

Transformation of the Forms of Scientific Communication in a Historical Retrospective

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Abstract—The paper is concerned with the study of transformations of historical forms of scientific communications and the prerequisites of their development. The authors analyzed the main general historical stages: Antiquity, Middle Ages, Renaissance and the New Age, XX-XXI centuries. In this paper, the authors studied the informal intellectual communication scientists and revealed that this form of scientific communication is an important role for the development of the scientific knowledge. The authors highlighted the main historically established forms of scientific communication and traced their qualitative transformation.

Keywords—*scientific communication; scientific knowledge; informal communication of scientists; information society; scientific revolutions*

I. INTRODUCTION

Communication is vital for the correct development and functioning of the scientific community. In the process of scientific communication, there is a discussion of interesting questions presented in the form of a report or paper, contributing to the development of scientific knowledge and the formation of a scientific picture of the world.

Turning to history, it can be noted that already in the Middle Ages attempts were made to formalize the process of scientific communication. At the European universities of that time, the treatises prepared by scholastics, critical notes were copied and then sent to colleagues interested in the discussion. Thus, a system of operational communication was established, based on concerted actions and the self-organization of scientific communities. Thus, the beginnings of a system of scientific communications were laid, which received in-depth development in the subsequent period.

II. TRANSFORMATION OF FORMS OF SCIENTIFIC COMMUNICATIONS IN THE HISTORICAL CONTEXT

To understand the role of scientific communication, it is necessary to analyze the historical forms of scientific communication and the prerequisites for their development, based on the main generally accepted historical stages: Antiquity, the Middle Ages, the Renaissance and the New Age, XX-XXI century.

The first stage is Antiquity.

At this time the polis culture was developing, which gave humanity two great inventions - democracy and theoretical science [1].

Euclidean geometry, Pythagorean and his school, "Dialogues" of Plato and his Academy can be designated as the first attempts to formulate the theory as a new kind of knowledge. Referring to the literature describing the life of ancient philosophers, one can find numerous stories about their travels, which they carried out with the aim of introducing knowledge that is available in other countries. The conversations conveyed events, names, scientific facts and discoveries. It is a known fact that the mathematician Thales did not leave a record of his evidence, however, telling his interlocutors any evidence, he asked only that, in passing the evidence to other people, they mentioned that it was Thales who conducted the reasoning. However, it should be noted that all the discoveries that were made in the school of Pythagorean were attributed to its founder, Pythagorean, and not to the students.

"The scientific school of antiquity was not so much a center of scientific knowledge, but rather a keeper of a certain philosophical direction, and the head of the school was the guardian of the purity of scientific tradition, this philosophical school peculiar to" [2].

At this time, a specific form of organized conversation - dialogue. Referring to the "Dialogues" of Plato, we can distinguish the following feature: Dialogue as a form of communicative process involves the formation of any thought, which must be transmitted and accepted by both participants in the dialogue, at the same time, for a productive dialogue, the willingness of each interlocutor to consider the point of view of the other is necessary. Thus, it is possible to assert with confidence that in antiquity the rules for conducting dialogue, conversation, and discussions are beginning to take shape. It is also worth noting that in the texts of the era of antiquity there are links to the manuscripts of other authors and to earlier sources.

Summing up, we can conclude that the norms of oral communication are formed in antiquity, and the first handwritten books with scientific texts appear [3]. The next stage in which we will continue to consider the development of forms of scientific communication will be the Middle Ages (XI-XV centuries). The peculiarity of medieval philosophy is a special understanding of man, created in the image and likeness of God.

A cult of the human mind develops, capable of understanding and comprehending the mystery of divine creation, deciphering the letters that God laid into the world when he created it. The latter circumstance should be noted especially: the purpose of knowledge was precisely the decryption of the providence of God, the plan of divine creation realized in the world. The main purpose of the philosophers and scholars of the Middle Ages was the interpretation of the scriptures, which undoubtedly left a special religious imprint on the development of scientific knowledge. Formation and transfer of knowledge took place within the walls of religious schools and monasteries.

Medieval universities emerged as autonomous unions of academic teachers and students. Their activities were aimed primarily at ensuring the continuity of scientific creativity, as well as the initiation of the student to research work. These goals were achieved by three main principles - the fullness of scientific knowledge, freedom of teaching, self-government [4].

