

Towards E-science: Scientific Communication on the Verge of Paradigm Change

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Abstract. *Information and communication technology (ICT) has a great influence on scientific communication and work of scientists. Globally, scientists are experiencing changes in ways in which they create, find, share, process, store and use scientific information. They communicate in electronic environment with their colleagues, publish their works in electronic journals and store them in digital repositories and create virtual scientific communities. However, all aspects of scientific communication on the Internet are still not known, and require additional research. This paper offers an insight into number of aspects of communication between scientists at the Faculty of Social Science and Humanities in Zagreb.*

Keywords. Scientific Communication, E-science, Croatia, University

1. Introduction

Information and communication technology (ICT) has a great influence on scientific communication and work of scientists. Ways in which research is conducted have changed; science has become more highly collaborative, network-based, and data-intensive. To conduct their research more effectively scientists need modern information resources which would support their efforts and facilitate better communication with their colleagues. The traditional system of scientific communication and its important component, scientific publishing, are now over 300 years old and it has become clear that they should be changed to meet information needs of modern scientists. Their daily work depends on exchange of scientific knowledge, which is cumulative, and this accumulated knowledge has been communicated through the ages primarily via scholarly publishing [9]. The existing system of scientific publishing is experiencing pressure for

change under the influence of the exponential growth of information production, the dramatic increase in subscription fees, the increasing storage cost of printed documents, and the increasing power and availability of digital technology [13]. ICT have transformed the way in which scientists conduct literature reviews; access research libraries; collect, store and mine research data; publish written research outcomes; communicate with editors and publishers; apply for grants; exchange preprints and reprints; and maintain informal networks with their peers [6].

Changes in all areas of scientific endeavor contribute to the transformation of the paradigm of scientific communication. The new paradigm should offer more ubiquitous access to the scientific information, easier publishing of results of the scientific research, easier exchange of information and know-how among scientists and permanence of information in digital environment. None of these changes should compromise the quality of scientific research which will progress as more quality digital information resources become available online. Except for the global level, changes occur on the local level, the level of university or faculty. This paper will present results of the research among the scientists at the Faculty of Humanities and Social Sciences in Zagreb (Croatia) about habits and changes in their communication in digital environment in order to establish their viewpoint regarding influence of the ICT on the scientific communication paradigm change.

2. Impact of information and communication technology on scientific communication

In many cases the ICT improved the system of scientific communication. To prove this, Costa and Meadows investigated the impact of usage of computers on the scientific communication among social scientists in Brazil and UK and

found out that computer usage introduced greater interactivity among scientists and that the ICT increased information exchange with known contacts, but also the making of new contacts within scientific community [2]. Another research showed that the Internet has made it easier for researchers to locate, make contact with, and respond to contact from, scientists who were previously unknown to them [6]. For other authors, like Haythornthwaite, the Internet can be a limiting factor in the scientific communication. She investigated social networks among scientists and found out that the Internet may be the means for exclusion of those scientists that don't use it. Those without the means to access it are excluded from its information [8].

Owing to the ICT and existence of online information resources such as digital libraries and digital repositories, scientific communication has proliferated because new opportunities are presented for faculty, staff, students, and even the university community as a whole, to share their work with a number of people without the reliance on the traditional publishing venues [7]. The widespread availability of digital content is creating opportunities for new forms of research and scholarship that are qualitatively different from the traditional way of using academic publications and research data [1]. For instance, while in a traditional library scientists personally browsed library collections by using catalogs and took books off the shelves, in digital libraries computer programs perform role of agent for people in extracting small parts of the digital library collection and scientist rarely view individual items [1].

The Internet has also influenced development of scientific journals, still most valuable media for dissemination of scientific information. We are witnessing greater acceptance of electronic publications stimulating gradual change in perceptions of prestige and priority for established journals [14]. The Internet and its use in scientific communication brought about a new change related to journals and journal articles. Until recently, the scientific article has been a basic unit of communication. Today, sets of data or datasets are becoming as valuable as research articles, which in many cases could be considered as interpretations of data [4].

