

Statement of problem. Today, the world is steadily moving towards a society in which information, knowledge, and their application are gaining strategic importance and are the basis of social and economic development. There are cardinal changes concerning the role of science, research studies and their implementation in practical activity. The constant scientific information gain, its accumulation and updating have created certain challenges and put forward new requirements for the technology for organizing the process of scientific research, which is

the basis of any science [10].

Science is a very popular concept in the modern world. The rapid development of scientific processes, modernization of science as a concept in general, the ability to predict and analyse events creates the preconditions for further development of organizational processes of scientific research. Therefore, the development of science is directly dependent on the development of scientific research. And social and economic, political, cultural development is impossible without active implementation of scientific research [9, p.9].

Analysis of recent papers. Works by modern researchers study the following aspects of the problem: public administration in the field of science, namely the development of e-science and e-infrastructures (A. Yu. Vasylenko) [1, p.4; 2, p.5; 7]; taking into account national interests in the process of integration of Ukrainian science into the world research space (M. S. Kelman, V. S. Lozovyi) [6; 8]; peculiarities of scientific research in the modern world and information as a strategic resource for organizing a research process (O. S. Mantur-Chubata, Yu. A. Dubilei, A. V. Mikhalets; G. Muravytska) [9, 10]; development of e-infrastructures for research and innovations, digital e-science services (V. Nochvai; N. P. Pasmor) [11; 12], Ukrainian research e-infrastructures as a tool for integrating young scientists into the international scientific space (S. V. Tarnavska, H. V. Sereda) [14], (O. S. Chmyr) [15], achievements of Ukraine in the field of science digitalization (A. Yu. Shevchenko) [16, 17].

The issues of e-science and Ukrainian e-infrastructures remain relevant and unresolved, because the overall problem is the lack of a unified state policy in Ukraine regarding e-science and Ukrainian e-infrastructures.

Aim of the paper. The aim of the paper is to specify the concepts of the latest phase of science development, as well as to systematize and structure major European trends and achievements of Ukraine in the development of e-science and e-infrastructures.

Materials and methods. Science is a special form of cognition, which is performed by special groups of people with the help of special means; there is also an opinion that science is social in its origin, development and application [9, p.9].

In the process of evolutionary transformations, views on the origin of science and approaches to understanding this concept have changed. Figure 1 presents the main approaches and views on the emergence of science, which are reflected in modern scientific publications.

Throughout history, there has occurred transformation of a traditional society into an information society, in which information is gradually transformed into the main resource category. An information infrastructure is formed in the society, which includes the normative-legal bases of information activity, the system of search, processing and storage of scientific and technical information, analytical and think tanks, etc. The share of the population working in the information sphere, as well as the number of computer and Internet users is increasing. Under the influence of the rapid increase in the amount of information, its socio-economic significance, fundamental changes are taking place in all spheres of human life, in particular in scientific and scientific-practical activities. Science acquires a new meaning, it is considered in dynamics, movement, and development. These changes transform human life qualitatively and bring forth problems of adaptation to the information civilization [10].

For Horizon 2020 Programme, DG DG Connect prepared a concept paper which summarizes the term of digital science, which combines e-science, open science and science 2.0 as a means of using e-infrastructures by society through new tools for intensive computing, processing and storing of data, methods of openness of studies and new ways of mass collaboration in research studies which fundamentally change a technique for conducting them.

European trends in the development of e-science and the latest achievements of Ukraine in this direction are presented in Table 1. According to modern researchers, e-science is a process of conducting scientific research using the power of e-infrastructures [2, p.5].

Open science is aimed at transforming scientific activity with the help of ICT, networks and mass media in order to make research more open, global, collaborative, creative and closer to society [17, p.35].

