Chapter

Multiple Facets of Open: A Different View on Open Science

Anne-Katharina Weilenmann

Abstract

Open – a well-known word, but with multiple facets: open, open-minded… In the publishing industry, "open" and "openness" describe a movement which has been setting the scene over the last decades, however the opening of science is not a new momentum. Writing down our thoughts and ideas is regarded as a first indicator of opening the human mind. To cope with information overload, paper slips were used as a favourite device - a precursor to modern index cards and card catalogs. The internet opens the doors to disseminate and share knowledge in a fast and easy way. Now, science is emerging in cyberspace and an innovative level of science is shaping, the evolution of Cyberscience. Science is shifting into the open, Open Science is developing as an additional form of doing research. These diverse perspectives are part of a colorful picture of an evolving scientific landscape, which will rise awareness of changing work behaviors.

Keywords: Knowledge sharing, History of Open Science, History of Open Access, Open Data, Open Educational Resources (OER)

1. Introduction

Our world is a complex (eco)system, consisting of tiny structures, known and unknown secrets. Great creativity, genius ideas, surprising thoughts: these are only a few aspects of the creation of new knowledge, which allows to generate extraordinary findings and to disclose these secrets. It is a long and sophisticated process, sometimes an exhausting way to attain scientific and trusted results. Scientists carry a lot of responsibility, they are seen as experts „engaged entirely in a cognitive process, whose observation of phenomena and expertise in understanding what is observed leads to new knowledge." [1]. Observation of phenomena may be an important part of the whole scientific action and output; scientists may observe the entire environment and must have a critical view of the daily life. A lot of elements determine and influence the scientific process such as: thinking out of the box, curiosity, inspiration, the desire to investigate complex facts, great enthusiasm, staying power. Heinze focuses on scientific creativity and argues that essential elements of creative ideas and artifacts are usefulness and relevance [2].

1.1 The system of science

Each scientist has probably his own strategy to reach his goals. The aforementioned abstract expressions show the complexity of the scientific system and raise the question of how we can describe this. What does «science» mean, is there any definition for this umbrella term? Kuhn [3] states: "If science is the constellation of facts, theories, and methods collected in current texts, then scientists are the men who, successfully or not, have striven to contribute one or another element to that particular constellation." "At the same time, he doubts whether very much can depend upon a definition of «science» [3]. He highlights the diverse facets and broad meaning of «science», which is a difficult task, and shows its lack of transparency. The lack of transparency fosters the notion of the ivory tower where an elite works on scientific outputs, not interested in communicating these to society [4, 5]; the scientist is „the mad scientist reduced to a brain in a jar." [1].

To get out of this ivory tower, the scientific community has to demonstrate its experiments, developments, findings to a wider public, in a comprehensible form. Projects like PopSci [6, 7], the YES!-project [8], and initiatives enabling access to academic collections for laymen [9] are indicative of a better and clearer communication of science.

1.2 Citizen Science

Another approach is the engagement of society in scientific processes; this is the aim of «Citizen Science». Its origins go back to two different sources: on the one hand, research goals are determined by scientists and the public [10]; on the other hand, Bonney [11] refers to plenty of projects in avian research, in which citizens play an essential role as researchers. Hecker et al. [12] give a good overview of variations and distinct definitions concerning Citizen Science, especially mentioning the terminology set by governments and policymakers. They argue that participation serves as a basis for Citizen Science, that involving citizens in research is a key factor for this development. The whole process of creating new knowledge, from idea generation and planning to conducting the research and disseminating outputs, is now opened for all. Thus, Citizen Science is an integral aspect of the Open Access and Open Science movements.

Another viewpoint to consider is inclusivity in an open scientific landscape. The Association of College and Research Libraries (ACRL) outlines three elements to be addressed: people, content, and systems [13].

1.3 Open Science

The objectives of making science more visible and to communicate its findings fast and expediently open the door to a new movement, «Open Science». The driving factor of this initiative is openness to everyone. «Open» as a very broad expression illustrates the multiple connotations that go into this direction, but a formal definition of Open Science is lacking [14]. The Organisation for Economic Co-operation and Development (OECD) states that „... the term refers to efforts by researchers, governments, research funding agencies or the scientific community itself to make the primary outputs of publicly funded research results – publications and the research data – publicly accessible in digital format with no or minimal restriction as a means for accelerating research." [14].

Open Science is more than seamless access; Open Science is an attitude, a behavior; personal beliefs and values are predominant. But researchers face high barriers in their commitment to Open Science; neither using Social Media [15], nor sharing data [16, 17] to communicate latest findings are part of their daily working routines. Even early career researchers (ECRs) are reluctant to adopt new behaviors and to try Open Science tools [18].

Nielsen [19] sees Open Science not only as a «simple» movement, he speaks of a revolution, whereas Bartling et al. [20] argue that Open Science has the power to effect a profound metamorphosis and will change scientific communication and collaboration within the next 20 years more than has been done in the past 200 years (a detailed listing of different pillars of Open Science is explained in section 3).

2. Historical traces of Open Science

The difficulty to find a short and clear description of Open Science can be compared to that of tracing back the roots of this movement. There are many subtle indications of the presence of open knowledge. I will focus on some significant landmarks in the past which symbolize the current discourse of today.

2.1 Open Science – first signs

According to Borgman [21], the philosophy of Open Science goes back to Saint Augustine in the fourth and fifth centuries. Willinsky [22] and Stracke [23] see the beginnings of Open Science in the Middle Ages, referring to David [24] who analyses its history dating to the late sixteenth and early seventeenth centuries. If we take a closer look, we can dive deeper and go back to Antisthenes (444? BC, after 371 BC), a follower of Socrates (469 BC, 399 BC), who argued: „You would have done better to commit them to your mind than to your papers." [25]. The brain is a powerful instrument enabling us to store everything. The concept of memorizing by writing down essential thoughts leads to an underestimation of the brain - the brain would be «useless» if all of knowledge could be documented. This radical change can be seen as an initial evidence of openness: ideas are released from one's own closed mind and are opened up to everyone.

2.2 The Open Science revolution

As a consequence of this evolution, a scientific revolution is slightly shaping the future. Nielsen [19] describes the enthusiasm and eagerness of early discoverers to announce their innovations, but there was a little problem: how could they claim credit? Thus, for example, Galileo Galilei (1564 – 1642) had an unconventional plan: he sent his findings in the form of an anagram to the scientific community, so researchers were informed but did not know any details. Concerning openness, this means that scientists wished to spread their inventions, but at the same time they were reluctant to do so, because they were afraid of plagiarism. This behavior led to a new form of closure and indicated only a partial opening.

