////// tematické studie / thematic articles //////////////////////

## TRANSFORMATION OF SCIENCE COMMUNICATION IN THE AGE OF SOCIAL MEDIA

**Abstract:** *The aim of the present article is to discuss several consequences of the Open Science from a perspective of science communication and philosophy of communication. Apart from the purely communicative and philosophical issues, the paper deals with the questions that concern the science popularization process through social media (especially Twitter and blogs). The article consists of three sections: the first one suggests a definition of science communication and social media, the second examines the transformation of science in the Age of the Internet and considers the influence of social media on science communication, the third and final one presents some case studies and philosophical observations. The most important conclusion to be reached here is that the social media have changed science and science communication. Twitter and blogs as novelty tools of science communication can be useful and meaningful for both science and society. Furthermore, social media can be used to facilitate broader involvement of citizens in the discussion about science.*

**Keywords:** *science communication; social media; blog; Twitter; Open Science*

## Transformace komunikace vědy ve věku sociálních médií

**Abstrakt:** *Článek se zabývá některými důsledky otevřené vědy z perspektivy komunikace vědy a filosofie komunikace. Kromě čistě komunikačních a filosofických témat se text věnuje i otázkám tykajícím se procesu popularizace vědy prostřednictvím sociálních médií (zejména Twitteru a blogů). Článek se sestává ze tří oddílů: první navrhuje definici komunikace vědy a sociálních médií; druhý zkoumá proměnu komunikace vědy v éře internetu a zabývá se vlivem sociálních médií na komunikaci vědy; třetí a závěrečný oddíl přináší několik případových studií a filosofických postřehů. Nejdůležitějším, zde dosaženým závěrem je tvrzení, že sociální media vědu a vědeckou komunikaci proměnila. Twitter a blogy jakožto nové nástroje vědecké komunikace mohou být užitečné a smysluplné pro vědu i společnost. Sociální media mohou být navíc použita k usnadnění širšího zapojení občanů do diskusí o vědě.*

**Keywords:** *komunikace vědy; sociální média; blog; Twitter; otevřená věda*

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## Introduction and resolutions in terminology

The shape of science communication depends on the media which prevails in a given era. However, the dissemination of the so-called social media has transformed not only the way we communicate about science, but also contributes to the radical change in the way science itself is practiced. The development of the mass media (radio, press, television) allowed for the transfer of the popularisation of science to a whole different level of accessibility. The classical mass media did not change suddenly, and the study of their impact on the various social practices included primarily the aspect of content broadcasting (unidirectionality of traditional mass media). The advent of the universally available Internet and tools based on the co-creation of content (referred to here with the umbrella term Web 2.0)[1] resulted in significant transformation in communication practices.

The purpose of this article is to present and discuss the fundamental changes taking place in science communication under the influence of social media. Some of the tools which transform the science communication will be presented as well.

The thesis outlined in this article is as follows: social media have changed the way of practicing science communication and expanded the instrumentation of academic research. The development of Internet tools allowed for open access to scientific publications, greater transparency of the reviewing process, and the transformation of the classical method of publication of scientific papers. The collection of these postulates and ideas is defined herein as the Open Science. Open Science is a term referring primarily to the way of performing science communication.

I would like to thank the two anonymous reviewers for their helpful comments and useful suggestions

[1] The relation between the term "Web 2.0" and "social media" is very difficult to determine. It should be said that social media is included in Web 2.0 (co-creating of content on web sites is their common feature). The "2.0" in the expression does not mean a new version of the Internet, but a new way of using it through co-creation. However, social networking sites additionally gather a large group of users who share and comment on the co-created content (this requirement need not be fulfilled by the services referred to as Web 2.0).

**Science communication as a practice**

Science communication is a practice which is realised at two levels: individual and social.[2] At the individual level a scientist publishes scientific papers, stays in contact with other researchers, promotes science, etc. At the social level, the researcher thus keeps science functioning as a kind of social practice – science communication is a part of the scientific process, the same as collecting and analysing data. Communicating about science is therefore not regarded merely as "information about the work of scientists," but becomes (in the view of e.g. the philosophy of culture) the process of perpetuation of science itself.

The title of this article, employs the term *science communication*, which in the presented approach is understood in a broad way. *Science communication,* also incorporates, these practices, which are referred to by such terms as *scientific communication* and *scholarly communication*. All the three terms refer generally to communication processes taking place in the framework of scientific practices. In other words, they concern communicating of science and communication in science. Although there are distinctions[3] indicating that the *scholarly communication* refers mainly to publishing of scientific papers, the *scientific communication* refers to explaining and popularising of science by the columnists, journalists (though not scientists), whereas *science communication*[4] refers to promoting and explaining the results of scientific research. In this paper, however, all three areas are marked with the term *science communication*.

This terminological solution, however, imposes a need to indicate two subtypes of science communication differing by the groups of their recipients. The first subtype – the "external communication science", is addressed mainly to non-scientists, while the users of the "internal communication science" are mainly professional researchers. The classification is relevant for my argument because in this article I undertake to discuss the issue of

[2] The exact characteristics of these two levels in social practices has been outlined in the book: Emanuel KULCZYCKI, *Teoretyzowanie komunikacji* [Theorizing Communication]. Poznań: Wydawnictwo Naukowe Instytutu Filozofii UAM 2012.

[3] *Cf.* Vladimir de SEMIR, *Meta Review. Media for Science Forum, Madrid* [online]. 2010. Available at: <http://www.mediaforscience.org/Resources/documentos/booklet_en.pdf> [cit. 15. 11. 2012], pp. 11–13.

[4] It should be emphasized that *science communication* is also sometimes used to refer to a research discipline. See: Henk A. J. MULDER – Nancy LONGNECKER – Lloyd S. DAVIS, "The State of Science Communication Programs at Universities Around the World." *Science Communication*, vol. 30, 2008, no. 2, p. 278 (277–287).

research transformation primarily in the field of "internal communication of science."

Science communication of the first type is the process of explaining and popularising academic research through e.g. publishing of popular science texts, organizing science festivals, creating an image of a scientist and science (e.g. a scientist as the main character of the popular TV series). In other words, it is the popularisation of science and explaining the work of scientists and its results. It is "external" communication because its recipients are "outside" the communicating group – scientists communicate to non-scientists.[5]

Science communication of the second type includes such phenomena as publishing research papers, scientific blogs, managing and using social networking sites for scientists. It is "internal" communication, because its basic premise is communication of scientists with scientists. These two kinds of communication complement and interact with each other.