Lectures at universities were mostly read from books written in the era of antiquity. In addition, disputes become an integral part of education, the holding of which contributed to the development of the theory and practice of conducting discussions as a form of scientific communication. At the end of the course, the necessary condition for obtaining a degree was the participation of a student in a public dispute: the student would submit theses for protection, to which he was offered objections, and he had to respond. The atmosphere of the debates was very emotionally intense, which often led to clashes, sometimes even with the use of physical force.

Medieval studies in conducting studies traditionally took place at monasteries, when a teacher could demonstrate to a student the basic principles of conducting an experiment. In addition, training in religious communities contributed to the reproduction of knowledge and education of teachers. Thus, during the Middle Ages, the following steps were taken to

form scientific communication: the translation of books from one language to another, the appearance of typography in the XIV century, which later had a great influence on the authors' abilities and communication style [5].

The next stage is the Renaissance, smoothly passing into the New Age, which is characterized as the time of "scientific discoveries". "In the Renaissance, many of the achievements of the ancient tradition are being restored, but this changes the attitude to the idea of the likeness of man to God. For example, M. Kopernik did not just introduce a new heliocentric system of planets location for his time, but thought about the possibility of changing the position of a person in the World in relation to God. The image of the world is affirmed as a simple mechanical system of watches that God once started" [6].

The Renaissance was the starting point for the development of technology and technology. This era is characterized by a fundamentally new attitude to knowledge: to know, not just to know, but to know, in order to apply this knowledge. A striking example of this thesis may be related to mathematics. On the one hand, without the knowledge of mathematical tools, it would be impossible to study theoretical sciences, on the other hand, mathematics is the basis of architecture, which speaks of its practical utility.

Speaking of mathematics, it is also worth noting the emergence of mathematical disputes, participation in which provided the winner fame. The university's community of scholars and professors transmitted classical ancient knowledge of philosophy, theology, and the beginnings of arithmetic. Practical tasks and research in the field of natural science were mainly dealt with by amateurs - quite wealthy people.

In the science of the 17th century, the book (book, manuscript) becomes the main form of consolidation and transmission of knowledge, which sets out the fundamental principles and principles of the "nature of things". The book becomes a means of fixing the new results of nature research. In addition, it is becoming a significant addition to the traditional system of teacher-student direct communication, a new form of communicative interaction that ensures the transfer of knowledge from teacher to student "here and now".

"The scientists of the 17th century faced a very difficult task. It was not enough for him to get any particular result; his "duties" included building a complete picture of the universe, which should find its expression in a fairly voluminous folio. The scientist was obliged not only to make separate experiments, but to engage in natural philosophy, to relate his knowledge to the existing picture of the world, making the appropriate changes" [7].

In accordance with this scheme, all the outstanding thinkers of this time worked - I. Newton, G. Galileo, R. Descartes, G. Leibniz, etc. The development of science led to the need to form such a form of scientific communication that could ensure joint discussion by scientists not only final and specific tasks, but also intermediate results of research. In the XVII century, a special form of consolidation and

transfer of knowledge - the correspondence between scientists. The letters exchanged by scientists included the results of the study, as well as a description of the way they were received. Thus, the letters turned into a scientific message, which presented the results of individual studies, their arguments and discussion, as well as counter-arguments. The correspondence between scientists was systematically conducted in Latin, which contributed to the translation of results, ideas and reflections among scientists living in various parts of Europe.

“One example is the circle of M. Mersenne, who was essentially the coordinator of European scientific life during the first half of the seventeenth century. The members of this group conducted an active correspondence with almost all the prominent scientists of the time: M. Mersenne’s 78 correspondents were G. Galileo, R. Descartes, B. Pascal, P. Gassendi, Pierre de Fermat, P. Cavalieri, H. Huygens, G. Roberval, E. Torricelli, and many others. During his long stay in Paris, he had weekly meetings (“Thursdays of Mersenne”) meetings of mathematicians and physicists took place. The purpose of these collections was the mutual exchange of thoughts and reports of the results obtained in the studies undertaken. Later, Paris Academy of Sciences was formed from this group with the assistance of Jean-Baptiste Colbert” [8].

This is how a special type of community arises, which has chosen the letter that unites European researchers into the so-called “Republic of scientists” (LaRepubliquesLettres) as the main means of scientific communication.

The republic of scientists served to designate the community of Europeans, bringing together thinkers in different countries of Europe.