The vibrant time when Henry Oldenburg founded the world's first scientific journal in 1665, the Philosophical Transactions of the Royal Society, marks for Nielsen [19] the first Open Science revolution. Oldenburg asked scientists to disseminate their ground-breaking findings in a new medium, with the aim that communicating innovations would enhance and accelerate science [19]. But at the beginning, scientists did not trust this strange system and were suspicious to communicate and publish there.

2.3 From paper slips to the card catalog

Step by step, a specialized ecosystem was formed and a flourishing scientific community and networks were established, which became an efficient way to share new insights and discuss different results. This development contended with the task of how to organize and structure increasing amounts of information. In the early modern period, scientists used their own methods to confront information overload: they wrote their observations into commonplace books which consisted of bound manuscripts subdivided by headings; thus, news and topics had a fixed and permanent order [25, 26]. For the Swedish naturalist Carl Linnaeus (1707–1778), this strategy was not suitable. To best organize his system of plant classification, he took little paper slips of a standard size to sort all of the collected information about plants and animals; as the paper slips looked like modern index cards [26], this could be seen as a sign of a transition to the progressive card catalogue. With his paper slips, Linnaeus was able to work with a powerful instrument. Ordering the snippets in the correct form (alphabetically), allowed him to find the appropriate information, while at the same time he could make mistakes in arranging the cards [26]. Thus, the momentum of ordering could also be seen as an act of disordering; it enables and improves access to a vast amount of collected information, which again fosters an enhanced dissemination of knowledge.

The card catalog as device for the structuring and representation of knowledge offers, according to Krajewski [27], the possibility to preserve written text and to store it for the long term. As a logical continuation, he proposes to put this «genius apparatus» to an electronic level. The shift to the electronic/digital age gets the new paradigm and builds the next step on the way to openness.

2.4 Cyberscience

A great progress in this direction was the invention of the Internet with its nonlinear structure of hypertext [28]; it opened (and continues to open) the door to the discovery of endless content and has revealed (and continues to reveal) previously unknown topics. The progressive transformation from analog to digital science was shaping, which marks for Nentwich [29] a new scientific era, the beginning of cyberscience (the word «cyberscience» was coined and introduced by Nentwich [29] in the year 2003): „The point is that the new science is taking place in a new space, cyberspace, and not (only) in real places, which can be reached via telecommunication.» [29].

A new era, new technologies, new workflows; the scientific community is experimenting with amazing tools and is testing and exchanging many extraordinary experiences. The vanishing of reality and virtuality as unique places has led to the creation of one big room and should enhance science; however, this remains a big challenge for all stakeholders.

2.5 Cyberscience – a broad range of terms

The experimentation phase may be perhaps the reason why the terms and expressions concerning science in cyberspace are manifold.

Hey and Trefethen [30] use the expression «e-Science» to describe the digital developments, for O'Brien [31] «e-Research» is more appropriate, Borgman [21] defines it as «i-Science» and at the same time she distinguishes between «Open Scholarship» and «Open Science» [21].

In accordance with the shift from real spaces to virtual spaces, science becomes «Science 2.0», which indicates a new level of connectivity, and additionally «Science 3.0» is rising. Whereas Teif [32] with «Science 2.0» indicates and discusses the concerns of Open Access, especially the peer reviewing system, Basset et al. [33] refer to «Science 3.0» as a vague new system of open innovation and semantic search tools. Hoefler et al. [34] point to the difference between «Science 2.0» and «Open Science»; they see the aim of Open Science as opening up science, while Science 2.0 implicates the use of web 2.0 tools for science.

Another approach to underline the digital turn of science is represented with the notion of «Open-notebook Science», introduced by Bradley [35, 36]. He is not satisfied with the present system: when discovering new substances he would not publish these in journals, because he would not have the desired impact. Therefore, he started the blog «UsefulChem»; (the last post is dated from September 03, 2006), where he posts all the information written in paper notebooks. As he did not find an equivalent electronic tool that was open enough to communicate his findings, he collected his insights into a wiki, which is the beginning of the «Open-notebook Science».

Here it is not the process of doing science that determines the word «open», but rather it is its instrument. This may be a prompt to the integration of «open» in the daily working habits of scientists.

By placing the focus more and more on the philosophy of «open», the expression «Open Science» has gained wider acceptance. In the year 2014, the first international conference on the subject of science and openness, «Science 2.0», was held in Hamburg (Germany); now the conference is regularly held in Berlin, under the name «Open Science Conference» [37].

3. The pillars of Open Science

3.1 General aspects

As mentioned above, we will not find a standardized definition for the global movement of Open Science; a single definition is missing. In most cases, there are very vague descriptions, consisting of general formulations like «publicly accessible in digital format» [14].

A more concrete explanation is offered by «Open Definition» [38] which tries to define the meaning of «open» in the context of knowledge: «Knowledge is open if anyone is free to access, use, modify, and share it - subject, at most, to measures that preserve provenance and openness.» [38]. Furthermore «Open Definition» outlines two aspects that are of essential importance: «Open works», which has to fulfill the requirements of the open license, accessibility, machine readability and the open format; and «Open Licenses», which should be compatible with other open licenses [38]. A more distinct view is given by Fecher and Friesike [39] who consider five principles to introduce Open Science - the five basic «schools of thought». First, they propose the «infrastructure school», which relates to the technological aspects of Open Science; by «public school» they mean accessibility of knowledge creation; the «measurement school» implies the discourse concerning alternative impact; then there are the «democratic school» and the «pragmatic school», concerned respectively with access to knowledge and collaborative research [39]. With their study, Fecher and Friesike [39] point to the diverse directions and meanings, through which Open Science can be established; this is an essential basis to advance the notion of Open Science.

3.2 The different pillars of Open Science

Which components are needed to build and maintain a reliable Open Science system? How will Open Science look like in detail? Here again, we will see varied ideas and opinions to «design» a sustainable Open Science organism. Different approaches are proposed concentrating either on the infrastructure or on the workflows and tools.

In the year 2014, the European Grid Infrastructure (EGI) developed the vision of the Open Science Commons, consisting of four key pillars: data as the main basis of research, e-Infrastructures (future-driven technologies, connected services) scientific instruments (equipment and data centers) and knowledge [40]. As a leader in the Open Science movement, the University College London (UCL) presents a more sophisticated view on this and defines eight different pillars for an Open Science enhanced work [41]; these are the «FAIR Guiding Principles» (FAIR Data Principles: Findable, Accessible, Interoperable, Reusable Data [42], see section 3.2.3), research integrity, next generation metrics, while further important points are topics of tomorrow like the future of scholarly communication, Citizen Science, education and skills, rewards and initiatives, and the European Open Science Cloud (EOSC) - the ambitious project of the European Union.