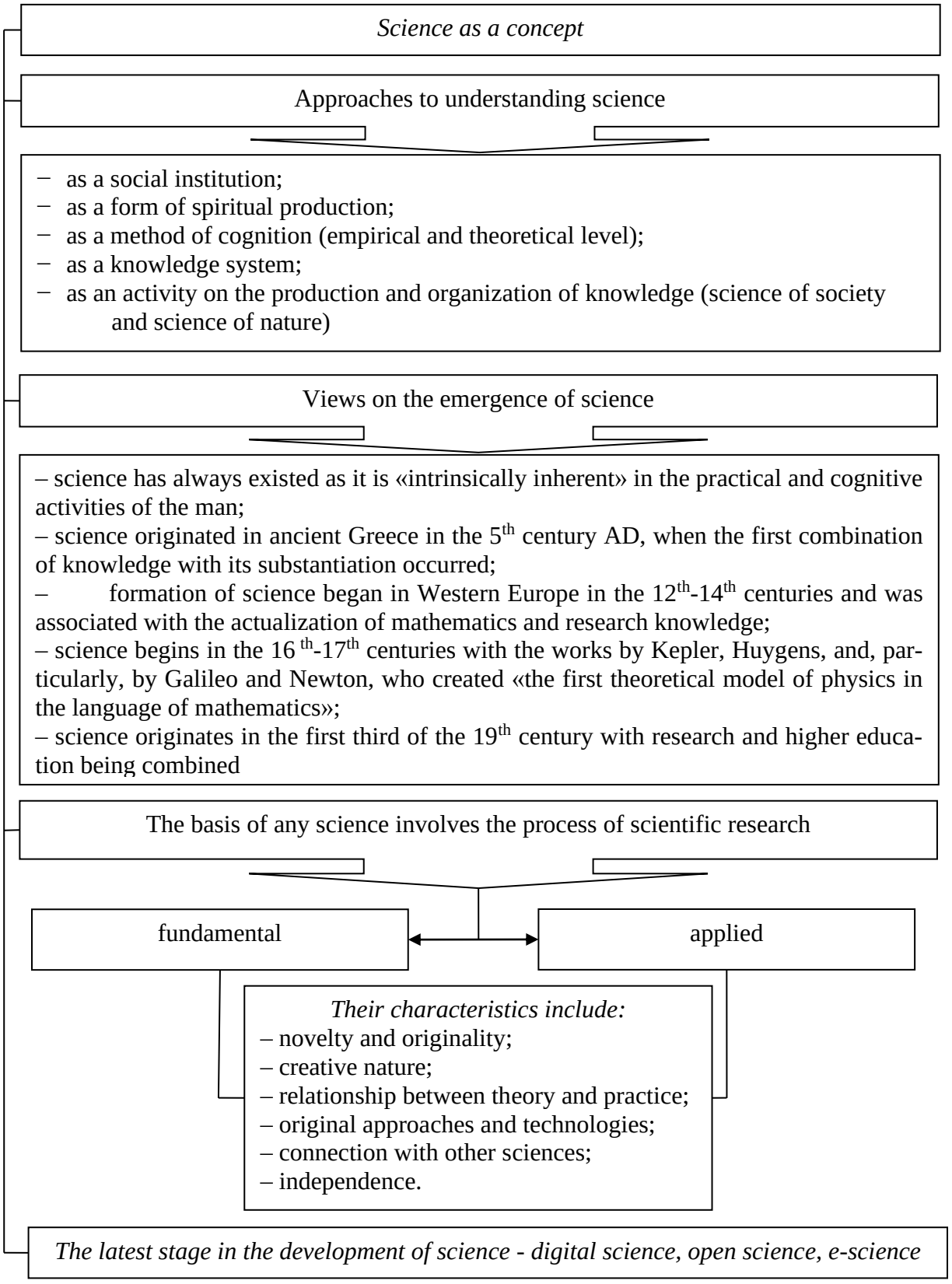

Figure 1 – Approaches to understanding science and views on its origin throughout history
Developed by the authors on the basis of [6, p.149; 9, p.10] and their own observations

Table 1

European trends in the development of e-science and the latest achievements of Ukraine in this direction