This perpetually increasing quantity of digital content of scientific nature requires adequate preservation. Moghaddam investigated archiving of scientific electronic journals and concluded that the content of digital files may be lost to

future scientists because the physical item deteriorates, the information cannot be extracted and interpreted correctly and because of the short lifecycle of digital media and obsolescence of the technology used. The format of the digital resources can be damaged or lost and may no longer be intact, retrievable, understandable, or displayable [15]. The solution to this problem can be found in form of digital repositories. Digital repositories are digital archives of the intellectual product created by the faculty, research staff, and students of an institution and accessible to end users both within and outside of the institution, with few if any barriers to access [10]. More details about digital repositories will be given in the following section of the paper.

3. Towards E-Science

Scientists and librarians are looking for a replacement or at least an enhancement for scientific journal, the information resource that have been defining scientific communication for centuries, and / or delivery of the content published in journal to the place of scientists' work. Technological change that happened in science had the most rapid impact in the science-based disciplines, where academics are most comfortable with technology and are often actively at the forefront of developing technological means to support their research [11]. In the last couple of years, involvement of ICT in collaboration of scientists is known as e-science. E-science is referring to scientific activities supported by high bandwidth computer-mediated telecommunications networks, and particularly to encompass the variety of such digital information-processing applications that are expected to be enabled by the grid i.e. the general purpose network technology which will serve to facilitate new, computationally intensive forms of scientific inquiry [3]. E-science offers better support to collaborative science i.e. the ability to have broader interactions through the sharing of data, experimental approaches and both intermediate and final results in systems that will maintain a history of the data, processes, outcomes and conversations among scientists [18]. For e-science to be successful, new infrastructure is necessary. This infrastructure includes collaborative activities that combine the abilities of distributed groups of researchers in order to achieve research goals that individual researchers or local groups could not hope to accomplish

[17]. It also incorporates digital repositories, as the next feasible solution to the problem of collecting, organizing, storing and using peer reviewed scientific content as well as research data.

As the number of digital repositories available on the Internet grows, world scientific community is investigating their good and bad sides in order to estimate whether they really represent an appropriate replacement for printed scientific journals. Digital repositories partially inherit the practice of printed scientific journal by offering functions of traditional printed scientific journals [16]: registration, certification and awareness. Digital repositories mirror at least three functions of traditional journals: registration – by depositing in the repository the researcher would make claim to their discovery; awareness – by constructing the repository to OAI standards the institution would ensure that the researcher's work would be found by search engines and available to their peers and archiving – the institution would be responsible for maintaining the long term archive of all the work produced by members of that institution.

These functions confirm the growing importance of digital repositories in preserving and making available research data and research papers. Digital repositories are becoming an essential component of the e-science infrastructure. The Croatian universities have already initiated development of digital repositories, confirming that they are integral part of the scientific global information infrastructure.

4. Research

Changes in scientific communication paradigm initiated by ICT have affected the whole global scientific community, and they are described in details in numerous articles and books. However, articles and books about changes in communication process between scientists in Croatia are very rare, especially about scientists in the field of social sciences and humanities. An extensive research of scientists in the field of social sciences in Croatia was done in 2003 as a part of the PhD thesis written by author of this paper (“Influence of networked information resources on development of scientific communication in the field of social sciences in Croatia”). The research presented in this paper is a follow up of the research done for the PhD thesis and a new study into changes

which ICT brought to communication of scientists in the field of social sciences and humanities. Due to the space restrictions, only selected results of the study will be presented in this paper.