Bosman and Kramer [43] provide a remarkable contribution. As they recognize that there is no general discourse on Open Science perceptions and definitions and that there are many irritating statements on this, they undertake an exhaustive review of terms and expressions, resulting in the proposal «Defining Open Science Definitions» and conclude with the following «six shades of open» [43]:

Open Source
Open Hardware
Open Access
Open Data
Open Educational Resources (OERs)
Open Science

Whereas Open Science is the umbrella term for the aforementioned five components, the purpose here is to point to these five parts, to raise the awareness for remarkable insights and to highlight outstanding papers; thus, to complete the big mosaic of Open Science and so to show the multi-faceted views on this topic.

3.2.1 Open Source, Open Hardware

The subject of Open Source and Open Hardware is as broad and multilayered as the history of Open Science.

«Free/Libre/Open Source Software, or FLOSS, describes both a philosophy of software freedom and a widely accepted set of best practices for the development of software by distributed communities, often made up of volunteers. The core philosophy of software freedom is that software should be free to use, study, copy, modify, and redistribute.» [44]. Going back to the roots, Richard Stallman initiates the General Public License (GNU) project in the year 1984 and establishes the Free Software Foundation a year later [22, 45]. An essential factor to support this new idea is to understand the backgrounds of «free software»: «'Free software' is a matter of liberty, not price» [22], in other words, creativity and freedom are the basis to use, reuse, change the code and share free software.

The main prerequisite for realizing Open Science projects is to work with Open Source Hardware and Open Source Software; perhaps, this may be regarded as a matter of course, but sometimes it is neglected. Some proposals on how this could be accomplished are offered, for instance, by Pearce [46].

The world of galleries, libraries, archives and museums (GLAM) can also benefit from Open Source Software; in these institutions almost every task can be fulfilled in this manner. Chudnov [44] shares some thoughts and suggestions to set up Open Source Software in libraries. Further instructions, literature and all stuff to stay up to date, can be found in the e-journal «The code4lib journal» [47], which was established in the year 2007 and is free to access.

3.2.2 Open Access

Probably the most common component of Open Science is the Open Access movement, often very enthusiastically and controversially discussed. Officially launched with the «Budapest Open Access Initiative» in 2002 [48], then followed by the «Bethesda Statement on Open Access Publishing» (2003) [49] and the «Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities» in the same year [50], the consensus on Open Access is, in a nutshell, that the content and software tools must be openly available and compatible [49].

These important initiatives and claims let us sometimes forget that there are a few essential cornerstones to mention which have influenced strongly this new challenge. In an illuminating synopsis of the prehistory of Open Access, Moore [51] debates and explains the highlights of a gradual opening. In 1971, Michael S. Hart founded "Project Gutenberg" [51] at a time when the Internet was in its early stage. The aim of this activity was and is to make electronic texts (Etexts) available in the simplest and easiest forms to use [52]. Whereas this ambitious plan was intended for a more general public, the scientific community was confronted with other challenges. Hence, Paul Ginsparg launched the arXiv preprint database (1991), an email/FTP server for high-energy physics research articles [51, 53]. The big potential of this server was the simplicity and promptness in being able to post and share the latest research findings. Prior to this, there was another extraordinary service that deserves a mention, perhaps it was only an experiment. In 1961, the National Institutes of Health (NIH) in the United States formed the Information Exchange Groups (IEGs); their task was to circulate biological preprints among the community, which became a great success [54]. Despite this success, the IEGs had to be abandoned in 1967, because journal publishers refused papers circulated as pre-prints. This was a brave attempt and at the same time a predecessor of today's pre-print servers.

The Open Access landscape exhibits a bright picture with different shades of color. Björk [55] has given an enlightening overview of this landscape. He describes the whole range: from green (manuscript self-archival), to gold (full Open Access, with article processing charges - APCs), to platinum Open Access (non-APC-charging gold Open Access) to black (illegal Open Access), to point in the end to rogue or Robin Hood Open Access, a term taken from Archambault [55] (rogue or Robin Hood Open Access is accessible for free, despite of restrictions, usage rights, or copyrights [56]).

We could consider these colors as a metaphor for the economic models of Open Access. In September 2018, the announcement of Plan S [57, 58] was like a disruptive shift; this proposal is to change the whole publishing industry. The scope of Plan S is that all funded European scientific papers have to be published in compliant Open Access journals or platforms and that they are immediately accessible by 2020, which is an enormous requirement. This topic is now permanently in the centre of attention, critical voices are heard and are not rare [59–61]. Plan S and its consequences are still in an experimental phase, we are yet to see whether this will lead to an acceptable foundation.

It might be advisable to take a look at the economic effects of Open Access and to shed light on several outstanding views. While Tennant et al. [62] and Fell [63] concentrate on the societal and economic impacts of Open Access or rather Open Science, Eger and Scheufen [64] see it in a broader perspective. In an international survey with more than 10,000 respondents from 25 countries, the authors conclude that

"… OA is more likely to be driven by the respondents' field of research than by their country of residence." [64] and that the gold road of Open Access (with publication fees) is the common model for publishers.

Besides this informative economic discourse, it was perhaps especially the spirit and the enthusiasm of the Internet pioneers and their developments which could be seen as early signals for a general opening (of minds); it is their unnoticed work which also merits appreciation.

3.2.3 Open Data

Data sharing is a conundrum [65], perhaps data are an obscure object of fascination. Borgman [65] describes research data as difficult to interpret; moreover, she states that they are available in many forms and are used in many ways. This variety indicates that science is data-intensive; it is imperative that there are reliable guidelines for dealing with research data and for coping with ethical issues.

The most important subjects to consider here are the «Panton Principles» [66] and the «FAIR Guiding Principles» [42, 67], to GO FAIR [68]. As one of the essential points to ensure a critical and appropriate handling of data when publishing it, Murray-Rust et al., the authors of the "Panton Principles", recommend the "explicit and robust statement" [66] of the author's own wishes in regards to how the data can be (re-)used. Once published, data must follow the «FAIR Guiding Principles» [67], formulated by an international group of researchers and other stakeholders. Data should be, to outline the key points:

Findable: data must contain rich metadata, (meta)data must have a unique and persistent identifier;

Accessible: (meta)data must be accessible, even when the data are no longer available;

Interoperable: (meta)data have to use a formal, accessible, shared, and applicable language;

Re-usable: data should have a clear and accessible data usage license.

