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CHARACTERISTICS OF SCIENCE AND SCIENTIFIC ACTIVITIES; CONSIDERATIONS ABOUT WHAT IS AND WHAT IS NOT SCIENTIFIC

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Abstract: *The paper deals with non-traditional, but highly needed issues: to formulate the criteria of scientific activity. It is really unbelievable that in the period of information and scientific society there is a lack of such criteria and the assessment of scientific activities is totally voluntary. In the presented paper the authors have tried to propose the attributes of scientific activities.*

Keywords: ***Characteristics of science, basic scientific fields and branches, scientific activities, non-scientific activities, systemic methodology.***

1. Introduction

Definitions of science, scientific activities, or a scientist as a person can be formulated at various levels of knowledge, in dependence on the person dealing with these notions. In everyday life most people do not need to deal with their definitions at all. In a general meaning, the science is understood as something connected with some hardly understandable theories, activities related to these theories are scientific activities, and a person dealing with science is called scientist.

Another situation exists in the professional community of scientists who are frequently confronted with these notions because of various reasons. Either they „practice“ the science as a professional activity or they judge the results of a scientific work of someone else.

In any case they need to have a certain opinion concerning the notions scientific activity and science. There are someones who think everything to be clear, and any discussion dealing with these terms to be unnecessary, or even audacious and provocative. For „more contemplative“ scientists, thinking about the discussed notions may bring problems, growing sometimes to a stressing, traumatizing or even frustrating situation. A responsible answer to the questions what is the science or what is a scientific activity requires a complex of informational, creative, evaluating and decission-making activities (Janíček, 2007).

What was the motivation of the authors to write this paper? First, a personal one: they found out that the answer is not unique and unambiguous in literature sources and also the interviewed scientist were not able to formulate clear and satisfactory answers. Second, there is an objective reason: if there is a tendency to unify anything throughout the EU, a unification in such an important field like decission (judging) whether a certain activity is really scientific or not is highly needed. Shortly, also the rules in fhe field of the science should be unified, not only in Europe but in all the world.

The authors express there oppinion that these reasons are sufficient for an attempt trying to fill this lack and to formulate some criteria for activities to be „scientific“, with the aim to make possible an objective decission what is and what is not scientific. The authors base their paper on a systemic approach, it means they started with a literature search about science, they evaluated a number of facts concerning science, they selected their substantial features and in this way they formulated attributes of science and scientific activities. Their effort aimed at achieving objectivity of their decissions.

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2. Comprehensive characteristics of science

A solution to the problematic situation requires informational, creative, evaluating or decission-making and executive activities. In other words, first it is necessary to collect information about what is considered to be a science nowadays, then it is necessary to process this information and to make a decission in a creative way about how a comprehensive characteristic of the science could be formulated on their basis.

As an representative example of various definitions of the science let's cite M. Spala, (2006) „*Science is a systemic observation of natural effects and states with the aim to find out the characteristic facts and, consequently, to formulate laws and principles based on these facts.*" It is evident that the author is natural scientist and science in this definition is limited to this field. And what about the other scientific fields?

On the basis of comprehensive analyses of actual definitions of science and from analyses of the philosophy of science (Feyerabend, 1980; Spala, 2006; Fajkus, 2005; Marshack, 1972) it was shown the following notions are used in these definitions: a durable and critical effort, an activity, a veritable and general cognition, a compilation of true pieces of knowledge, truthfullness, accuracy, possibility to be verified, structured, proved and systemic investigation of something novel, application of scientific methods, unavoidable role of the ethical community of scientists (the concept used and defined in (smolin, 2006)), applicability, etc. Consequently the following characteristics have been summarized:

Science is a human activity with the following characteristics:

❶ Science is a durable, targeted, creative, structured, organized and mostly collective **activity of persons (scientists)** having a form of investigation and cognition and a character of real as well as abstract and **mutually interconnected processes**; they start by formulation of hypotheses, continue through their testing (transformation of hypotheses into theories), and may be concluded by participation in applications of the results of these activities.