Naturally, there are other categorizations of "the same" science communication.[6] One of the most interesting is the approach of Michel Cloître and Terry Shinn, *in which they identify four main stages within the process of scientific communication*[7]*: (1) intraspecialistic – at this level there are empirical data, references to experimental activities, (2) interspecialistic – at this level interdisciplinary articles are published, (3) pedagogical – at this level e.g. coursebooks are published – it is "the stage where the theoretical body is already developed and consolidated"*[8]*; (4) popular – it is the level of populari-*

[5] Of course one may indicate a much needed sphere of communicating about science, i.e. popular science publications which are created by journalists or columnists. It is exactly this practice which is referred to as *scientific communication*. However, I believe that all of such practices should simply be called *science communication*.

[6] One can not indicate a single "authorised" categorisation, nor can one specify such a definition of communication, which all researchers would agree with. Therefore, in addition to the classification which I assume (the distinction between the "internal" and "external" classification) I point out another commonly accepted distinction of science communication types. As demonstrated by Mikołaj Domaradzki – in communicating about communication, we can not escape beyond the metaphor that language imposes on us – see: Mikołaj DOMARADZKI, "Miejsce metafor w badaniach nad komunikacją." *Folia Philosophica*, vol. 25, 2012, pp. 1–10.

[7] Michel CLOÎTRE – Terry SHINN, "Expository Practice: Social, Cognitive and Epistemological Linkages." In: SHINN, T. – WHITLEY, R. (eds.), *Expository Science: Forms and Functions of Popularization*. Dordrecht: Reidel 1985, pp. 31–60.

[8] Massimiano BUCCHI, "When Scientists Turn to the Public: Alternative Routes in Science Communication." *Public Understanding of Science*, vol. 5, no. 5, 1996, p. 378 (375–394).

*sation of science in magazines, newspapers, film documentaries and in such magazines as Scientific American.*

## Research perspective

In the present considerations, a research perspective is adopted, which combines the findings of the Toronto School of Communication Theory (a version of the technological determinism)[9] and of the philosophy of communication.[10] Of course, we need to keep in mind the limitations and weaknesses of the technological determinism which has been put forward as a "tempting alternative" to "communication microhistory."[11] The technological determinism has been criticized mainly when used as a tool to write "the history of the world" from the perspective of a medium that emerges in its final form and thus changes e.g. the organisation of societies. It is primarily the emphasis on one efficient cause of the social order change that is criticised. However, such a reductionist approach, where technology is reified, may be useful cognitively and some findings and hypotheses of the

[9] I am referring here to such researchers as Walter Ong, Jack Goody, Harold Innis or Marshall McLuhan.

[10] It is not, however, about the normative philosophy of communication, just like the one by e.g. Jürgen Habermas and his *Theory of Communicative Action*, or Karl-Otto Apel, who demonstrates how communication is possible at all. It is rather about the descriptive philosophy of communication which defines the communication process and describes its role in social processes (e.g. Umberto Eco's considerations in the field of semiology, reconstruction of seven traditions of communication theory by Robert T. Craig or Peter Burke's philosophical insights on the cultural history of communication). In this paper the perspective of the philosophy of communication shall be adopted, which recognizes communication as an element of social practices, and thus in a sense recognizes philosophy of communication to be a subdiscipline of the philosophy of culture, or a type of communication theory based on considerations about culture. In other words: the philosophy of communication adopted here recognizes the indivisible connection between all forms of communication and culture. See: James W. CAREY, *Communication as Culture: Essays on Media and Society.* Revised edition. New York: Routledge 2008; Robert T. CRAIG, "Metadiscourse, Theory, and Practice." *Research on Language & Social Interaction*, vol. 32, 1999, no. 1–2, pp. 21–29; Michał WENDLAND, *Konstruktywizm komunikacyjny.* Poznań: Wydawnictwo Naukowe Instytutu Filozofii UAM 2011.

[11] By writing about the microhistories of communication I mean writing a history of communication from the perspective of one (national) medium, such as the history of the French press. Before Harold Innis or Marshall McLuhan's works gained popularity communication was often analysed in such a "fragmentary" way. The works of the Toronto School have provided tools for a "total" analysis, which of course are subject to a variety of problems.

Toronto School may be considered interesting and will be used in this article in an instrumental way – they will serve as heuristic tools.

Therefore, it is assumed that a change in the form of communication changes the social practice. The emergence of a new medium and its use is a change not only quantitative, but also qualitative, which has an impact on the practice. Referring to Marshall McLuhan[12], it can be say that one should examine not only the "what" is being said through the new medium, but also what is "going on" with existing practices in which the new medium was begun[13] to be used.

One of the most important representatives of technological determinism, Harold Innis, showed in his writings that transformations of society affect the *biases* of media. Two biases may be indicated: time- and space-biased media. The first group focus on communication which takes place "now" (they may be permanent inscriptions in stone which can not be moved, but usually it regards oral communication). Second (space-biased media) are transportable and can be transmitted over distances (book, radio). Innis indicated that as the dominant media types change, so do the societies. It turns out, however, that this distinction becomes less important in the case of social media, because they are both time- and space-biased (direct conversations on videoconferences which overcome great distances). Although it should be noted that this process began with the development of the telegraph and telephone.

However, it should not be therefore inferred that technological determinism as a research perspective is useless. On the contrary, the impact of these new space-time-biased tools on scientific communication should be examined.

Thanks to the technological determinism approach the impact of social media on scientific communication can be indicated and the large-scale sociocultural transformation can be described. Of course, other research approaches may be used to examine these changes (such as the sociology of science, philosophy of science, digital humanities), however in this article the emphasis is put on the blogs and microblogs as media, not as genres. Therefore, the prospect of technological determinism, which focuses on medium – despite some theoretical and conceptual basis is useful. Therefore,

[12] Specifically to his famous expression "The medium is the message." (Marshall McLUHAN – Quentin FIORE, *The Medium Is the Message: An Inventory of Effects*. New York: Random House 1967, pp. 126–128).

[13] See: Harold INNIS, *The Bias of Communication*. Second Edition. Toronto: University of Toronto Press 1999, pp. 35–60.

the technological determinism perspective, which focuses on the medium is useful – despite some theoretical and conceptual basis.

In this article we will look at not only the content of blogs and microblogs, but also at what is changing in science itself through such. In other words, what is the impact of the new communication technology (social media) on the social practice i.e. science communication. Therefore, the term *social media* that appears in the title of this paper requires discussion and explication.

**Social media as a science communication's tool**

*Social media* is a very difficult term to define clearly.[14] For the purpose of this paper, it is assumed that *social media* are Internet tools which can take the form of blogs, forums, microblogs, social networking sites or *media sharing*.[15] The descriptions of social media stress that "a unique aspect of many social media sites is that their content is cocreated."[16] This way the opportunity to contribute and share content forms a definitional attribute of *social media*.[17] Media may be divided into the old ones (television, radio, newspapers) and the new (blogs, podcasts, YouTube). The new ones are new due to the technological change, which allows single individuals to publish material (in the "old media" it was hard to have one's own radio show – it is very easy in the new media). The new media are called *digital media* due to the form of record: digital, not analog (which was prevalent in most old media). A subgroup may be specified within the new media, i.e. the social media, which put the emphasis on commenting and participation. Thus, the new media, which operate in the internet may be identified with Web 2.0 (see: footnote 2). Some of the most popular social media sites are Facebook,

[14] Authors often do not define the term, only indicating what services or tools fall into this category. *Cf.* Zeynep TUFEKCI – Christopher WILSON, "Social Media and the Decision to Participate in Political Protest: Observations From Tahrir Square." *Journal of Communication*, vol. 6, 2012, no. 2, pp. 363–379.