Since both groups of scientists work at the Faculty of Humanities and Social Sciences in Zagreb, this research aimed at investigating parameters of their communication habits under the influence of ICT. Main objective of this research was to collect data about habits and preferences of communication of scientists at the same Faculty. The main hypothesis for this research was that employees at the Faculty of Humanities and Social Sciences in Zagreb are already involved in change of scientific communication paradigm that is taking place at other universities in the world by communicating with their colleagues in Croatia and abroad and by sharing results of their research with them. Web survey was chosen as a method of conducting the research since all scientists and teachers at the Faculty have a personal e-mail address which they must use regularly. The research started on September 16th 2009 by sending e-mail invitations to all employees at the Faculty of Humanities and Social Sciences in Zagreb who regularly participate in research and teaching process at this Faculty to collect as many responses as possible. The survey was available until December 1st 2009. The total of 151 participants filled out the online survey, 46 male and 103 female respondents (2 respondents didn't give indicate their sex). The following part of the paper will present results of the research.

The structure of the respondents was the following: Assistant (65), Assistant professor (4), Professor (19), Associate professor (14), Senior assistant (12), Senior lector (7), Lector (3), Lecturer (1), Senior lecturer (1), Professional associate (1).

In the initial part of the survey, the respondents were asked about forms of communication they used for establishing contact with their colleagues. Most of them used e-mail (148), significantly fewer respondents used social networks (43), and almost none used blogs (2). Since e-mail is a very popular method of communication between scientists, 124 respondents used this means of communication for sending their published works to other colleagues, while 102 respondents used it for distribution of yet unpublished works (manuscripts). The results clearly indicate that e-mail is still the most used form of direct

electronic communication between scientists in this research, while other and newer forms of communication like social networks and blogs are not accepted among the participants of this survey. Generally speaking, e-mail is one of the basic Internet services accessible globally; it is stable, well developed and widespread. In contrast to e-mail, social networks and blogs haven't yet proved to be as reliable and stable as e-mail. Therefore, scientists use technology which they can rely on and on which they are accustomed to.

The Internet is also used for cooperation with colleagues in joint scientific projects. 56 respondents participated with their colleagues at the Faculty in joint scientific projects, while 64 respondents participated in such projects remotely, with colleagues outside the Faculty. Finally, 53 respondents didn't use the Internet for this type of activity. Clearly, the capacity of the Internet for use in joint scientific projects communication is still underused.

The next section investigated scientists' opinions about burdening of their daily work additionally by using the Internet as communication medium. 46 respondents were burdened additionally by electronic communication, 85 didn't feel any additional burden, and 19 respondents couldn't estimate. Though significant number of respondents used ICT on daily basis without feeling additional burden, 46 of all respondents still felt that ICT is taking their valuable time during working hours. Further study is needed to investigate reasons that are causing this condition.

The next section investigated opinions about appropriateness of electronic communication for establishing contact with colleagues. 141 of them confirmed that this type of communication was appropriate for them, while only 1 respondent found it inappropriate and 5 respondents couldn't decide. Use of the Internet improved communication between scientists in case of 132 respondents, while 6 respondents couldn't feel improvement and 11 respondents couldn't estimate possible improvement. Answers in this section indicate that ICT in general and the Internet in particular have become integral part of scientists' daily work.

In spite of insufficient use of the Internet for cooperation in joint projects, scientists and teachers at the Faculty felt that communication on the Internet encouraged them to cooperate across scientific disciplines. 124 respondents were encouraged to do so, 10 didn't and 15

couldn't estimate whether there was any encouragement. Direct communication on the Internet introduced loss of boundaries between formal and informal communication in science. 57 respondents confirmed perception of loss of boundaries between formal and informal communication, 56 claimed that there wasn't any loss of boundaries and 36 couldn't decide.

Printed journals have been and still are main communication channel in almost all scientific disciplines. The next part of the survey presents scientists' opinions about use of printed and electronic journals for research.