In addition to the «FAIR Guiding Principles», The Global Indigenous Data Alliance launched the «CARE Principles for Indigenous Data Governance» [69]. While the FAIR initiative puts the focus on the characteristics of data, CARE is more people-oriented. It contains four key points and reads as follows [69]:

Collective Benefit: inclusive development, citizen engagement, equitable outcomes;

Authority to Control: rights and interests, data for governance;

Responsibility: for positive relationships, for expanding capability, for indigenous language and worldviews;

Ethics: for minimizing harm and maximizing benefit, for justice, for future use;

When implementing all of these principles the scientific community will «Be FAIR and CARE», (#BeFAIRandCARE) [70] and can act in a reliable manner.

Data – a «magical» and precious conundrum, may be a great challenge for researchers. Data sharing is not as easy as it seems; often, researchers do not see any need for it and are reluctant to share their data. Data sharing depends, too, on the researchers' mindset and personality.

The researchers' working methods and especially their sharing habits are heavily observed and under scrutiny by the Open Science community. Two fundamental studies examine the barriers for sharing and for not sharing data. Tenopir et al. [71] explore barriers and enablers of data sharing among 1329 scientists; their findings show that scientists are not willing to make their data electronically available and that this is often a question of culture. According to Borgman [65], there are four distinct reasons to consider when sharing data: to reproduce research, to make publicly funded research available to the public, to enable others to ask new questions, and to advance the state of research and innovation. She argues that the challenge will be to understand which data might be shared and to have a deeper look at the collaboration patterns of the networked community. In another international study, Severin et al. [72] investigate discipline-specific Open Access publishing practices. They observe great differences among the various subjects, and especially in the legal domain the commitment to Open Access publishing is rarely present.

Kim et al. [73] shed light on the attitudinal beliefs and social norms of scientists, whereas Linek et al. [74] undertake an informative study based on their personalities. The results of the latter study show that sharing habits strongly depend on personality traits (extraversion, neuroticism, openness, agreeableness and conscientiousness).

Finally, it is worth mentioning that all publishing related phases can be realized in the "open" (Open Peer reviewing, Open Methodology).

3.2.4 Open Educational Resources (OERs)

In the year 2001, the Massachusetts Institute of Technology (MIT) launched MIT OpenCourseWare (OCW) [75], a learning platform with all MIT course content, freely accessible. This was the inspiring moment for other future-oriented institutions to experiment with free learning materials. Massive open online courses (MOOCs) and online universities were established and were prosperous, but the hype has ceased.

These developments show the potential of open content, as a new media type was created, namely the Open Educational Resources (OERs). The characteristics of OERs are «teaching, learning, and research resources that reside in the public domain or have been released under an intellectual property license that permits their free use or re-purposing by others.» [76]. In the Open Education License Draft, Wiley [77] defines the "Four Rs of Open Content":

Reuse – Use the work verbatim, just exactly as you found it;

Rework – Alter or transform the work so that it better meets your needs;

Remix – Combine the (verbatim or altered) work with other works to better meet your needs;

Redistribute – Share the verbatim work, the reworked work, or the remixed work with others;

For teaching and learning institutions, OERs gain more and more relevance and are considered as a factor of success and a competitive advantage for universities. How do faculty adopt and implement OERs, how should or could faculty and libraries collaborate to promote and produce OERs?

The first findings in this matter reveal that faculty are open to and appreciate the traditional tasks of librarians (discovery, cataloging, information literacy), but they do not like receiving librarian support otherwise [78]. In an extensive study, Proudman et al. survey 146 European libraries of higher education on the topics of Open Education and OERs [79]. Eight aspects are investigated: the costs of education and Open Education; organization; Open Education Policy; library engagement and leadership; Open Education Advocacy; services; skills and challenges; and opportunities. The authors conclude that the greatest obstacles in supporting OERs are lack of funding and questions of culture.

OERs are a great driver for libraries and institutions of higher education; therefore, this topic should become a matter of course for all information professionals and library-related organizations.

3.3 Open Science consistently in mind

If we recognize the values and philosophy of the Open Science movement, in the final analysis this would mean that the full research process, from the beginning to the end, including the writing process, is documented, open, and transparent. Christian Heise has made an audacious attempt in describing the difficult phases of writing his doctoral thesis as an Open Science project [80]. Apart from the fact that it is the «first completely open humanities-based PhD thesis» [81], the result indicates that Open Access to the content is only the first step, and that additional smaller and bigger efforts are required for the opening of science.

3.4 Skills and expertise

A well-structured Open Science system is an important precondition for the promotion of Open Science and for supporting its aims. What does this mean for researchers? Are they now working in another connected environment, in an open-minded context? Do they need further skills to fulfill their tasks?

In a report, the Working Group on Education and Skills under Open Science [82] analyses the most indispensable competencies for researchers on the way to openness. These competencies are divided into four categories: knowledge concerning Open Access publishing, knowledge regarding research data and data production, a close connection to the researcher's own scholarly and disciplinary community, and supporting citizen science.

With FOSTER, a training platform for the research community was created, covering all aspects concerning Open Science, with detailed learning materials and guidelines [83]. A special feature of this platform contains the vast terminology related to Open Science [84]. The European Commission released the report «Digital skills for FAIR and Open Science» [85], to shed light on these two evolving topics, to strengthen their importance and interaction. The aim of this report is to develop the next generation of «FAIR and open science professionals» [85] within the European Open Science Cloud (EOSC) [86]. In a detailed description, ten roles of envisioned Open Science professionals are defined (researcher, EOSC enabler, data scientist/data analyst, research software engineer, data research infrastructure support professional, EOSC educator, data curator, data steward/data librarian, citizens, policy maker). The future plan is to compile a catalogue of learning and training resources.

These skills might be very important; however, workflows and processes in the Open Science era do not require more specific knowledge. It is essential to be up-to-date and to be aware of 21st century technologies and new tools, to use them and integrate them into daily routines. A substantial factor will be to open up one's own "knowledge treasure" and to share valuable insights while working in the openness.

4. Vision «Open Space»

To go back to the roots of «open», showing the multi-faceted meanings of this term, enables to draw a fine-grained picture, a picture which is not yet completed, with parts which can and must be changed and expanded to represent the dynamic status of research and innovation.

Disruptive technologies and digital transformation are key drivers of change in our social system. This has great implications for further and higher education and on the working behaviors of scientists (and all other researchers). Universities worldwide are under great pressure to adopt new forms of teaching and learning.