[15] Matthew R. AUER, "The Policy Sciences of Social Media." *Policy Studies Journal*, vol. 39, 2011, no. 4, p. 711 (709–736).

[16] David C. DeANDREA, "Participatory Social Media and the Evaluation of Online Behavior." *Human Communication Research*, vol. 38, 2012, no. 4, p. 510–528.

[17] "Social media refers to a set of web-based services that enables users to share content with each other." Daniel TROTTIER – David LYON, "Key Features of Social Media Surveillance." In: FUCHS, Ch. – BOERSMA, K. – ALBRECHTSLUND, A. – SANDOVAL, M. (eds.), *Internet and Surveillance: The Challenges of Web 2.0 and Social Media*. New York: Routledge, pp. 89–90.

Twitter, Youtube. One could also point to the social media addressed directly to the academic community (Academia.edu, ResearchGate.net, Mendeley).

Social media as a young research subject has already been described in several interesting studies.[18] It should be emphasized, however, that the analyses are carried out mainly in the context of these tools' use in marketing and advertising. Literature which could be indicated here, in terms of what is analyzed in this article, may be divided into three groups: (1) the analysis of specific cases of the social media use in science communication,[19] (2) research on the consequences of the social media use,[20] (3) considerations that analyse the transformation of science and humanities which take place under the influence of the new media – relative to such issues as: digital humanities or digital storytelling.[21]

The title of this paper contains the expression "the Age of Social Media," which is a certain specification of the expression "the Age of the Internet".[22] Both are imprecise and refer to a number of phenomena which are not subject to easy categorization, and their use functions as rhetorical and heuristic.

[18] Laura BONETTA, "Scientists Enter the Blogosphere." *Cell*, vol. 129, no. 3, 2007, p. 443 (443–445); Sara KJELLBERG, "Blogs as Interface between Several Worlds. A Case Study of the Swedish Academic Blogosphere." *Human IT*, vol. 10, 2010 [online]. Available at: <http://www.hb.se/bhs/ith/3-10/sk_eng.pdf> [cit. 15. 11. 2012]; Danah M. BOYD – Nicole B. ELLISON, "Social Network Sites: Definition, History, and Scholarship." *Journal of Computer-Mediated Communication*, vol. 13, 2007, no. 1, pp. 210–230; Jason PRIEM – Bradely H. HEMMINGER, "Scientometrics 2.0: New Metrics of Scholarly Impact on the Social Web" *First Monday*, vol. 15, 2010 [online]. Available at: <http://firstmonday.org/htbin/cgiwrap/bin/ojs/index.php/fm/article/viewArticle/2874> [cit. 3. 11. 2012].

[19] See: Xiaoguang WANG – Tingting JIANG – Feicheng MA, "Blog-supported Scientific Communication: An Exploratory Analysis Based on Social hyperlinks in a Chinese Blog Community." *Journal of Information Science*, vol. 36, 2010, no. 6, pp. 690–704; Lisa WADE – Gwen SHARP, "Sociological Images: Blogging as Public Sociology." *Social Science Computer Review*, vol. 31, 2013, no. 2, pp. 1–8; Nicki DABNER, '"Breaking Ground' in the Use of Social Media: A Case Study of a University Earthquake Response to Inform Educational Design with Facebook." *The Internet and Higher Education*, vol. 15, 2012, no. 1, pp. 69–78; Ercan TOP, "Blogging as a Social Medium in Undergraduate Courses: Sense of Community Best Predictor of Perceived Learning." *The Internet and Higher Education*, vol. 15, 2012, no. 1, pp. 24–28.

[20] See Mariano LONGO – Stefano MAGNOLO, "The Author and Authorship in the Internet Society: New Perspectives for Scientific Communication." *Current Sociology*, vol. 57, 2009, no. 6, pp. 829–850; Nicholas W. JANKOWSKI, "Exploring e-Science: An Introduction." *Journal of Computer-Mediated Communication Journal*, vol. 12, 2007, no. 2, pp. 549–562.

[21] See Lev MANOVICH, *The Language of New Media*. Cambridge, MA: MIT Press 2002; Albert-Laszlo BARABASI, *Linked: How Everything Is Connected to Everything Else and What It Means*. New York: Plume 2003.

[22] *Cf.* de SEMIR, *Meta Review,* pp. 29–33.

Science practiced in the Age of Social Media (or the Internet), is a science, which – on the one hand – uses social media, on the other, is subject to changes that result from the media.[23] The expression "science in the Age of Internet" might as well be replaced with (under certain assumptions) the expressions Science 2.0 or e-Science.

Social media do not only change science communication, but also politics, journalism, education, and all other major areas of human activity. It is a global tool which should be intensively examined in order to understand its full impact on our society. In the perspective of technological determinism, it is assumed that the tool itself (i.e. a form of communication) can change not only the way in which the content of the communication is received, but also alter other remote fields of social practices (as e.g. the appearance of the writing – according to Jack Goody – influenced the way societies were organised[24]). In the process of science communication the social media do not only change the way we communicate about science, but also affect the involvement of the society in the process of production of scientific knowledge and the promotion of scientific publications. The authors of the book *Open Science: A new "Technology Trust"* wrote explicitly that "opening up the methods of science to wider audiences has implications not only for how science is done but also for public engagement with science".[25]

## Open Science as a communicative issue

An analysis of how the internet has changed the way research is performed *in toto*, is, for obvious reasons, beyond the scope of this study. It is an incredibly extensive issue, and therefore a certain quantitative and qualitative framework should be specified for the purpose of this analysis. Therefore, the following discussion will focus on the issue of Open Science i.e. such an idea of the development of science whose primary determinant of scientific practice is its openness, transparency and dissemination (of course, all the requirements of the scientific method, intersubjective communicability and verifiability are not negated).

[23] *Cf.* Intesar MAHMOD – Richard HARTLEY – Jennifer ROWLEY, "Scientific Communication in Libya in the Digital Age." *Journal of Information Science*, vol. 37, 2011, no. 4, pp. 379–390.
[24] Jack GOODY, *The Logic of Writing and the Organization of Society.* Cambridge: Cambridge University Press 1986. See in particular the section "The state, the bureau and the file".
[25] Ann GRAND – Clare WILKINSON – Karen BULTITUDE – Alan F. T. WINFIELD, "Open Science – A New 'Trust Technology'?" *Science Communication*, vol. 34, 2012, no. 5, p. 681 (679–689).