Year	European trends
1	2
2013	For Horizon 2020 Programme, DG Connect prepared a concept paper Digital Science in Horizon 2020, which summarized the term of digital science, which combined e-science, open science and science 2.0 as a means of using e-infrastructures by society through new tools for intensive computing, processing and storing of data, methods of openness of studies and new ways of mass collaboration in research studies which fundamentally change a technique for conducting them.
2014	A survey was conducted on the use of science 2.0, the problem of existing support and finding a new name for these tools and methods of discovery and collaboration in research. As a result, instead of digital science, the term of Open Science appeared, as well as research works which tried to find differences in the use of the terms Digital Science, Open Science and Open Digital Science in the world.
2015	Announcing the new initiative, EU Commissioner Moedas added two main tools to the term Open Science: the European Open Science Cloud and the integrity of data and research.
February, 2016	Draft European Open Science Agenda was adopted on the development of five policy directions at the European and national levels
At the end of the year 2016	At the Amsterdam conference, a call was adopted for the implementation of this Agenda, which consisted of 12 items that should remove barriers to open science, develop the necessary research infrastructures, create incentives for open science, and make the mainstream of the policy promotion, stimulation and introduction of open science for research and society. In parallel with the development of a new Open Science policy, a policy is designed for the development of e-infrastructures and an infrastructure management system, as well as a data and knowledge management system – Open Science Commons. All these directions are trying to address the main question: how to create a digital European research space and to ensure its governance system such as the modern Internet to the best advantage, and from what sources to provide finance for its infrastructure, which should be open and accessible, at least for 1.7 million European researchers, as well as its use for industry and government.
2016	Under the Digital Single Market Strategy, the European Cloud Initiative was proposed as part of a package of proposals for the digitalisation of industry. The initiative proposes to create a single, data-driven e-infrastructure for research and economics in Europe. The cloud initiative consists of two parts: the European Open Science Cloud, which is mainly provided by a public partnership, and the European data infrastructure, which are to be based on Eflops supercomputers, which are built on public-private partnerships. The European Open Science Cloud is being developed by creating a federation of existing European e-Infrastructures and European Research Infrastructures, which can provide digital remote services. The federation must meet the needs of intensive data management as well as long-tail data. The European data infrastructure should provide intensive data processing not only for 1.7 million researchers, but also for 70 million European professionals in various areas of the digital market.

Continuation of table 1

1	2
	Achievements of Ukraine
2013	The Comprehensive Target Research Program of the National Academy of Sciences of Ukraine «Grid Infrastructure and Grid Technologies for Scientific and Applied Applications» was launched, within which it is planned to develop cloud technologies, create a unified cloud of the Ukrainian National Grid (UNG) and to ensure its systematic integration into the European infrastructure, including with the PRACE Supercomputing Network, the EUDAT repository, the combined European cloud for research and innovation.
January, 2018	The Cabinet of Ministers of Ukraine approved the long-awaited Concept of Digital Economy and Society and measures for its implementation, which is based on the Digital Agenda of Ukraine, on the basis of the agenda adopted in 2016 at the Amsterdam conference, which consisted of 12 items. Within the framework of harmonization with European scientific initiatives, it is proposed to participate in the development of the European Open Science Cloud and the European data infrastructure, whereas paragraph 23 of the Measures indicates the need to develop draft act of the Cabinet of Ministers of Ukraine on participation in the European Cloud Initiative, which consists of these two infrastructures, in the first quarter of 2018.
March, 2018	The Board of the Ministry of Education and Science finally approves the Roadmap for Ukraine's integration into the European Research Area (ERA-UA), where priority 5b «Open Science and Digital Innovation» includes, in particular, «Participation in the building of the European Open Science Cloud» and «building the National Hub" EOSC on the basis of «FAIR principles», which is a «strategic document for long-term planning and development of further actions».
2019	«Program of Informational Support of the National Academy of Sciences of Ukraine for 2020–2024» is adopted. At the time of its adoption, the UNG includes 14 resource centres and 6 virtual organizations in various research directions, which belong to the EGI Foundation (EGI.eu) – a joint federation of national initiatives, as well as 10 clusters serving the institutes of the NAS of Ukraine and universities.
July, 2020	The draft order of the Cabinet of Ministers of Ukraine was approved «On approval of the Concept of implementation of the state policy of development of Ukrainian e-infrastructures until 2023 and approval of the Plan of measures for its implementation»
April, 2021	The order of the Cabinet of Ministers of Ukraine approved the «Concept of the State target programme for development of research infrastructures in Ukraine for the period up to 2026».