The campus as physical space serves no longer as the main area to meet and learn and is shifting to virtuality; virtual and physical spaces are merging [87]. The annually published trend scouting study «Horizon Report Trends» [88] scans technological developments and serves as a leading instrument of prospective tendencies in higher education. It gives an overview of trends to implement in the near future, categorizing them into five parts: social, technological, economic, political trends, trends in higher education. Procter et al. [89] describe research as «Research 4.0» and discuss the influence of Artificial Intelligence on academic research methods concerning the UK research landscape (but it also points to general transformations and changes).

How could these challenges determine the movement of «open» and the shift to a new perception of research, learning, and teaching? What does the future of Open Science look like, how could we build and develop an Open Science environment to best meet the requirements of researchers?

Openness does not depend on virtual or physical spaces; Openness means collaboration, sharing, using free tools, Open Access to scientific literature, to mention only a few points. Ayris et al. [90] and Ignat et al. [91] suggest to embed libraries in the Open Science landscape from a European perspective. Whereas they refer to the institutional level, I would focus here more on the researchers' view and imagine the vision of «Open Space».

«Open Space» is designed as an open research platform, which is seamlessly integrated into the whole Research Life Cycle [92], containing three phases: «before research», «during research» and «after research». When researchers begin their work, they are automatically connected to «Open Space» (the authentication procedure is done at the beginning of a new project), where they can meet the international research community of their discipline (as well as other disciplines) to search for collaborators. The process of finding other researchers is facilitated by the Current Research Information System (CRIS) of each university [93, 94], which is embedded in the "Open Space" platform. The CRIS offers a topical overview of the institutions' research output, documenting not only scientific publications, but also research projects, lectures, prices [94]. In this innovative environment, they can use the available toolbox, which contains important materials for the research process (e.g. for collecting data, reading and writing). The «Open Space» platform can be personalized (searching patterns, recommendations…); additionally, researchers will find an advice button for 24/7 consultation with the Open Science library division and guidance with the working processes. «Open Space» will be an open and scalable ecosystem, where all stakeholders are interconnected to build and expand a sustainable research infrastructure for a meaningful future. Such an «Open Space» platform would foster and encourage the creation of the «Openness Profile» [95], an initiative of Knowledge Exchange (KE) [96], "to enable open research practitioners to compile a diverse range of contributions and make those contributions accessible in order to get credit for them." [95]. The final version of this report [97], published in March 2021, puts the focus on the evaluation and recognition of publications to Open Scholarship practice. This scenario is a first input and could serve as inspiration; the design of a sophisticated platform has to be considered/examined well and can take months.

Finally, we should ask the question to what extent openness could go, how «open» such a system should be. Is there an unlimited openness? If we go back to envision the beginnings of the movement, the early adopters who opened their minds to taking notes of their inspirations (see sections 2.1, 2.2), then we could imagine a similar scenario in a new technological era, our brain connected to the computer: "Interface University would be based on the idea that machines cannot fully supplant human cognition and that thinking with machines allows students to engage in a level of cognition not possible with the brain alone." [98]. Might be, that these are perhaps thought-provoking ideas, but recognizing outstanding developments is an important pre-condition for creating future learning and research spaces.

5. Conclusion

The movement of «open» has a long and fascinating history, and to trace it back and unveil its origins is a complex task. The first steps of opening one's mind, communicating and sharing new thoughts, writing down unknown ideas on cards, and reaching a new level of openness and inter-connectedness with the Internet, show a slight shift from closeness to openness, but we have a rather long way to go: «'Open research' is a useful shorthand for the sort of open research practices that are thought to help to speed the pace of discovery – but it is far from a concrete concept and must be reified anew depending on the particularities of the research and the changing affordances of the wider technological, scholarly, and cultural environment.» [99].

Knowing the past means to raise awareness of future trends, to facilitate the work on concrete projects, to recognize little changes and hidden signs, and could thereby contribute to fostering the openness of science in a dynamic scientific landscape.

Conflict of interest

The author declares no conflict of interest.

Thanks

Thank you to Silvia Stoyanova for proofreading the manuscript.

Author details

Anne-Katharina Weilenmann
Biblink.ch, Schaffhausen, Switzerland

*Address all correspondence to: weilenmann@shinternet.ch

References

[1] Forero G. How scientists interact with bacteria: Creating new knowledge. Proceedings of the Association for Information Science and Technology. 2019;**56**:98-106. DOI: 10.1002/pra2.60

[2] Heinze T. Creative accomplishments in science: definition, theoretical considerations, examples from science history, and bibliometric findings. Scientometrics. 2013;**95**(3):927-940. DOI: 10.1007/s11192-012-0848-9

[3] Kuhn TS. The structure of scientific revolutions: with an introductory essay by Ian Hacking. 4th ed. Chicago: The University of Chicago Press; 2012. XLVI, 217 p.

[4] Shapin S. The ivory tower: the history of a figure of speech and its cultural uses. The British Journal for the History of Science. 2012;**45**(1):1-27. DOI: https://doi.org/10.1017/S0007087412000118

[5] McKiernan EC. Imagining the «open» university: Sharing scholarship to improve research and education. PLoS Biology. 2017;**15**(10): e1002614. DOI: https://doi.org/10.1371/journal.pbio.1002614

[6] Wolfer SA, Müller-Feldmeth DG, Konieczny L, Held U, Maksymski K, Hansen-Schirra S, Auer P. Popsci: A reading corpus of popular science texts with rich multi-level annotations: A case study (2013) [Internet]. 2013. Available from: https://freidok.uni-freiburg.de/data/117180 [Accessed: 2020-12-20]

[7] Held U, Maksymski K, Čulo O, Hansen-Schirra S. Understanding Science: A German popular science corpus [n.d.] (2x) [Internet]. o.J. Available from: https://www.cognition.uni-freiburg.de/forschung/projects/popsci/Materialien/PosterUnderstanding Science [Accessed: 2020-12-20]

[8] Linek SB, Scholz W. Public engagement in science: New ways of participative science communication and the practical use case of the YES!-project. Proceedings of the 12th International Conference on Education and New Learning Technologies (EDULEARN 2020). 2020: 4612-4621. http://hdl.handle.net/11108/449

[9] He D, Wang Z, Thaker K, Zou N. Translation and Expansion: Enabling Laypeople Access to the COVID-19 Academic Collection. 2020;**4**(3):177-190. DOI: https://doi.org/10.2478/dim-2020-0011

[10] Irwin A. Citizen Science: A Study of People, Expertise, and Sustainable Development. London: Routledge; 1995. XIII, 198 p.