The topic related to the Open Science, but often analysed separately, is the phenomenon of Citizen Science.[26] It has its roots in the development of communication technology and the possibility of the involvement of a large number of people to perform simple "scientific" tasks. However, Citizen Science is not only the "use" of volunteers to perform basic work, but also a very powerful tool for popularisation of science and a form of scientific education. However, in order for the Citizen Science to function efficiently, it is necessary that all those involved in a project keep working. The authors of the article *What's next for science communication? Promising directions and lingering distraction* write:

> To motivate and prepare citizens to use digital media to learn about science, share information, express their views, and coordinate activities, science organizations should partner with universities, social scientists, and journalists to develop "civic science media literacy" curricula.[27]

Analysing the issue of openness in science, Jennifer C. Molloy points out that "science is built on data: its collection, analysis, publication, reanalysis, critique, and reuse".[28] Therefore, the issue of distribution and availability of information is so important for the development of science. This issue must be understood very broadly, both in terms of data sharing (use of open formats, building independent infrastructure), building and dissemination of open source software, as well as communication between scientists themselves. Molloy emphasizes:

> In response to these problems, multiple individuals, groups, and organisations are involved in a major movement to reform the process of scientific commu-

[26] Of course one can indicate similar phenomena and concepts which arise with the development of the idea of "openness" in the rocesy of individuals and societies. The terms such as Open Knowledge, Open Research, Open Culture, Open Access, Open Source etc., have their common denominator in the belief that the knowledge and the products of human rocesy find their sense and usefulness at the time of their use, delivery, consumption by the whole society: "Open science has the potential to enable citizen scientists' participation to go beyond counting, checking, and organizing data to involvement in the full complexities of the research roces and in dialogue with researchers." *Ibid.*, p. 683.

[27] Matthew C. NISBET – Dietram A. SCHEUFELE, "What's Next for Science Communication? Promising Directions and Lingering Distractions." *American Journal of Botany*, vol. 96, 2009, no. 10, p. 1777 (1767–1778).

[28] Jennifer C. MOLLOY, "The Open Knowledge Foundation: Open Data Means Better Science." *PLoS Biology*, vol. 9, 2011 [online]. Availabte at: <http://www.plosbiology.org/article/info%3Adoi%2F10.1371%2Fjournal.pbio.1001195> [cit. 18. 11. 2012].

nication. The promotion of open access and open data and the development of platforms that reduce the cost and difficulty of data handling play a principal role in this.[29]

The transformation of the science communication process takes place in two ways. On one hand, such organizations are created as the Creative Commons, the Open Knowledge Foundation, the Public Library of Science, which are trying to accelerate the process of opening of science. On the other hand, the process often proceeds in an unintended manner, through the use of e.g. social media to promote or comment on scientific discoveries (blogging about science, providing preprints of work, etc.). In the first case, this "controlled" opening of science is based on development – e.g. at the level of law, infrastructure, software – solutions dedicated for scientists (creating repositories of open data, social networks only for researchers, publishing process management tools such as Open Journal Systems). In the latter case "regular Internet tools," such as blogs and microblogs, are used for scientific purposes. It should be emphasized that the Open Science initiative is not just about digital solutions. However, the impact of internet tools, particularly the use of social media, transforms the way science is opened.

It may be indicated that Open Science is not a new phenomenon, but an evolution of scientists' activities. For example it may be demonstrated that Open Science began in the seventeenth century with the formation of the first scientific journals, such as the *Philosophical Transactions of the Royal Society*, launched in 1665.

One should agree that this way it really is possible to see the source of openness in science. However, arguing this way, it early stages of this evolution should also be indicated: the invention of the printing press or even writing itself (but then we would not longer be talking about science – at least not science as it is understood today[30]). Therefore, in this study, I assume that Open Science is a modern phenomenon, whose beginning may be located within the final years of the twentieth-century. It is mainly related

[29] *Ibid.*

[30] Scott E. Hendrix showed what problems are raised by the use of the term *science* with reference to practices from many centuries ago: "Furthermore, application of the term 'science' to the work of scholars such as the thirteenth-century theologian who has been saint of scientists since 1931, Albert the Great (d. 1280), or his near contemporary Robert Grosseteste (d. 1260), imposes a series of expectations and perception-altering filters that only increases the distance between us and these historical actors." Scott E. HENDRIX, "Natural Philosophy or Science in Premodern Epistemic Regimes? The Case of the Astrology of Albert the Great and Galileo Galilei." *Teorie vědy/Theory of Science*, vol. 33, 2011, no. 1, p. 112 (111–132).

to the magnitude of publications, data, and information which are created as a result of scientific work. Julian Cribb and Sari Tjempaka in their book *Open Science: sharing knowledge in the global century* write:

> Scientific knowledge is now said to double about every 5 years, but its distribution among the seven billion citizens of Planet Earth proceeds far less rapidly. While the number of scientific papers published grows dramatically with each passing year, the rate at which their essential knowledge is transmitted to ordinary people who might use it in their lives lags far behind. Indeed, it has been claimed that up to half the world's published scientific papers are never read by anyone other than their authors, editors and reviewers – and 90 per cent are never cited.[31]

Therefore Open Science is the source of attacks in which it is indicated that the amount of data produced by scientists is so vast and disordered that adding more items to this collection may cause additional information chaos. It should be remembered, however, that openness in science is only a tool, not an end in itself.

In 2008 the project "Policy and Technology for e-Science" (carried out within the Science Commons) four basic principles relating to openness in science were developer.[32]

> *1) Open Access to Literature from Funded Research – all publications resulting from the research funded by public funds should be in digital form, available on the web – without the need to login to services or pay. Each user should have the right to use and re-use them.*
>
> *2) Access to Research Tools from Funded Research – all research tools (cell lines, model animals, DNA tools, reagents) which have been used in the study should be described in a digital form in such a way that successive researchers would also be able to use them.*
>
> *3) Data from Funded Research in the Public Domain – all data generated in such studies should be made available in the public domain. This is the only way to ensure full freedom in the distribution and the re-use of the data.*

[31] Julian CRIBB – Tjempaka SARI, *Open Science: Sharing Knowledge in the Global Century*. Collingwood: CSIRO Publishing 2010, p. 1.

[32] *Science Commons*: *Principles for Open Science* [online]. 2008. Available at: <http://sciencecommons.org/resources/readingroom/principles-for-open-science/> [cit. 11. 11. 2012].