Systematized by the authors based on [5; 7; 13; 16; 17].

The associate participation of Ukraine in the EU Framework Program for Research and Innovation «Horizon 2020» is important for the development of domestic science. Priorities for concentrating finance for this program include: information and communication technologies; nanotechnology; most advanced materials; biotechnology; space industry. This makes it possible to significantly increase the level of involvement of Ukrainian scientists in joint European research, as well as contribute to the creation of structural changes in the scientific and innovative sphere of Ukraine [8].

The Roadmap for Ukraine's integration into the ERA-UA includes, in particular, «Participation in building of the European Open Science Cloud» and «Construction of the EOSC National Hub» based on FAIR principles».

EOSC is a virtual environment with open and continuous services for storage, management, analysis and reuse of research data, regardless of borders and scientific disciplines [5].

It is created by combining existing and new infrastructures of scientific data by disci-

plines and countries. The cloud is a decentralized system based on collaboration and coordination and provides a combined use of existing digital infrastructures, which implement the FAIR principles for exchanging data and sharing software at all stages of the research lifecycle. The formation of EOSC takes place from the position of a quick start, namely the interoperability of existing e-infrastructures and research infrastructures, which have their own e-infrastructures. The development of the European data infrastructure should become the basis for high-performance, high-level computing and for the EOSC services that already exist: EGI, EUDAT, Open AIRE, Indigo Data Cloud, Helix Nebula, PRACE, GEANT.

E-infrastructures are either a digital tool for a scientist's work (for example, computing power where new scientific results are obtained) or a digital tool, which facilitates its work (for example, power to store or access research data). It will be appropriate to compare them with a microscope and a library of traditional science, respectively [2, p.5].

Table 2 shows the views of domestic researchers on the concept of «e-infrastructure».

Table 2

Domestic researchers' views on the category of «e-infrastructure»

Author	Characteristics
A. Yu. Vasylenko [1, p.4]	An e-infrastructure is a separate type of digital infrastructures, whose main task is to obtain, store, manage and integrate research data, their in-depth analysis, visualization, creation of models based on them, other types of processing of scientific information and data, as well as services provided through the use of the Internet and, as a consequence, can be carried out without being limited to one institution
V. Nochvai [11]	An e-infrastructure is a digital infrastructure for research, a unique infrastructure based on information technology, which provides users with easy and secure web access to resources, tools, methods and means needed for research, and thus facilitates the transformation of research studies into even more complex, of global and interdisciplinary ones.

Generalized by the authors on the basis of [1, 11].

In the draft resolution of the Cabinet of Ministers of Ukrainian filed to the Ministry of Economic Development and Trade of Ukraine, the working group of the National Academy of Sciences of Ukraine proposed to implement the minimum viable EOSC system in Ukraine – EOSC National Hub based on existing e-infrastructures and the model of «integrated EGI cloud». It is proposed [16]:

− to upgrade the equipment at the UNG resource centres and deploy the combined cloud infrastructure in two regional (Kharkiv and Lviv) resource centres as well as the Basic Coordination Centre (Kyiv), which will be included in the general resource pool of the National Hub;

− to certify it in EOSC Hub and EGI;

− to ensure joint participation in the centres of competence of EOSC Hub research infrastructures for access to thematic services, as well as in the relevant digital innovation hubs of EOSC Hub along with business;

− to upgrade the equipment and control system with UARNet fibre-optic channels used by UNG to 300 Gb/s;

− to work out the mechanism of using EUDAT data exchange and storage services for the network of centres for collective use of equipment;

− to ensure the interoperability of the National Hub with distributed repositories for data storage, software and publications within OpenAire;

− to introduce training for the profession of «data steward» to reduce the «cultural» gap between scientists and infrastructure providers (according to the European Commission, it is necessary to have 1 data steward in each scientific discipline for 20 scientists);

− to scale this system to 9 more resource centres, which are certified in EGI as grid-sites, and, therefore, have collaboration experience and relevant experts.