Correspondence between scientists was not only a form of knowledge transmission, but also served as the basis for the formation of new research tools.

The thought experiment received its consolidation as a sensible research technique precisely due to the correspondence of scientists, when in the process of describing a real object it turned into an idealized object that did not coincide with the real object.

In the second half of the 17th century, communities of research specialists formed in various countries, often supported by public opinion and the state. A community of German chemists is an example. This community was one of the first national disciplinary associations of researchers that took shape in Germany by the end of the 18th century.

Science theorist V.S. Stepin wrote about the community as follows: “At the end of the 18th century, Germanic chemists formed a single community. They began to treat each other as indispensable colleagues and main arbiters in all that relates to scientific truth and personal achievements” [9].

Gradually, the correspondence loses its status as one of the main unifying researchers. A multitude of national disciplinary-oriented communities appears, replacing the

“Republic of Scientists”. Internal communication in these communities proceeds much more intensively than external.

The first scientific journals that appeared in the second half of XVII almost simultaneously in 1665 are the *Journal des savants* in France and the *Philosophical Transaction* of the Royal Society in England.

With the advent of scientific journals, the paper acquires special significance. The main advantage of the paper in relation to the book is that it is smaller in volume; it does not need to present the entire system of views, which means that the time for its publication is significantly reduced. The paper becomes a new form of consolidation and translation of a new scientific result, demonstrating the scientific interests of a research scientist. In order to preserve new knowledge in culture, it is necessary to consolidate it in a text that would be accessible to researchers in various fields of knowledge. The article successfully solved this problem.

The old language of scientific communication - Latin - is gradually giving way to the generally accessible national language, which is transformed thanks to special terms, a special system of scientific concepts. In the language of scientific communication. It allows an ever-wider circle of researchers to be acquainted with the scientific results obtained and include them in your own research [10].

As for the advantages of a scientific paper over such a form of communication as a letter, the main thing will be that the paper is focused not on a specific reader (subscriber), but on a certain circle of specialists and interested persons. In view of this, the author of a scientific article should more carefully select arguments to substantiate the assumptions.

Only by the middle of the XIX century, the paper acquired the functions in which it is represented in the modern scientific community. This is because during this period there is an intensive formalization of the disciplinary organization of science [11].

The paper began to act as one of the dominant forms of knowledge transmission, while maintaining a connection with previous knowledge, since writing it implies pointing to sources — links, while being an application for new knowledge.

The appearance of the article gave impetus to the creation of periodicals, their organization and publication. Initially, they performed the functions of integrating research scientists in order to demonstrate the results of their activities. Scientists and researchers working in various fields of scientific knowledge are beginning to unite in scientific societies (chemical, biological, physical, etc.). New forms of organization of science generated new forms of scientific communication. As the main form of knowledge transmission, scientific journals increasingly began to appear, around which scientists united in interests. For example, the journal “*Chemical Annals*” allowed intensive discussion of problems on its pages, prompting German chemists to consider each other as the main audience [12].

The development of scientific journals led to the birth of a problem associated with a priority application for a

scientific discovery through the publication of an article in a journal: the founders and editors of scientific journals began to use their official position for personal gain. One example is the accusation of misappropriating other people's discoveries made to G. Leibniz, Augustin Louis Cauchy, who received and deliberately delayed articles in order to study the issue, after which they published the results under their own name.

In connection with the intensive development of scientific knowledge, two problems arise related to the growth and volume of scientific information:

- Limited human capacity to “accommodate” a large amount of information.
- The need for special training of scientists, because the lovers of science, growing out of apprentices, replaced the new type of scientist as a type of university professor.

Thus, the special training of scientific personnel designed the special profession of a scientist. Science gradually became a profession requiring special social organization [13].

It is worth noting that the associations that emerged at the end of the 18th — first half of the 19th centuries — academies — can be considered not only the first institutions, but also the prototypes of the first scientific conferences. This fact is justified by the fact that the main purpose of the conferences is not only the presentation of a scientist with a report, but also its discussion in order to find solutions to the problems encountered.

III. INFORMAL INTELLECTUAL COMMUNICATION AS A KIND OF SCIENTIFIC COMMUNICATION

Informal intellectual communication played a special role in the development of scientific communications in the 20th century. In this context, the hypothesis of “invisible colleges” put forward by J. Price and very popular in scientific use is very interesting 1960s.