*4) Invest in Open Cyberinfrastructure – not only the data generated in research should be open – the rule should also apply to all the infrastructure that allows recombination and reconfiguration of the research data.*

The above principles apply mainly to projects financed by public funds. It is the first step towards the openness of science – it is, according to the authors, not only justified (the public should not have to pay for the access to research results which have been financed with taxes), but also necessary to create and develop standards and good practices. The proponents of Open Science emphasize that the process of data generation and scientific results publication is not yet the end of the scientific process. Cribb and Tjempaka point out that "Open Science contends that we should be putting as much money, effort and creativity into communicating science as we do into discovery".[33] It is worth noting that open access to data and scientific publications does not destroy the commercialisation of research results. The benefits which stem from science should be understood more broadly than before. Shawn H.E. Harmon, Timothy Caufield and Yann Joly suggest that the commercialisation of science must also take into account such a thing as "social benefit", because modern science is not just for generating financial returns.[34]

The consequences of Open Science, which is supported with tools of global and instant communication, are immense. The following areas, which undergo some basic changes may be specified:

*Democratisation and a broad access to knowledge* – in recent years, access to the Internet has become something very common, therefore sharing the latest publications and research results in Open Access allows for an elimination of economic barriers in access to knowledge. Accelerating the development of science requires not only big financing but also the support of current students (the future scientists) which could develop from the convention of allowing them to become familiar with the full spectrum of scientific materials. The popular science materials, which are also a kind of superstructure of scientific publications, must not be forgotten either.

[33] CRIBB – SARI, *Open Science*, p. 12.
[34] Shawn H. E. HARMON – Timothy CAULFIELD – Yann JOLY, "Commercialization versus Open Science: Making Sense of the Message(s) in the Bottle." *Medical Law International*, vol. 12, 2012, no. 1, pp. 8–9 (3–10).

*Quick verifiability and publication of negative data* – publishing negative data, failed experiments is not only necessary and useful for financial reasons (multiple financing of the same experiments, entering a "dead-end" project, the lack of wisdom coming from the mistakes of colleagues), but also changes the perception of science. Science does not grow by leaps and bounds – from success to success – it is rather a manifold and continuous process of experimentation and interpretation of results of all sorts. Sharing of data generated in the study allows their verification by other research groups, and thus affects the credibility of researchers and science itself.

*Citizen Science* – the scientific process engages volunteers who help with basic work (data collection), or provide processing power of their personal computers. One of the most popular of such projects is the Galaxy Zoo, in which volunteers classify galaxies through <http://www.galaxyzoo.org> page. The Citizen Science is not a recent idea[35], though since the 90's of the twentieth century it has gained momentum and allowed researchers carry out experiments on unprecedented scale.

*Social media in science communication* – published articles are analysed and criticised not only in scientific journals – they are discussed on Twitter, blogs, Facebook. This in turn means that the classical ways of evaluation of a publication or journal (impact factor and h-index) are starting to have competition in social indicators: *h5-index* as an alternative to *impact factor* and *altmetric* as an alternative to the number of citations and the *h-index*.

This paper focuses on the latter, that is the social media used in the process of science communication. It should be noted that the relation (not being identical) between the Open Science and the social media is very powerful. On one hand, the use of social media is the result of opening of science. On the other hand, social media change and accelerate the opening. Referring to the technological determinism perspective one can say that social media are becoming a kind of *extension* of science communication (more specifically an extension of the scientists who use social media).

[35] Already in 1900, The Audubon Society began to use the work of volunteers and began to carry out Christmas Bird Count. See Nancy DeWITT, "Christmas Bird Count" [online]. *Newsletter*, vol. 4, 1998, p. 2. Available at: <http://www.alaskabird.org/wp-content/uploads/2011/05/winter1998.pdf> [cit. 8. 11. 2012].

**Social media as tools of science communication**

In this chapter, the consequences of using social media in science communication are exemplified by means of a few instances. The analysis of these cases shows that the medium itself directs manner in which scientific debates, criticism, and results check are conducted.

I have already indicated earlier that there are two types of online tools in science communication: (1) sites created for a "normal" user, but used for scientific purposes, and (2) sites dedicated to scientists. This division corresponds with the division into two types of science communication: *internal* and *external*. The external scientific communication primarily uses the first group of tools, those aimed at a "normal" user. While the tools dedicated for researchers are used only in *internal science communication.*

Among the various tools addressed to a wide audience the following groups may be considered social media:

– social networking sites (e.g. Facebook, Google Plus, Diaspora, Pinterest);
– microblogging sites (e.g. Twitter, Flaker, Pinger);
– bookmarking and sharing (e.g. Delicious, Blinklinst);
– content sharing (e.g. Issuu, Flickr, SlideShare, Youtube)
– blogging platforms (e.g. Blogger, Wordpress, Posterous).

Whereas the social media targeted to researchers tend to develop standard solutions to suit their needs (e.g. there is a possibility to post a list of publications with appropriate metadata). The following group of social media may be specified:

– bibliometric and webometric tools (e.g. Google Scholar Citations, ScienceCard);
– publications and bibliography management (e.g. Mendeley, Zotero);
– social networking sites for scientists (e.g. Academia.edu, ResearchGate.net);
– academic blogging services and aggregators (e.g. PLOS Blogs Network, Research Blogging).

Both groups of tools transform many of the basic practices within science communication. For example, let us consider the issue of publishing research results in scientific journals. Until now (i.e. in "the era before Social Media") an author made his decision regarding where to publish on the basis of the reputation of a given journal. Now, increasingly often it may be

observed that authors pay attention not only to the reputation of the journal, but also to whether the journal is available in Open Access, whether preprints and postprints can be posted at Open Repositories, and whether the publications (and the citations of the publications in the journal) are visible in the major scientific search engines.

Moreover, the publication of a scientific text is only the beginning of a debate, initiated by the author, with other scientists and the public. In the classical model of science communication a thesis presented in an article published in a journal would be most often debated by means of another article (published as a polemic in the same journal or in another one). Even with journals which were issued with a relatively high frequency such a "dialogue" was spread over time.

In the era of social media, such a debate literally begins at the moment of the publication of the text on the web. The authors inform their colleagues about the publication through social networks (Facebook), post an electronic version of the text (e.g. Academia.edu) and tweet about the article, providing a link to the full text. After a while (of course it depends on the subject area and author's status) a debate on the article begins. Blog entries are written, not only describing the text, but also commenting on it, criticising it or indicating its shortcomings. At this point, various social media channels (blogs, social networks, microblogs) overlap and interact. Before a "real" polemic appears in a scientific journal, the dialogue in the social media had already begun.

Therefore, quantitative assessment of a scientific article, which is created within the framework of bibliometrics, is beginning to evolve in the direction of scientometrics based on webometrics – a quantitative assessment of what "echo" the article raises in the Internet. One of the newest and most interesting projects which analyses the "impact" of a given article on the basis of social media is the *altmetrics* project. Its creators write in its manifesto:

> No one can read everything. We rely on filters to make sense of the scholarly literature, but the narrow, traditional filters are being swamped. However, the growth of new, online scholarly tools allows us to make new filters; these altmetrics reflect the broad, rapid impact of scholarship in this burgeoning ecosystem. We call for more tools and research based on altmetrics.[36]

[36] Jason PRIEM – Dario TARABORELLI – Paul GROTH – Cameron NEYLON, *altmetrics: a manifesto* [online]. 2010. Available at: <http://altmetrics.org/manifesto/> [cit. 10. 11. 2012].