Representation in EOSC, creation and provision of a model of sustainable financing activities, management of common resources and subsequent connection and deployment of other research and e-infrastructures require the formation of an «easy» coordination system, such as a three-level one (Figure 2), as in EOSC. The issue of disclosure of data before the adoption of the «Open Science» agenda at the legislative level can be solved at an individual level and on a voluntary basis.

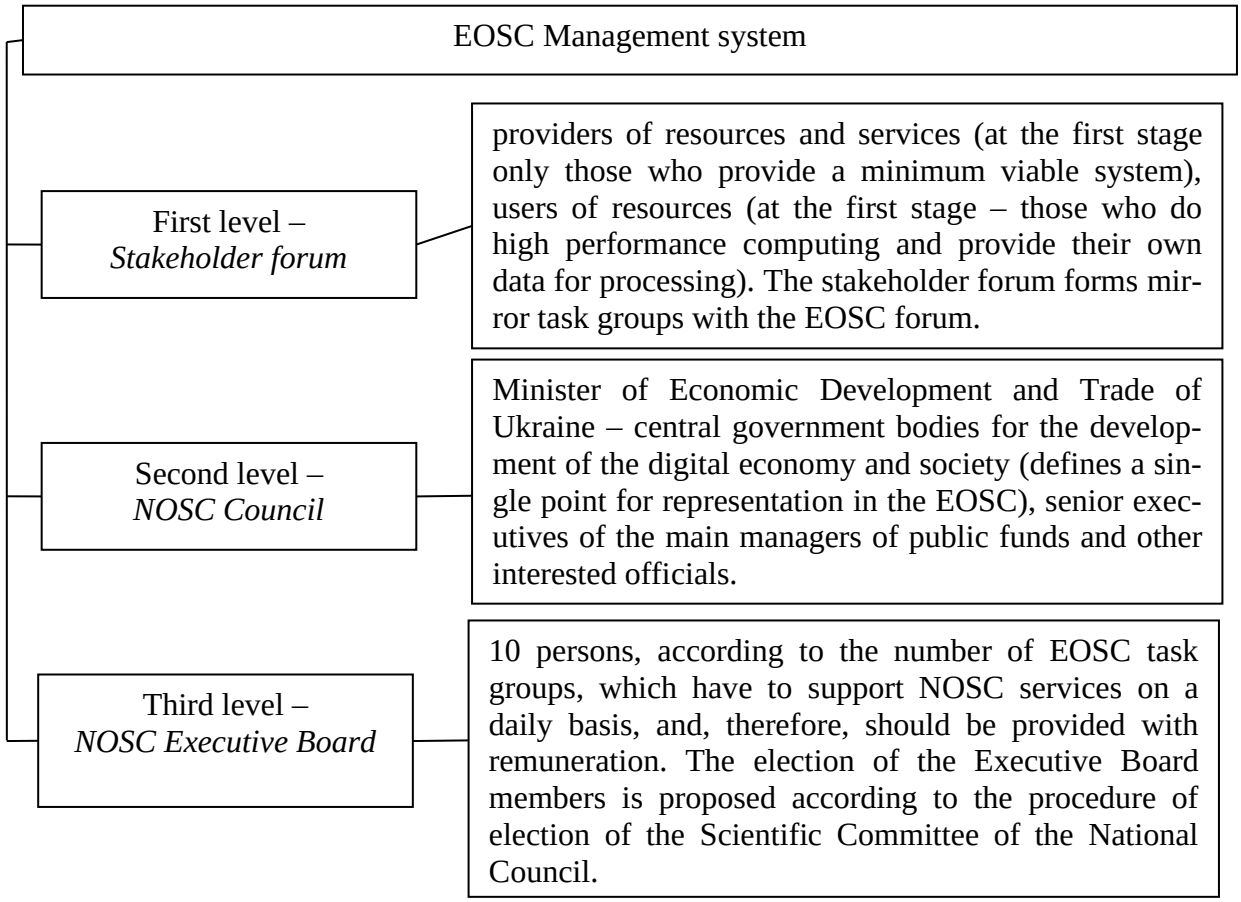

Figure 2 – EOSC Management system
Developed by the authors on the basis of [16].