❷ The objective of science is a durable acquiring of **primary novel scientific pieces of knowledge** about everything being part of the known Universe, i.e. all entities either natural or man-made; this fact defines the science as a **multi-element system** with various fields and branches.

❸ The science applies the scientific methodology in its cognitive processes, as a summation and intersection of various **scientific methods**, theories, approaches and algorithms.

❹ The scientist aims at the **verity of the scientific pieces of knowledge** and they do their best in the investigation process to ensure this in the terminal phase of the scientific cognition.

❺ The science verifies the **validity of scientific hypotheses** and **credibility of scientific pieces of knowledge** in two different ways:

① by suitable, specific branch oriented **testing processes** (testing of statistical hypotheses, verification, falsification),

② the oppinion of the **ethical community of scientists** about the content, methodology, methods, algorithms and results of the scientific investigation.

❻ The decissive arbiter for judging what activity is accepted as scientific is the oppinion of the **ethical community of scientists**, under consideration of all their specific features.

It holds that there is no limitation concerning the specific **field of human activity**, in which the scientific investigation is carried out in the sense of the above characteristics of science. Also the **grade of practical applicability** of scientific pieces of knowledge is no characteristic of the science and can be very different. However, a practical application of the scientific pieces of knowledge is considered to be positive, because it represents an objective benefit ensuring a development of the society.

3. Scientific methodology

In general, the **methodology** is defined as a discipline dealing with **methods** (a coherent set of rules and descriptions of verified procedures how a certain problem can be solved with certain SW and HW instruments) and **method algorithms** for a certain field of human activities. **Scientific methodology** uses to be understood as a theory of scientific methods and algorithms. It develops the methods of formulations of scientific problems, their multifactorial analyses, verification of hypotheses, creation of theories, ways of solutions to scientific problems, realization of cognitive processes, etc. According to the authors' meaning, the following equation can be formulated:

***Scientific methodology = systemic methodology*.**

To formulate such an equation is one thing but the problem is how to substantiate its validity. Let's make an attempt to do it. The systemic methodology is a generalized, it means interdisciplinary?? methodology for any real or abstract system. It is a methodology of the theory of systems, which can be defined as follows (details (Janicek, 2007)):

The systemic methodology *is and abstract subject, the structure of which is created of systemic approach and thinking, systemic methods and algorithms.*

Since the time of its birth, i. e. approx. the year 1950, nobody has disputed against the theory of systems as a component part of scientific cognition. In other words, the community of scientists has accepted this theory as scientific. Consequently, the systemic methodology can be considered to be scientific as well.

The systemic methodology is based on the **systemic approach** ((Janicek, 2007, p. 12). This approach is actually considered to be a generalized creative (inventive) methodology of thinking and activities, applicable on abstract as well as real entities, with systemic attributes being its fundamentals. However, the actual situation in relation to the systemic approach is more proclamative than user-oriented; it is seldom really applied. Everybody is speaking about it, somebody is thinking to apply it; in fact, however, there is a lack of its full-valued aplications.

The **systemic methods** can be overviewed as follows: ① system of logical methods, created by intersection of these paarwise methods: induction – deduction, analysis – synthesis, abstraction – concretization, ② experimental methods, ③ modelling (in its material or abstract forms), ④ statistical methods. These methods are scientific, it means appreciated (accepted) by the community of scientists.

4. Truthfullness of the scientific pieces of knowledge

The philosophical cathegory „t**ruthfullness"** is a component part of nearly all partial definitions of the science. Commonly it is used in the sense of identity between the results of the cognitive process and the objective reality (see the term testing procedures).