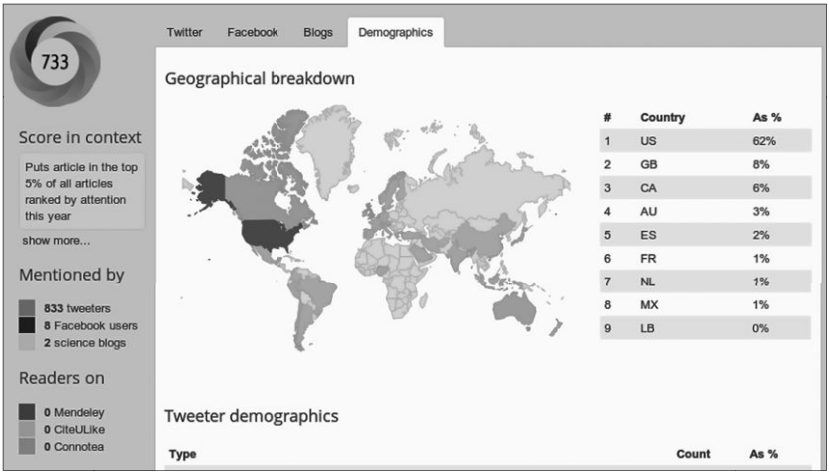


Figure 1: *Printscreen of the "Altmetric Explorer" for the article "A vote for science" – 10th November 2012.*

The altmetrics project allows for the evaluation of the "popularity" of an article on the basis of a variety of social media channels. Below there is a printscreen of the data concerning the article "A vote for science" published on 24th October 2012 in *Nature* and indexed in *altmetrics*. Within days of the publication a few hundred people from different countries discussed the text[37] – no classical scientific journal is able to apply such a model of communication.Of course, it must be emphasized that in no way is the quality, reliability or innovation of the publication evaluated. These are only quantitative data, which are nevertheless used in the evaluation of science. Of course, it has not been established specifically by social media – consider e.g. the *impact factor*. It is the most well-known quantitative evaluation index

[37] Data from the "Altmetric Explorer" (www.altmetric.com), accessed at 10th November 2012 (20:10 hrs). The following criteria were selected: "Mentioned in the past: 1 week, With keyword: science communication." Among the results the first position was occupied by the article "A Vote for Science" from *Nature*. From the moment of its publication (24th October 2012), the text has been mentioned hundreds of times (by 833 Twitter users, 8 users of Facebook and on two academic blogs). In addition to links to any such posts there is a map with the data concerning the places of the remarks' publication.

of scientific journals. It is used to indirectly assess not only journals, but also articles or researchers themselves. Therefore, the issue of the validity of this type of webometric projects of science evaluation deserves a separate study. This article, however, focuses on the issue of the "qualitative" assessment of scientific publications in the social media.

Blogs have become the subject of analysis from their onset.[38] They are most often analysed, on the basis of geographical criteria (e.g. all blogs in France or in Russia) or the thematic ones (culinary blogs, political blogs, etc.). I am interested in the scientific blogosphere[39] (sometimes referred to as the academic blogosphere), in the context of scientific publications reviews, which are done on science blogs. Therefore, the issue of researching the scientific blogosphere will be ignored, as well as the matter of other functions that this type of blogosphere can be used for,[40] and problems such as the one of arguments against the use of blogs in science communication.[41]

Science blogs are beginning to transform the classical peer review of scientific publications, which – in its current form – has its roots in the eighteenth-century publication selection process[42] (although, of course, one

[38] With the development of Web 2.0 attempts to define what a blog is have become very problematic. Therefore, I simply assume that a blog is a kind of website which contains chronologically and, where possible, regularly posted entries, and that the owner of the blog (blogger) is the author of the entries. Categorising blogs on the basis of their content (text, audio, photos, video) seems to be ill-founded in the era of Web 2.0. Therefore, I treat "blog" as a kind of medium rather than a literary genre. And therefore I agree with Inna Kouper, who wrote: "Science blogs are too heterogeneous to be understood as an emerging genre of science communication. The blogs employ a variety of writing and authoring models, and no signs of emerging or stabilizing genre conventions could be observed." Inna KOUPER, "Science Blogs and Public Engagement with Science: Practices, Challenges, and Opportunities." *Journal of Science Communication*, vol. 9, no. 1, 2010, p. 3 (1–10).

[39] A detailed analysis of the types of scientific blogs and the thematic areas pervading the academic blogosphere has been included in the text: Emanuel KULCZYCKI, "Blogs and Scientific Services: Scientific Communication in Culture of Convergence." In: SÓJKOWSKA, I. (ed.), *Materiały konferencyjne EBIB nr 22*. Toruń: Stowarzyszenie EBIB 2012, pp. 1–24.

[40] Blogs, in addition to the reviewing function, which has been mentioned in this text, perform a number of other important roles, e.g. serve as tools of education and teaching, allow the dissemination of one's research results, publication of negative results – or – may serve merely as a self-promotion tool for a scientist.

[41] This issue also requires a separate study. It should be emphasized, however, that blogging by scientists is not always seen as something positive: occasionally it is pointed out that the image of a scientist-blogger is not fitting for serious scholars or that it is simply a waste of time.

[42] GRAND – WILKINSON – BULTITUDE – WINFIELD, "Open Science," pp. 679–680 (679–689).

might try to identify even earlier processes as the source).[43] Bloggers are beginning to act as an "instant reviewer," that is, they undertake to critically assess the scientific publications immediately after their propagation – they are trying to bolster the reliability of research with their criticism. And the results of these reviews appear on blogs, which makes them publicly available (it should be noted though that not all the texts reviewed by bloggers are available in Open Access). The universally binding method of reviewing and publishing of scientific results leads that:

> journals and their editorial boards regulate and control access to scientific communication. Multiple norms and values, which have been developed within the field of science, directly bear upon publication behaviour. […] The current peer review system puts up a barrier, but also grants a minimal form of credit or recognition to published research findings.[44]

Therefore, it is important to show that there is an alternative which consists in debating about science in the social media – and more precisely, in reviewing research on science blogs. It is in fact possible to indicate many interesting case studies in which science blogs and bloggers play the leading role. I would like to focus primarily on the case of a publication in the journal *Science*, in 2010, concerning "a new form of life."