Open science is good for the world in general. It helps to bridge the cultural and technological gap between countries and regions. Underdeveloped countries receive much more from the implementation of Open Science priorities. EOSC and NOSC do not provide for their use for national defence capability, i.e. for data protected for reasons of national security. Science in Ukraine is already in real isolation in the world due to low funding of the industry and its logistics, and EOSC has to solve the problem of isolation in terms of access to data and access to international value chains [16].

The research infrastructure comprises equipment and devices for conducting studies in a certain scientific area.

Until recently, digital research infrastructures (or e-infrastructures), which include computing resources for processing and receiving new data, separated the introduction of data storage resources and data transmission channels to any part of the world.

Modern trends in combining large research infrastructures with e-infrastructures for storage, processing and remote access to experimental data result in the fact that researchers disregard this infrastructure and the data itself becomes an infrastructure for them. Data becomes available not only for people, but also for machines, computers, software platforms if it is open for use and meets certain standards, including the FAIR.

The FAIR is principles with which data and metadata (data description) should comply

in order to make it easy to find available data (Findable), provide access to it (Accessible), be interoperable, i.e. compatible for general use (Interoperable), and making them reusable, i.e. have licenses available for this (Reusable).

The infrastructure of such open data is EOSC – the European Open Science Cloud. Cloud is a technology used mainly for joint data processing tools. This tool is not exceptionally European – the first similar data infrastructure was the infrastructure of the US National Institutes of Health. The Australian and African open science clouds are now being developed on the model of the EOSC. Japan has decided to add its national data infrastructure to the European one.

By the way, EOSC is part of three different EU policies – the Digital Single Market Strategy and the European Cloud Initiative, the European Research Area, and the Digitalisation of Industry. In addition, the EOSC concept covers not only the technological infrastructure, but is also part of Open Science in Europe – from infrastructures and data to services and skills which should contribute to the creation of a competitive economy of data and knowledge in the global world.

In general, the EOSC policy now focuses on four elements, which are important for interoperability – data, skills, services and infrastructure.

It is worth noting that any research infrastructure, particularly a global one, arises at the request of scientists, governments and communities looking for responses to new challenges. This question was first put on the agenda by researchers engaged in high-energy physics and the search for the Higgs boson. For these tasks, not only the unique Large Hadron Collider (LHC) was built, but also a grid infrastructure was created for modelling experiments, data processing, which involved scientists, IT specialists, innovators, businesses and citizens from almost all countries.

After Silicon Valley – as an innovative local cluster of the of international standard – the CERN became an example of an innovative breakthrough based on the global digitalization of scientific processes and the creation of a allocated global open innovation ecosystem, which provided fast data interchange and its processing through open source, global cooperation, involvement of IT specialists and also enabled the scientific discovery of the international standard. And due to the open exchange of research results, obstacles and delays in the way of their verification were eliminated. Next time, the Open Science principles were tested in practice during an Ebola outbreak. Then about half a thousand scientists from all over the world discovered raw data from their research for exchange and use [5].

The Ministry of Education and Science got approval for the final draft of the Concept for the Development of Research Infrastructures in Ukraine Based on Communications Technology. The document, in particular, provides for the creation of a platform for the all-Ukrainian digital scientific space and the development of a national plan for open science [3].

Moreover, the project will promote the emergence of new Ukrainian research e-infrastructures. Therefore, scientists, engineers, inventors and entrepreneurs from Ukraine will have access to digital services for storage, management, analysis and reuse of open scientific data. In particular, it is referred to carrying out super complicated calculations with application of cloud technologies.

According to the Concept, Ukrainian research e-infrastructures should include the following (Figure 3) [3].

Today, the national policy of digital services of open science emphasises the need to more effectively use the world's largest international scientometric and bibliometric search systems and platforms Google Scholar, Web of Science, Scopus in science. In accordance with these databases, the most objective scientometric Profile of a scientist, the Hirsch Index, is formed, the ranking of citation, relevance, and activity of the use of scientific content is performed, that is, the integration of national branch scientific achievements and discoveries into the united European space of scientific research takes place.