[11] Bonney R. Citizen Science: A Lab Tradition. Living Birds. 1996;**15**(4): 7-15.

[12] Hecker S, Haklay M, Bowser A, Makuch Z, Vogel J, Bonn, A. Citizen Science: Innovation in Open Science, Society and Policy. London: UCL Press; 2018. DOI: https://doi.org/10.14324/111.9781787352339

[13] Association of College and Research Libraries. Open and Equitable Scholarly Communications: Creating a More Inclusive Future: Prepared by Nancy Maron and Rebecca Kennison with Paul Bracke, Nathan Hall, Isaac Gilman, Kara Malenfant, Charlotte Roh, and Yasmeen Shorish. Chicago: Association of College and Research Libraries; 2019. DOI: https://doi.org/10.5860/acrl.1

[14] Organisation for Economic Co-operation and Development, OECD. Making Open Science a Reality. Paris: OECD Publishing; 2015. DOI: http://dx.doi.org/10.1787/5jrs2f963zs1-en

[15] Lemke S, Mehrazar M, Mazarakis A, Peters I. When you use social media you

are not working: Barriers for the use of metrics in social sciences. Frontiers in research metrics and analytics. 2019; **3**(39). DOI: 10.3389/frma.2018.00039

[16] Severin A, Egger M, Eve MP, Hürlimann D. Discipline-specific open access publishing practices and barriers to change: an evidence-based review. version 2; peer review: 2 approved, 1 approved with reservations. F1000Research. 2018;7(1925). DOI: https://doi.org/10.12688/f1000research.17328.1

[17] Stieglitz S, Wilms K, Mirbabaie M, Hofeditz L, Brenger B, López A, Rehwald S. When are researchers willing to share their data?: Impacts of values and uncertainty on open data in academia. PLoS ONE. 2020;**15**(7): e0234172. DOI: https://doi.org/10.1371/journal.pone.0234172

[18] Nicholas D, Watkinson A, Boukacem-Zeghmouri C, Rodríguez-Bravo B, Xu J, Abrizah A, Świgoń M, Clark D, Herman E. So, are early career researchers the harbingers of change?. Learned Publishing. 2019;**32**(3): 237-247. DOI:10.1002/leap.1232

[19] Nielsen MA. Reinventing Discovery. Princeton: University Press; 2012. 264 p.

[20] Bartling S, Friesike S. Preface. In: Bartling S, Friesike S, editor. Opening Science: The evolving guide on how the internet is changing research, collaboration and scholarly publishing. Cham: Springer; 2014. p. v-vi. DOI: 10.1007/978-3-319-00026-8

[21] Borgman CL. Scholarship in the digital age: information, infrastructure, and the internet. Cambridge, Mass.: MIT Press; 2007. XXIV, 336 p.

[22] Willinsky J. The unacknowledged convergence of open source, open access, and open science. First Monday. 2005;**10**(8). DOI: https://doi.org/10.5210/fm.v10i8.1265

[23] Stracke CM. Open Science and radical solutions for diversity, equity and quality in research: A literature review of different research schools, philosophies and frameworks and their potential impact on science and education. In: Burgos D, editor. Radical solutions and Open Science: An open approach to boost Higher Education. Singapore: Springer Nature; 2020. p. 17-37. DOI: https://doi.org/10.1007/978-981-15-4276-3

[24] David PA. Understanding the emergence of 'open science' institutions: Functionalist economics in historical context. Industrial and Corporate Change. 2004;**13**(4): 571-589. DOI: http://dx.doi.org/10.1093/icc/dth023

[25] Blair A. Too much to know: Managing scholarly information before the modern age. New Haven: Yale University Press; 2010. XV, 397 p.

[26] Charmantier I, Müller-Wille S. Carl Linnaeus's botanical paper slips (1767-1773). Intellectual History Review. 2014;**24**(2): 215-238. DOI: 10.1080/17496977.2014.914643

[27] Krajewski M. Paper machines: about cards & catalogs, 1548-1929. Cambridge, Mass.: MIT Press; 2011. VI, 215 p.

[28] St. Laurent S. Why Hypertext for History? (1992) [Internet]. 1992. Available from: http://www.simonstl.com/articles/hypehist.htm [Accessed: 2020-12-20]

[29] Nentwich M. Cyberscience: Research in the age of the Internet. Vienna: Austrian Academy of Sciences Press; 2003. XXII, 490, A-79 p. http://epub.oeaw.ac.at/cyberscience_1.pdf [Accessed: 2020-12-20]

[30] Hey T, Trefethen AE. Cyberinfrastructure for e-Science. Science. 2005;**308**(5723): 817-821. DOI: 10.1126/science.1110410

[31] O'Brien L. E-Research: An imperative for strengthening institutional partnerships. Educause Review. 2005;**40**(6): 64-77. https://er.educause.edu/articles/2005/1/eresearch-an-imperative-for-strengthening-institutional-partnerships [Accessed: 2020-12-20]

[32] Teif VB. Science 3.0: Corrections to the science 2.0 paradigm (2013) [Internet]. 2013. Available from: https://arxiv.org/pdf/1301.2522 [Accessed: 2020-12-20]

[33] Basset H, Stuart D, Silber D, Boutin F. From science 2.0 to pharma 3.0. Oxford: Chandos Publishing; 2012. XVI, 276 p.

[34] Hoefler AM, Scholz W, Tochtermann K. Science 2.0 and Open Science: Similar but still different (2015) [Internet]. 2015. Available from: https://www.zbw-mediatalk.eu/2015/09/science-2-0-and-open-science-similar-but-still-different/ [Accessed: 2020-12-20]

[35] Weinberger D. Too big to know. New York: Basic Books; 2011. XIV, 231 p.