A group of scientists associated with NASA, on December 2nd, 2010, published in the *Science* journal an article entitled "A Bacterium That Can Grow by Using Arsenic Instead of Phosphorus".[45] The published results were to prove that a new form of life was discovered in California's Mono Lake – Arsenic Bacteria (which can grow using arsenic instead of phosphorus). The very next day first comments on the text from *Science* began appearing on blogs. Two days later, microbiology professor Rosie Redfield posted

[43] Ray SPIER, "The History of the Peer-Review Process." *Trends in Biotechnology*, vol. 20, 2002, no. 8, p. 357 (357–358).
[44] Raf VANDERSTRAETEN, "Scientific Communication: Sociology Journals and Publication Practices." *Sociology*, vol. 44, 2010, no. 3, p. 561 (559–576).
[45] Felisa WOLFE-SIMON – Jodi S. BLUM – Thomas R. KULP *et al*., "A Bacterium That Can Grow by Using Arsenic Instead of Phosphorus." *Science*, vol. 332, 2011, no. 6034, pp. 1163–1166.

a comment,[46] containing very strong criticism. Over the next few days, there have been much additional criticism on various blogs.[47]

What is crucial in the story is that the authors refused to refer to the criticism made by Redfield and other bloggers. The rationale was that the article was published in a peer-reviewed journal and therefore, only such criticism (i.e. of "peer" status) would be responded to. David Dobbs, the author of the popular science blog "Neuron Culture," wrote at the time that: "Rosie Redfield *is* a peer, and her blog is peer review. NASA has bungled its presentation of this paper from start to finish. It makes worse by trying to dismiss critiques this way. This is the wrong stuff".[48] During the discussion on how reviewing of scientific papers should be performed bloggers claimed that a real review begins only with the official publication of a text (before the publication most often there is only a double-blind review).

It is important to note that as early as two weeks after the publication of the text in *Science* the editors of equally prestigious *Nature* took the side of the "community reviewers" and gave them the right to review, writing:

> Bloggers and online commentators have an important part to play in the assessment of research findings, and many researchers' blogs, in particular, contain better analyses of the true significance of a scientific finding or debate than is seen in much of the mainstream media. Science journalists who repeated NASA's claims on the arsenic bacterium and did not tap into the widespread criticisms, did little to defend themselves from claims of reporting by press release.[49]

Rosie Redfield's criticism did not end with a single post. In 2011, she decided to recreate the study criticized. As early as January 2012 an article was submitted for review in *Science* – in the research Redfield's team confirmed

[46] Rosie REDFIELD, *Arsenic-associated Bacteria (NASA's Claims)* [online]. 2012. Available at: <http://rrresearch.fieldofscience.com/2010/12/arsenic-associated-bacteria-nasas.html> [cit. 09. 11. 2012].

[47] An interesting "day after day" summary of various entries appearing on blogs was made by Ed Young – a science blogger who writes a blog on the "Discover Magazine": Ed YOUNG, *Arsenic bacteria – a post-mortem, a review, and some navel-gazing* [online]. 2010. Available at: <http://blogs.discovermagazine.com/notrocketscience/2010/12/10/arsenic-bacteria-a-post-mortem-a-review-and-some-navel-gazing/> [cit. 9. 11. 2012].

[48] David DOBBS, *The Wrong Stuff: NASA Dismisses Arsenic Critique Because Critical Priest Not Standing on Altar* [online]. 2010. Available at: <http://www.wired.com/wiredscience/2010/12/the-wrong-stuff-nasa-dismisses-arsenic-critique-because-critical-priest-not-standing-on-altar/> [cit. 9. 11. 2012].

[49] Editors, "Response Required." *Nature*, vol. 468, 2010. p. 867.

its earlier criticism. What is important, once the manuscript was sent to the magazine, it was immediately placed in the most famous repository of unpublished (yet) articles – arxiv.org[50] – so that everyone (before publication) could get acquainted with the text. The article was accepted and published a few months later.

This representative example shows how the opening of science may not only contribute to a better circulation of data, dissemination of science, but also improve the quality of research. Until now social media in this article were discussed as a communication tool (whether in terms of observing of an ongoing communication in the *altmetric* project, or as tools for critique as in the case of science blogs).

However, social media are not only a means of communication, but also a tool which allows for a recognition of new areas (which were so far invisible to science). I'm referring to the fact of new empirical data which is generated and can be used in research.

Twitter is a microblogging service, established in 2006, with the number of its users currently estimated at about 500 million. The site serves as a platform where entries (tweets) are published, up to 140 characters long, possibly including hyperlinks and images. Twitter is used by politicians, actors, ordinary users. It is used for advertising, teaching[51] and academic work – e.g. to provide information on new publications, or to measure the interest sparked by one.

In terms of technological determinism can be said that microblogs have become an extension of users: in this sense, they not only expand the scope of their impact (number of recipients, engaging multiple senses), but also determine what we can express and – above all – how we can do it. Such extensions are not neutral, neither are technological limitations (e.g. the aforementioned 140 characters).

Twitter users can enable a geolocation service thus providing information about which place on earth they tweet from. This particular feature has

[50] Marshall Louis REAVES – Sunita SINHA – Joshua D. RABINOWITZ – Leonid KRUGLYAK – Rosemary J. REDFIELD, "Absence of Detectable Arsenate in DNA from Arsenate-Grown GFAJ-1 Cells." *Science*, vol. 337, 2012, no. 6093 pp. 470–473.

[51] An interesting discussion on the use of Twitter as a tool for teaching has been presented by Eva Kassens-Noor in her article: Eva KASSENS-NOOR, "Twitter as a Teaching Practice to Enhance Active and Informal Learning in Higher Education: The Case of Sustainable Tweets." *Active Learning in Higher Education*, vol. 13, 2012, no. 1, 9–21; Ben LOWE – Des LAFFEY, "Is Twitter for the Birds? Using Twitter to Enhance Student Learning in a Marketing Course." *Journal of Marketing Education*, vol. 33, 2011, no. 2, pp. 183–192.

been used by a team led by Adam Sadilek of the University of Rochester. The description of the project includes:

> Given that three of your friends have flu-like symptoms, and that you have recently met eight people, possibly strangers, who complained about having runny noses and headaches, what is the probability that you will soon become ill as well? Our models enable you to see the spread of infectious diseases, such as flu, throughout a real-life population observed through online social media.[52]

Utilizing Twitter users' activities consisting of simply informing that one has the flu, or certain symptoms of the disease, the researchers developed a probabilistic model which can very precisely predict how the disease would spread in a given the area.: "Our model is highly scalable and can be used to predict general dynamic properties of individuals in large real world social networks".[53] The team examined nearly 16 million tweets published by users residing in the New York City within a month (starting from 18th May, 2010). Figure 2 is a printscreen with the visualization of the research results which was published in the video entitled "Spread of Flu in New York City: Second-By-Second Over One Day".[54]

Building such models without the use of the data from social media would be impossible. Scientists merely use the information that users voluntarily share on the Internet. Of course, they do not do it the same way as volunteers in the Citizen Science – those do it deliberately and know what project they are participating in – and rarely are the volunteers themselves analysed. Users whose posts were used in Sandilek's study "simply" published their posts – not knowing that they became "test subjects" of a sort. Of course, this raises a number of ethical and moral problems, which science in the age of social media will have to face.