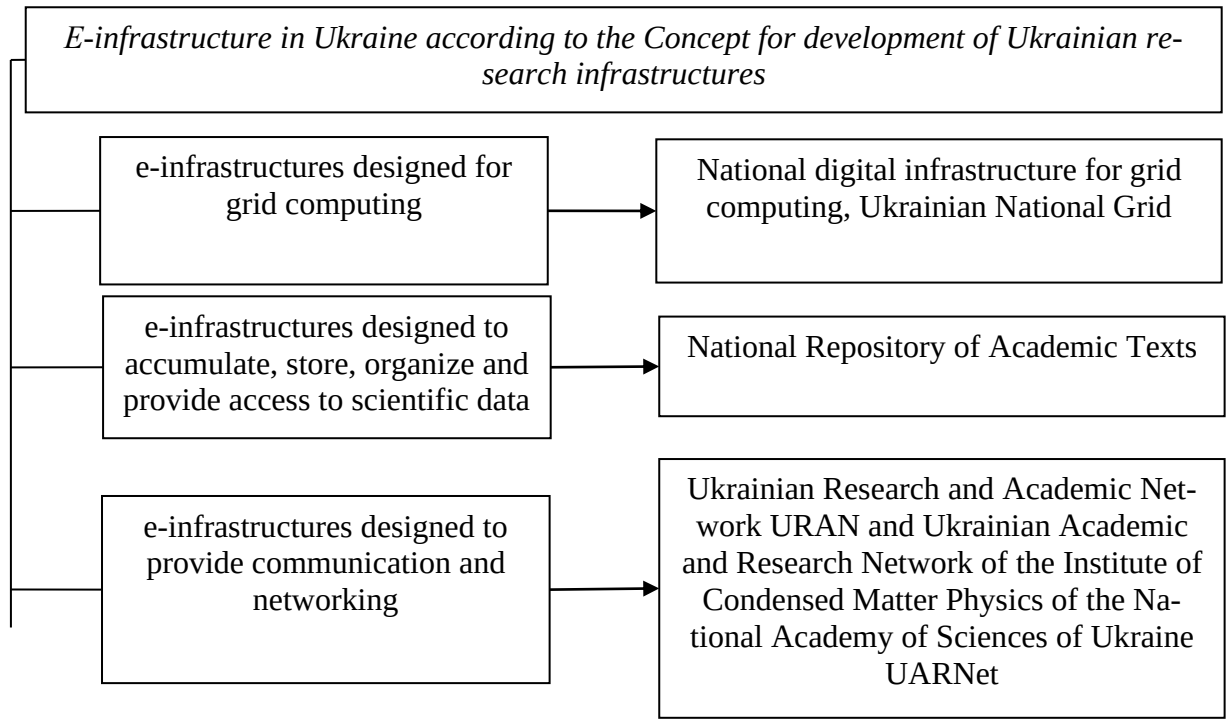

Figure 3 – E-infrastructure in Ukraine according to the Concept for development of Ukrainian research infrastructures
Developed by the authors on the basis of [2, p.5; 14, p.119].

In view of this, in September 2018, the Ministry of Education and Science of Ukraine subscribed to and increased the access of higher education institutions to the international scientometric platforms Scopus and Web of Science, due to which Ukrainian scientists began to use these databases five times more often. Resolution of the Cabinet of Ministers of Ukraine No. 541 of 19.07.2017 requires that the National Repository of Academic Texts (NRAT) should be formed as a national distributed electronic database in which academic texts are accumulated, stored and systematized [15].

The primary goal is to promote the development of educational, scientific, scientific-technical and innovative activities by improving access to academic texts and promoting academic integrity.

Structurally and functionally, the National Repository of Academic Texts consists of a central repository (supported by the NRAT Manager) and local repositories (supported by institutional participants (higher education institutions, research institutions, scientific publishers, libraries)).

This year, the text operation of the official web portal of the NRAT server has been launched, which provides work with the register of academic texts from the Research & Development and Dissertation Fund.