By “invisible college”, J. Price understood informal contacts between the elite of the most productive scholars within the research field. “These people make up the core, uniting all more or less well-known researchers in this field, they are able to control the funding and laboratory support of research ..., they have a decisive influence on the prestige of other scientists, on the fate of new scientific ideas, so in the end, they have the decisive voice in determining the strategy of scientific research in this area” [14].

In the 1960s N. Mullins, who argued that science was organized not as strong associations, but as a dispersed communication network, so that an “invisible college” can only be a noticeable fragment of a large network of scholar [15], criticized J. Price’s hypothesis.

At the same time, D. Crane showed that the hypothesis of “invisible colleges” does not take into account the communication between active and ordinary participants, as

well as the role of “extraneous” factors in shaping the social organization of science. [16].

In the 1990s thanks to the publications of R. Collins, who investigated communication between philosophers for two thousand years, interest in the theory of communication links in science has increased significantly.

R. Collins advanced the theory of intellectual attention space [17]. R. Collins describes science as a “field” (Bourdieu’s terminology), a space of limited attention. As a methodology, he uses a network methodology - the study of networks of teachers and students, colleagues and rivals that make up the structure of the scientific community.

According to this theory, intellectual creativity is concentrated in vertical and horizontal chains of personal contacts; it is a collective result of cognitive and cultural exchange, as well as emotional participation in science. An important component of this theory is the position that creativity is organized through the opposition and that it is rivalry rather than unity that stimulates creativity.

Thus, the presence of “leading” theoretical schools is considered through the analysis of the interaction of scientists and the constellations of rival groups. This theory in a new way raises the question of what laws distribute attention and recognition in science. The main difference of the theory of R. Collins from the theory of J. Price is the idea of several structurally competing groups. Many representatives of the scientific community note the high role of informal communication in the development of scientific knowledge, the presence of “invisible colleges”.

For example, Russian scientists claim that they could hardly have taken place as scientists without talking in the corridors of the institute, in “intellectual kitchens”, without a lively and informative discussion of scientific problems at home, public and cathedral seminars. The home seminars of V. A. Lefebvre, A. A. Lyapunov, V. S. Bibler, and G. P. Shchedrovitsky were widely known.

As noted, in connection with the increase in the amount of information and the need to systematize the processes of development of scientific knowledge in the late 50s - early 60s. There is a massive study of the system of scientific communications by representatives of various scientific disciplines: psychologists, sociologists, and computer scientists [18]. This trend was due to the problems of the so-called “information explosion” and the development of the information revolution.

IV. CONCLUSION

Because of the study, the following forms of historically established types of formal communication can be distinguished.

A. Letters

Since the times of Antiquity, the basic way of communication between scientists was letters. There were not so many scientists, and the news was spread in a rather narrow circle. One example is the theory of probability,

which was born in the correspondence between Pierre de Fermat and B. Pascal. The number of scientists increased, and it became increasingly difficult to reach everyone in the correspondence. In the second half of the XVII century. M. Mersenne succeeded in this, J. Bernal called it “the main post office” for scientists from all over Europe. Nevertheless, such extensive correspondence is not for everyone. Gradually, personal correspondence lost its importance for scholars, books replaced it.

B. Typography

There were more and more people involved in science, respectively, and the number of books grew exponentially. In a large number of books written, knowledge appeared fragmented, it was necessary to integrate scientific knowledge.

C. Scientific Journals

The first scientific journal, which appeared in the XVII century, can be considered “Scientific Notes of the Royal Society”. They were qualitatively different from modern scientific journals, they published various reviews, preliminary reports of unfinished research, abstracts. Widespread in the XVII - XVIII centuries. Received “Magazines for letters”, the purpose of which was to familiarize various specialists with the ongoing research. Recognized genre of scientific communications was “Letter to the Editor” In the XIX century. Scientific journals as a kind of scientific communication took the leading position; however, the standard view in which each new paper developed and supplemented the provisions expressed in previous publications, and thus became the foundation of the research, these journals acquired only in the twentieth century.

At all times, the publication of research results was a priority application for scientific discovery. The impetus to the transformation of forms of scientific communication was the rapid development of information arrays in the 60s of the twentieth century. This “information explosion” led to the information revolution of the 80–90s of the XX century and the formation of the modern information society [19]. A society based on knowledge, where the intellectual capital of an individual becomes the dominant value, which he realizes and improves with the help of modern information and communication technologies.

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