Important note: If we insist on the above statement on „truth in the science", then an „excommunication" of some scientists (or their groups) would be a necessary consequence, namely of those trying to find evidences of truth of their hypotheses but having not yet managed it. As a particular example, this is the case of all the scientist dealing with the so called **theory of strings**. They have created a hypothesis the elementary particles of matter are not point-like objects, but their essence is „string-like"; it means their shape becomes more elongated if their energy increases and they shorten when their energy is decreasing. The ambition of the theory of strings is (in the case this hypothesis will be verified experimentally) to unify the quantum theory, gravitational theory and physics of elementary particles. The scientific community, however, have not acknowledged (confirmed) this hypothesis as a theory. Lee Smolin writes in his book (Smolin, 2006): *„String theory either is or is not the culmination of the scientific revolution that Einstein began in 1905. This kind of assessment cannot be based on unrealized hypotheses or unproved conjectures, or on the hopes of the theory's adherents. This is science, and the truth of a theory can be assessed based only on results that have been published in the scientific literature; thus we must be careful to distinguish between conjecture, evidence, and proof."*

The community of scientists considers also creation and elaboration of **scientific hypotheses** to be a scientific process, under condition they comprehend a methodology how their verity can be proven.

This fact, however, excludes the truthfullness as an explicite characteristic of the science. In other words, also those cognitive processes, which have not proven their truthfullness yet, can be considered as scientific, if an evident effort is shown to prove their verity. Therefore the par. ❹ of the above characteristics of the science cannot be formulated more strictly.

Photo : Cornelia Firsching, ČTK.

5. Community of scientists

Community of scientists it is a non-organized, voluntary group of individuals, scattered throughout the territory, which is dealing with scientific activities and representing „professing" fidelity to the ethical codex; the main idea of this codex is a rational analysis of arguments concerning credibility and verity of the scientific hypotheses and pieces of knowledge, a certain agreement with a new piece of knowledge, giving him a hollmark of a „collective credibility" or „collective correctness" (Janicek, 2007).

Note: The community of scientists is the only one relevant human arbiter of the science. This exclusivity does not mean they cannot fail; some short-term failures can occur in the following cases:

- A scientific piece of knowledge is revolutionary – a scientist presents a novel piece of knowledge, fully unknown and hardly believable to the others, so that they are not able to consider it to be a scientific benefit. This fact can be illustrated by the discovery of chemical oscilators at the beginning of the past century by Morgan and Bray, which was refused by the scientific community as a nonsense. The case of the Belousov's chemical oscilator (1951) is rather similar, he was waiting for a general acknowledgement for 17 years until Zabotinsky carried out the same expe-iment with another chemical system. Both of them became then famous scientists (Janicek, 2007, p. 1071).
- A syndrom of a collective (groupwise) thinking can occur in the community of scientists (or especially in its substantial but relatively closed part), so that some scientific pieces of knowledge are refused even when being correct. Such a situation can occur in the scientific practise (separation of the supporters of the hypothesis of strings and their refusal of the classical physics of elementary particles (Smolin, 2006), as well as in the reviewers teams of certain scientific journals.