Updated information on the basic directions of scientific, educational and innovative activities is presented in key rubrics: useful information (for scientists, educators, innovators), defence of a doctoral thesis, scientific dedicated periodicals of Ukraine, thematic collections of academic texts, scientific events, scientific metrics, scientific review, academic integrity, NRAT content (statistics).

Certainly, the introduction of Digital science and concern for the future of science make social and communication structures, scientific and library institutions, information centres, and universities transform and diversify the forms of scientific and informational, scientometric, and bibliometric activities.

Therefore, the Development Strategy for the of librarianship «Qualitative changes in libraries to ensure sustainable development of Ukraine» for the period up to 2025 provides comprehensive assistance for «development of open access to scientific information by increasing the number of electronic journals, open electronic archives-repositories» [4].

The objective of the Strategy corresponds to the IFLA Global Vision for libraries and is to ensure equal and free access to information and knowledge, to promote digital science and innovation; integration of innovation policy into the united European Research Area and others [12].

Conclusions. Thus, the trends of the latest stage of science in Ukraine are aimed at development of Ukrainian e-infrastructures and introduction of state policy of open science, which will contribute to the actual involvement of Ukraine in the ERS and correspond to the global trends.

Modern development of the latest information technologies has resulted in the emergence of electronic resources and services. Free orientation in information flows, provided the ability to find, process, store and apply information using computers, provides the opportunity to conduct modern research of any profile quickly, efficiently and using the most relevant information. Given that one of the functional purposes of e-infrastructures is processing of the big data, access to this data should be as open as possible and therefore further research should be conducted considering the experience in Open Science policy implementation, in particular, in the ERS countries.

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ТЕНДЕНЦІЇ НОВІТНЬОГО ЕТАПУ РОЗВИТКУ НАУКИ ТА НАУКОВИХ ДОСЛІДЖЕНЬ В УКРАЇНІ

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Методологія дослідження. Результати отримані за рахунок застосування методів: аналізу – при дослідженні основних теоретичних, методичних підходів щодо виникнення та розуміння науки як поняття; абстрагування – при визначені суттєвих ознак наукових досліджень; узагальнення – при визначенні європейських трендів розвитку е-науки та останніх досягнень України в цьому напрямку.

Результати. Досліджено, що стрімкий розвиток наукових процесів, модернізація науки як поняття у цілому, можливість прогнозувати та аналізувати події створює передумови подальшого розвитку організаційних процесів проведення наукових досліджень. Охарактеризовано, що в процесі еволюційних перетворень змінювались погляди на виникнення науки, підходи до розуміння цього поняття. Акцентовано, що розвиток науки перебуває в безпосередній залежності від розвитку наукових досліджень. А соціально-економічний, політичний, культурний розвиток неможливий без активного впровадження їхніх резудьтатів. Обґрунтовано, що у ході історичного розвитку відбувається трансформація традиційного суспільства в суспільство інформаційне, в якому формується інформаційна інфраструктура. А під впливом швидкого збільшення обсягів інформації, її соціально-економічного значення відбуваються кардинальні зміни, зокрема в науковій та науково-практичній діяльності. Наука набуває нового значення і розглядається у динаміці, русі, розвитку. Доповнено та охарактеризовано новітній етап розвитку науки.

Відзначено, що питання є-науки та українських е-інфраструктур залишаються актуальними та не розв’язаними, оскільки загальною проблемою є відсутність в Україні єдиної визначеної державної політики стосовно є-науки та українських е-інфраструктур. Аргументовано необхідність конкретизації понять новітнього етапу розвитку науки, а також систематизація та структурування основних європейських трендів та досягнень України в розвитку е-науки та е-інфраструктур.

Новизна. Удосконалено основні підходи та погляди на виникнення науки, які знайшли своє відображення у сучасних наукових публікаціях. Запропоновано з урахуванням надбань вітчизняних науковців та дослідників структурна система управління EOSC.

Практична значущість. Систематизовано автором європейські тренди розвитку є-науки та останні досягнення України в цьому напрямку. Наочно представлені є-інфраструктури в Україні згідно Концепції розвитку українських дослідницьких інфраструктур.

Ключові слова: наука, наукові дослідження, е-наука, українські е-інфраструктури система управління EOSC, цифрова наука.

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