[52] Adam SADILEK, *Research Overview* [online]. 2012. Available at: <http://www.cs.rochester.edu/~sadilek/research/> [cit. 9. 11. 2012].
[53] Adam SADILEK – Henry KAUTZ – Vincent SILENZIO, "Predicting Disease Transmission from Geo-Tagged Micro-Blog Data" [online]. 2012. In: *Twenty-Sixth AAAI Conference on Artificial Intelligence.* Available at: <http://www.cs.rochester.edu/~kautz/papers/Sadilek-Kautz-Silenzio_Predicting-Disease-Transmission-from-Geo-Tagged-Micro-Blog-Data_AAAI-2012.pdf> [cit. 8. 11. 2012].
[54] *Spread of Flu in New York City: Second-By-Second Over One Day* [online]. 2012. Available at: <http://youtu.be/3S2rq2SKTSw> [cit. 17. 11. 2012].

Figure 2: *Visualization of the spread of influenza – the result of Adam Sandilek team's research.*

## Conclusion

Transformations of science communication resulting from the use of social media have still not been sufficiently analysed. The rapidity of the changes continuously compels researchers to pose the same questions and try to find answers to them.

The article put forward mainly the positive aspects of this transformation: open access to scientific publications, engaging citizens in the process of research and popularisation through social media. Of course, one should bear in mind that opening of science and the use of social media has many enemies. Some of the allegations appear to be unfounded. For example, the claim that opening of science will result in science being used for "bad things." Science, like any other tool, can be used for good and bad purposes – it does not depend on its availability but on the users' intentions. Similarly, there appears to be no justification for the objection that the increase in the amount of scientific information appearing in the media, due to intensification of popularisation of science, will allegedly lead to an even greater lack of understanding of science by the society. Popularisation of science is sup-

posed to serve as a means of educating the society, rather than introducing information chaos. Again, the process depends on how it is performed and is not in its "essence" bad. Identically, opening of science is not at odds with the commercialisation of research and the legal protection of authors' ideas and publications.

It should be emphasized, however, that some of the criticism concerning Open Science is most reasonable and the supporters of open scientific process should consider it. This is the case with the growing number of publications and the amount of data that result in *information overload*.[55] For many years now within a single subdiscipline so many publications and data is being produced that an individual scientist or individual research groups are not able to keep up to date with all the achievements of their own subdiscipline. This leads to the narrowing of focus and specialisation, while simultaneously an emphasis is put on the cross-disciplinary approach to research. Creating of open data repositories, dissemination of not only publications, but also information on the process of creating such publications (i.e. Open Notebook Science) in fact makes it increasingly difficult to find relevant information.

It should be emphasized that the development of social media and their impact on science and science communication cannot be deemed only positive. Already Innis wrote that each medium which becomes an extension is not neutral. These changes result in a deepening *digital divide* and an increasing gap between the *digital natives* and *digital immigrants* (this distinction was introduced by Marc Presky).[56] This means that scientists who do not have access to modern equipment and do not have appropriate media competence to operate them are beginning to be excluded from the information loop. Moreover, the scientists who started working when the internet was not as popular (such as users called *digital immigrants*) face more problems than the younger generation growing up now, surrounded by computers (such users are called *digital natives*).

[55] *Cf.* Martin J. EPPLER – Jeanne MENGIS, "The Concept of Information Overload: A Review of Literature from Organization Science, Accounting, Marketing, MIS, and Related Disciplines." *The Information Society*, vol. 20, 2004, no. 5, pp. 325–344.

[56] This division shows that the use of modern solutions in all the processes of communication can lead to the exclusion of potential users due to the lack of adequate competence, computers, new devices such as smartphones and tablets. See Marc PRENSKY, Digital Natives, Digital Immigrants: A New Way to Look at Ourselves and Our Kid." *On the Horizon*, vol. 9, 2001, no. 5, pp. 1–6.

In addition, it should be noted that new tools appear very often, which makes it extremely difficult to determine what should be of interest to a scientist for scientific reasons and what is just a temporary fashion. This – together with the emergence of new bibliometric indicators based primarily on online databases (e.g. the h-index, the h5-index) or alternative metrics (e.g. the number of tweets) – means that the evaluation of scientific work begins to concentrate not on its quality, but on the amount determined by the number of clicks, displays in relevant programs and services.

However, referring to the analysis and the conclusions developed by the researchers of the Toronto School, it can be said that the changes taking place in science under the influence of the social media will eventually transform the whole process, regardless of whether we like it or not. Just as the invention of writing resulted in e.g. the transformation of people's perception of time, so too the *social media* gives a part of science away into the hands of non-scientists. And it does not matter whether it is right or not – because from the perspective of the "medium" such a criterion is unfounded (we ought to remember that in terms of technological determinism, it is not important "what" is being said, but what it is said through).

Considerations on the use of new tools in the scientific process shows that social media can have an impact on the way science itself is conducted. Referring to the concept of paradigm (the disciplinary matrix) as phrased by Thomas Kuhn, one can say that the elements of a scientific paradigm are transforming. Tools such as Twitter, alternative metrics or blogs do not have a major impact on such components of the disciplinary matrix as symbolic generalisations, metaphysical presumptions, exemplars[57]. However, under the influence of new media, the fourth component of paradigm, i.e. values, undergo a slow but noticeable change. Values refer to not only the ways of predicting and evaluating of theories, but also to such issues as whether science should be socially useful, or whether scientific results should be communicated in an understandable, if in some cases simplified manner. Within these paradigm changes, scientists need to develop a way to communicate research results. On the other hand the emergence of social media means that "internet visibility" of studies is not an additional value, but becomes a necessary condition.

Finally, one more conclusion can be drawn. The use of social media in science communication does not result in a rejection of the traditional

[57] Thomas S. KUHN, *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press 1996.

media which were used so far. Publication of criticism on scientific blogs does not mean that criticism does not appear in journals, posting preprints in Open Repositories does not mean that people stop buying books, and using data from Twitter does not render other kinds of phenomena predictions less important. A certain convergence of media has occurred in science communication. It leads to the "old" media being replaced with the "new" ones. Henry Jenkins, in his book *Convergence Culture: Where Old and New Media Collide*,[58] has demonstrated that the new media coexist with the earlier ones – this is the convergence which we can perceive in science. Twitter is used for conversations and comments on texts published in journals, blogs are used to comment on books, whereas Facebook is used to talk about the experiments described in the *Open Notebook Science*. In order to describe and understand these phenomena researchers first need to scrutinize the media themselves, before the "scientific content" transmitted through them can be analysed.

[58] Henry JENKINS, *Convergence Culture: Where Old and New Media Collide*. New York: New York University Press 2006.