[36] Bradley JC. The role of blogging in Open Notebook Science (2008) [Internet]. 2008. Available from: http://drexel-coas-elearning-transcripts.blogspot.com/2008/02/role-of-blogging-in-open-notebook.html [Accessed: 2020-12-20]

[37] Open Science Conference. [Internet]. Available from: https://www.open-science-conference.eu [Accessed: 2020-12-20]

[38] Open Knowledge Foundation. Open Definition: defining open in open data, open content and open knowledge. Version 2.1 [Internet]. Available from: http://opendefinition.org/od/2.1/en/ [Accessed: 2020-12-20]

[39] Fecher B, Friesike S. Open Science: One term, five schools of thought. In: Bartling S, Friesike S, editors. Opening Science: The evolving guide on how the internet is changing research, collaboration and scholarly publishing. Springer: Cham; 2014. p. 17-47. DOI: https://doi.org/10.1007/978-3-319-00026-8_2

[40] European Grid Infrastructure (EGI). Open Science Commons. Version 1 (2015) [Internet]. 2015. Available from: https://documents.egi.eu/document/2410 [Accessed: 2020-12-20]

[41] University College London (UCL). 8 Pillars of Open Science. (2018) [Internet]. 2018. Available from: https://www.ucl.ac.uk/library/open-science/8-pillars-open-science [Accessed: 2020-12-20]

[42] FORCE11. The fair data principles (2016) [Internet]. 2016. Available from: https://www.force11.org/group/fairgroup/fairprinciples [Accessed: 2020-12-20]

[43] Bosman J, Kramer B. Defining Open Science definitions (2017) [Internet]. 2017. Available from: https://im2punt0.wordpress.com/2017/03/27/defining-open-science-definitions/ [Accessed: 2020-12-20]

[44] Chudnov D. The future of FLOSS in libraries. In: Gordon RS, editor. Information tomorrow: reflections on technology and the future of public and academic libraries. Medford: Information Today; 2007. p. 19-30

[45] DiBona C, Ockman S, Stone M. What Is Free Software and How Does It Relate to Open Source? In: DiBona C, Ockman S, Stone M, editors. Open sources: voices from the open source revolution. Beijing: O'Reilly; 1999. p. 2-3

[46] Pearce JM. Building research equipment with free, opensource hardware. Science. 2012;**337**: 1303-1304. DOI: 10.1126/science.1228183

[47] Code4lib journal: C4LJ. [S.l.]: [S.n.]; 1.2007- https://journal.code4lib.org/ [Accessed: 2020-12-20]

[48] Budapest Open Access Initiative (2002) [Internet]. 2002. Available from: https://www.budapestopenaccessinitiative.org/read [Accessed: 2020-12-20]

[49] Bethesda Statement on Open Access Publishing (2003) [Internet]. 2003. Available from: http://legacy.earlham.edu/~peters/fos/bethesda.htm [Accessed: 2020-12-20]

[50] Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities (2003) [Internet]. 2003. Available from: https://openaccess.mpg.de/Berlin-Declaration [Accessed: 2020-12-20]

[51] Moore, SA. Revisiting "the 1990s debutante": Scholar-led publishing and the prehistory of the open access movement. Journal of the Association for Information Science and Technology. 2020;**71**(7): 856– 866. DOI: https://doi.org/10.1002/asi.24306

[52] Hart M. The History and Philosophy of Project Gutenberg (1992). [Internet]. 1992. Available from: http://www.gutenberg.org/about/background/history_and_philosophy.html [Accessed: 2020-12-20]

[53] Ginsparg P. The global village pioneers. Learned Publishing. 2009;**22**(2): 95-100. DOI: https://doi.org/10.1087/2009203

[54] Cobb M. The prehistory of biology preprints: A forgotten experiment from the 1960s. PLoS Biology. 2017;**15**(11): 1-12. DOI: https://doi.org/10.1371/journal.pbio.2003995

[55] Björk BC. Gold, green, and black open access. Learned Publishing. 2017;**30**(2): 173-175. DOI: https://doi.org/10.1002/leap.1096

[56] Archambault É, Amyot D, Deschamps P, Nicol A, Provencher F, Rebout L, Roberge G. Proportion of Open Access papers published in peer-reviewed journals at the European and world levels - 1996-2013 (2014) [Internet]. 2014. Available from: http://digitalcommons.unl.edu/scholcom/8 [Accessed: 2020-12-20]

[57] Plan S.: Making full and immediate Open Access a reality (2018) [Internet]. 2018. Available from: https://www.coalition-s.org [Accessed: 2020-12-20]

[58] Schiltz M. Science without publication paywalls: cOAlition S for the realisation of full and immediate Open Access. PLoS Biology. 2018;**16**(9): 1-4. DOI: https://doi.org/10.1371/journal.pbio.3000031

[59] Dodds F. The future of academic publishing: Revolution or evolution revisited. Learned Publishing. 2019;**32**(4): 345-354. DOI: https://doi.org/10.1002/leap.1258

[60] Frantsvåg JE, Strømme TE. Few Open Access journals are compliant with Plan S. Publications. 2019;**7**(2): 1-18. DOI: https://doi.org/10.3390/publications7020026

[61] Eysenbach G. The insanity (and probably illegality) of transformative agreements (including Plan S and Project Deal) - An Open Letter to Libraries and Coalition S. (2020) [Internet]. 2020. Available from: https://gunther-eysenbach.blogspot.com/2020/01/the-insanity-and-probably-illegality-of.html [Accessed: 2020-12-20]

[62] Tennant J, Waldner F, Damien CJ, Masuzzo P, Collister LB, Hartgerink CHJ. The academic, economic and societal impacts of Open Access: an evidencebased review. version 3. F1000 Research. 2016;**5**(632). 1-55. DOI: https://doi.org/10.12688/f1000research.8460.3

[63] Fell MJ. The economic impacts of Open Science: a rapid evidence assessment. Publications. 2019;**7**(3). 1-30. DOI: https://doi.org/10.3390/publications7030046

[64] Eger T, Scheufen M. The economics of Open Access: on the future of academic publishing. Cheltenham, UK, Northampton, MA, USA: Elgar Publishing; 2018. x, 156 p. DOI: https://doi.org/10.4337/9781785365768

[65] Borgman CL. The conundrum of sharing research data. Journal of the Association for Information Science and Technology. 2012;**63**(6): 1059-1078. DOI: https://doi.org/10.1002/asi.22634

[66] Panton Principles, Principles for open data in science. Murray-Rust P, Neylon C, Pollock R, Wilbanks J. (2010) [Internet]. 2010. Available from: https://pantonprinciples.org/ [Accessed: 2020-12-20]

[67] Wilkinson M, Dumontier M, Aalbersberg I. et al. The FAIR Guiding Principles for scientific data management and stewardship. Sci Data. 2016;**3**(160018): 1-9. DOI: https://doi.org/10.1038/sdata.2016.18

[68] GO FAIR (2018) [Internet]. 2018. Available from: https://www.go-fair.org/how-to-go-fair/ [Accessed: 2020-12-20]

[69] CARE Principles for Indigenous Data Governance (2019) [Internet]. 2019. Available from: https://www.gida-global.org/s/CARE-Principles_One-Pagers-FINAL_Oct_17_2019.pdf [Accessed: 2020-12-20]