Table 1. Type and frequency of use of professional and scientific journals

	Printed journals (N)	Electronic journals (N)
Never	0	1
Very rarely	6	10
Rarely	3	5
Sometimes	19	28
Often	38	38
Very often	66	50

Table 2. Criteria for choosing journals for reading (multiple answers)

	Printed journals (N)	Electronic journals (N)
Relevance to the area of my work	127	118
Informative value of articles	90	95
Novelty of articles	66	89
Accuracy of information	77	64
Publisher reputation	53	44
Professional reputation of publisher	40	28
Reliability of journal	94	83
Fact that my colleagues publish in this journal	50	31

Results in Tables 1 and 2 suggest that electronic journals are well represented and used among the participants of the survey. They were very precise when choosing criteria for use

(reading) of printed and electronic journals. In addition to printed format, journals are distributed electronically, on the Internet in form of full text databases and digital repositories. 106 respondents used full-text databases on the Internet and more than a half of the respondents used digital repositories (more details about the last result can be found in Table 3).

Table 3. Use of digital repositories (at other universities in Croatia and abroad)

	N
Yes	74
No, because I don't know what a digital repository is	35
No, because digital repositories are not accessible to me at my working place	0
No, because (state your reason)	19

74 respondents used digital repositories, 35 didn't used digital repositories and 19 respondents gave additional reasons for not using digital repositories: there isn't any repository relevant for my field of work; didn't need repositories so far (multiple answers); I have sufficient information even without access to digital repositories; inadequate ICT literacy; I'd have to investigate whether they offer papers related to my work, however, this may take some time; there aren't many open access repositories in my field of work; they don't offer content relevant for my work (multiple answers); I don't know what they offer; I intend to use them in future; I use them sometimes but not every day; my PC is too old. In the last 15 years digital repositories have become relevant source of information for scientists. Scientists who still aren't acquainted with the existence of digital repositories should be informed about their characteristics and values. Problems suggested by 19 respondents who are aware of the existence of digital repositories but are still unable to use them should be solved since digital repositories offer not only journals articles and books but also research data. Today, research data are especially important as starting points for new research.

Use of digital information resources can save significant amount of time during preparation and performing of research. 61 respondents saved time during preparation and conducting the research significantly, 46 partially, 13 could estimate how much time they saved, 3 didn't save any time but were close to the expected

amount of time used, and 4 respondents needed even more time than initially expected.

Digital repositories are gaining popularity among scientists who want to publish their articles in this networked information resource. Scientists and teachers at the Faculty of Humanities and Social Sciences in Zagreb were asked whether they would publish their works in digital repositories. 72 respondents would publish their work in a digital repository unconditionally, 5 would do so under explicitly stated conditions, 5 respondents would publish in a digital repository, 15 claimed that they didn't know what digital repository is, and 26 would like some kind of protection of their work and material compensation for publishing in digital repositories. Permanence of published scientific information will determine future development of communication channels in science. Scientific journals have been transferring scientific knowledge for over 300 years, and we expect that digital repositories will offer long term preservation of scientific knowledge and open access to it.

As a final confirmation of their opinion regarding printed resources of scientific information being replaced by the electronic resources, 20 respondents answered that electronic resources could replace printed, 74 respondents thought this is not possible, and 33 respondents couldn't estimate whether this is possible.

5. Conclusion

There is no doubt that the global system of scientific communication is undergoing a major change, the change towards more collaborative, networked science. The Croatian scientists are part of the global scientific community and they are already participating actively in this transformation by communicating with their colleagues on the Internet, by using electronic information resources for research and teaching, by exchanging their research with colleagues on the Internet and by determination to publish their works in digital information environment. The main hypothesis that employees at the Faculty of Humanities and Social Sciences in Zagreb are already involved in change of scientific communication paradigm that is taking place at other universities in the world by communicating with their colleagues in Croatia and abroad and by sharing results of their research with them was confirmed by this research. Yet, some

aspects of their communication require additional research like reasons for their reluctance to publish in electronic journals and in digital repositories which are very important for the future of scientific communication and possibility of more intensive use of the Internet in joint scientific projects with colleagues in Croatia and abroad.

6. References

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