[70] Be FAIR and CARE: #BeFAIRandCARE (2019) [Internet]. 2019. Available from: https://www.gida-global.org/care [Accessed: 2020-12-20]

[71] Tenopir C, Allard S, Douglass K, Aydinoglu AU, Wu L, Read E, Manoff M, Frame M. Data sharing by scientists: practices and perceptions. PLoS ONE. 2011;**6**(6): 1-21. DOI: https://doi.org/10.1371/journal.pone.0021101

[72] Severin A, Egger M, Eve MP, Hürlimann D. Discipline-specific open access publishing practices and barriers to change: an evidence-based review. version 2, peer review: 2 approved, 1 approved with reservations. F1000Research. 2020;**7**(1925): 1-41. DOI: https://doi.org/10.12688/f1000research.17328.2

[73] Kim Y, Nah S. Internet researchers' data sharing behaviors: an integration of data reuse experience, attitudinal beliefs, social norms, and resource factors. Online Information Review. 2018;**42**(1): 124-142. DOI: https://doi.org/10.1108/OIR-10-2016-0313

[74] Linek SB, Fecher B, Friesike S, Hebing M. Data sharing as social dilemma: influence of the researcher's personality. PLoS ONE. 2017;**12**(8): 1-24. DOI: https://doi.org/10.1371/journal.pone.0183216

[75] MIT OpenCourseWare (OCW) (2001-) [Internet]. 2001-. Available from: https://ocw.mit.edu [Accessed: 2020-12-20]

[76] Atkins DE, Brown JS, Hammond AL. A review of the Open Educational Resources (OER) movement: achievements, challenges, and new opportunities. [S.l.]: [S.n.]; 2007. ii, 80 p. http://www.hewlett.org/uploads/files/ReviewoftheOERMovement.pdf [Accessed: 2020-12-20]

[77] Wiley D. Open education license draft (2007) [Internet]. 2007. Available from: http://opencontent.org/blog/archives/355 [Accessed: 2020-12-20]

[78] Braddlee DR, Vanscoy A. Bridging the chasm: faculty support roles for

academic librarians in the adoption of Open Educational Resources. College & Research Libraries. 2019;**80**(4): 426-449. DOI: https://doi.org/10.5860/crl.80.4.426

[79] Proudman V, Santos-Hermosa G, Smith J, Ficarra V. Open Education in European libraries of higher education. [S.l.]: [S.n.]; 2020. 57 p. DOI: http://doi.org/10.5281/zenodo.3903175

[80] Heise C. Von Open Access zu Open Science: Zum Wandel digitaler Kulturen der wissenschaftlichen Kommunikation. Online Ed. Lüneburg: Meson Press; 2018. 309 p. DOI: 10.14619/1303

[81] Heise C, Pearce JM. From Open Access to Open Science: the path from scientific reality to open scientific communication. SAGE Open. 2020;**10**(2): 1-14. DOI: https://doi.org/10.1177/2158244020915900

[82] The Working Group on education and skills under Open Science, editor. Providing researchers with the skills and competencies they need to practise Open Science: report of the Working Group on education and skills under Open Science. Luxembourg: Publications Office of the European Union; 2017. 35 p. DOI: 10.2777/121253

[83] FOSTER (2014-) [Internet]. 2014-. Available from: https://www.fosteropenscience.eu [Accessed: 2020-12-20]

[84] FOSTER, Resources [(2014-)] [Internet]. [2014-]. Available from: https://www.fosteropenscience.eu/resources [Accessed: 2020-12-20]

[85] European Commission Directorate-General for Research and Innovation, Directorate G - Research and Innovation Outreach Unit G.4 - Open Science, editor. Digital skills for FAIR and open science. Luxembourg: Publications Office of the European Union; 2021. DOI: 10.2777/59065

[86] European Open Science Cloud (EOSC). [Internet]. 2020. Available from: https://eosc.eu [Accessed: 2020-12-20]

[87] Ninnemann K, Liedtke B, den Heijer A, Gothe K, Loidl-Reisch C, Nenonen S, Nestler J, Tieva Å, Wallenborg C. Hybrid environments for universities: a shared commitment to campus innovation and sustainability. Online Ed. Münster: Waxmann; 2020. 116 p. DOI https://doi.org/10.31244/9783830991793

[88] Educause, [editor]. The Horizon Report Trends. Educause Review. 2020;**#1**:10-22. https://er.educause.edu/-/media/files/articles/2020/3/er20_1114.pdf

[89] Procter R, Glover B, Jones E. Research 4.0: research in the age of automation. London: Demos; 2020. 32 p. https://demos.co.uk/wp-content/uploads/2020/09/Research-4.0-Report.pdf [Accessed: 2020-12-20]

[90] Ayris P, Ignat T. Defining the role of libraries in the Open Science landscape: a reflection on current European practice. Open Information Science. 2018;**2**(1): 1-22. DOI: https://doi.org/10.1515/opis-2018-0001

[91] Ignat T, Ayris, P. Built to last!: embedding Open Science principles and practice into European universities. Insights. 2020;**33**(1):1-19. DOI: http://doi.org/10.1629/uksg.501

[92] Bosch S, Scholten J, Bruyneel M, Pristupa A, Unger D. The research life cycle. version 1.0. 2020. [Internet]. 2020. Available from: DOI: http://doi.org/10.5281/zenodo.3754459 [Accessed: 2020-12-20]

[93] euroCRIS: The international organisation for research information. [Internet]. 2002. Available from: https://eurocris.org/ [Accessed: 2020-12-20]

[94] Azeroual O, Schöpfel J. Quality issues of CRIS data: An exploratory investigation with universities from twelve countries. Publications. 2019;**7,1**(14): 1-18. DOI: https://doi.org/10.3390/publications7010014

[95] Murphy F, Jones P. Openness Profile: Defining the Concepts (Version 1). [S.l.]: [S.n.]; 2020. 48 p. DOI: http://doi.org/10.5281/zenodo.3607579

[96] Knowledge Exchange (KE). [Internet]. [n.d.]. Available from: https://knowledge-exchange.info [Accessed: 2020-12-20]

[97] Jones P, Murphy F. Openness Profile: Modelling research evaluation for open scholarship. [S.l.]: [S.n.]; 2021. 68 p. DOI: http://doi.org/10.5281/zenodo.4581490

[98] Staley D. Interface university and other scenarios for the AI economy. Educause Review. 2020;**#3**: 40-49. https://er.educause.edu/-/media/files/articles/2020/8/er20_3103.pdf

[99] Stuart D. The meaning of open. Research information. 2019(104): 4-8. https://www.researchinformation.info/feature/meaning-open