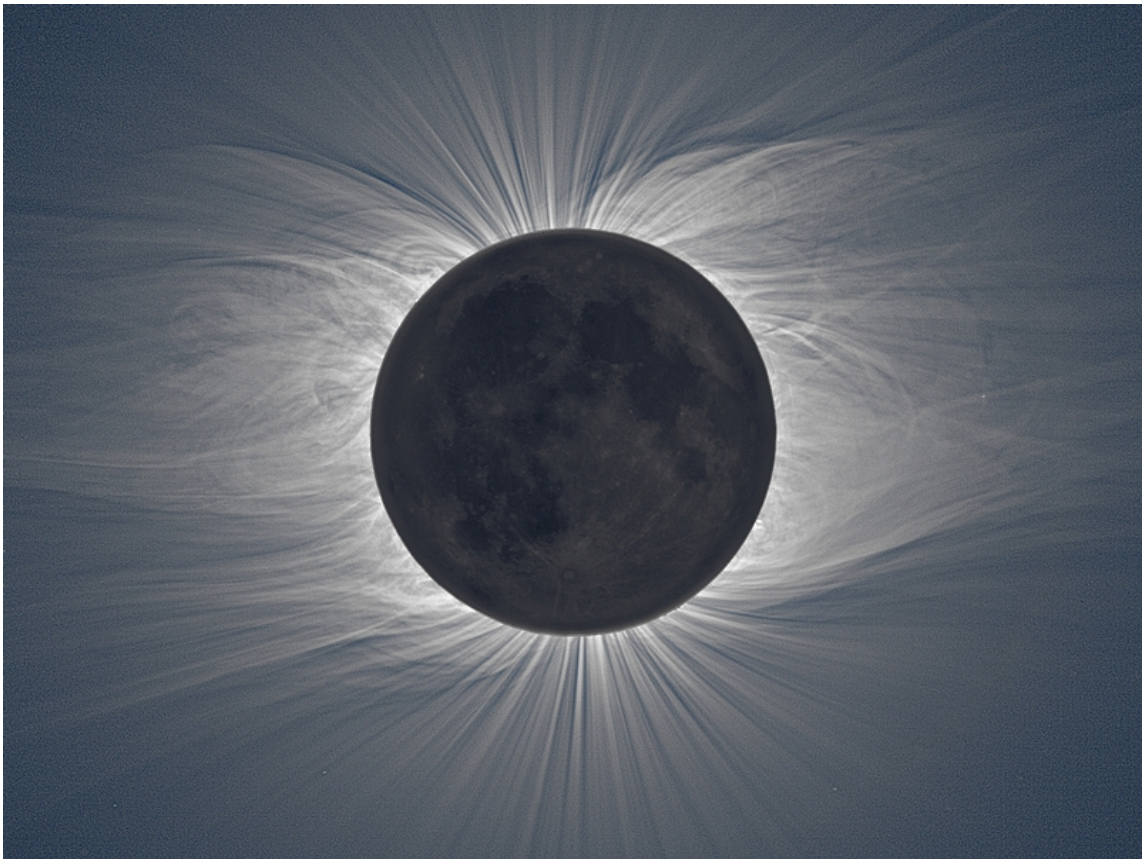
On the basis of (Smolin, 2006) we can express the following statement:

***Science** is able to function effectively **if and only if** the scientists create a community constrained and sustained by fidelity to the generally accepted ethic rules.*

The basic ethic principles of the scientific community can be expressed shortly as follows (from (Smolin, 2006)):

1st principle: If the disputation can be decided by scientists „in good faith (bona fide)“ on the basis of rational arguments applied on facts known and accessible in public, then it must be considered carefully and decided in this way.

2nd principle: If the rational arguments applied on facts known and accessible in public do not induce identical meaning of the scientists „in good faith“, then the individuals must be allowed or even encouraged by the community to deduce their own conclusions.



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6. Systemization of scientific fields and branches

The systemization of science into fields and branches can be based on various criteria, e.g., on the principle, method and object of the investigation, used in seeking for new pieces of knowledge. Here the ***criterion of the object of investigation*** is used. The authors have divided the scientific fields as follows: basic scientific fields (natural sciences), man-constituted sciences, humanities, and social, formal and complementary sciences. The grade of novelty is rather different among these fields, the first two fields aim strictly at discovering something novel, while supporting and complementary sciences contribute to discovering (however, also in these fields discoveries are possible).

6.1. Basic scientific fields

Cognitive activities are realized here with entities born and existing independently of humans. This entities are natural in the most general sense of this word. They can be divided into non-living (non-living nature) and living (living nature comprehending all organisms from bacteries up to humans). The basic scientific branches are commonly denoted as **natural sciences**.

① *Non-living entities* – can be represented by all the dead matter in the surroundings of humans, which originated without their contribution (humans have not contributed to its existence or modified it directly). By means of their creative activities, humans have constituted the following scientific branches dealing with the non-living nature: physics (astronomy), geology, chemistry and material sciences. Some of them were enhanced later to the living nature in the form of biophysics, biochemistry, biomaterial sciences, etc.

② *Living entities* – comprehend all the animated nature with a traditional division into fauna, flora and humans. The scientific fields belonging here are as follows:

+ biology (botanics, zoology, biology of human),
+ biochemistry, biophysics, organic chemistry,
+ medical sciences, as intersection of biological and social sciences, they deal with anatomical and functional changes in the human organism as a consequence of deseases, including their prevention and therapeutics.

6.2. Man-constituted scientific fields

In these fields the entities made by humans are investigated, namely these fields bring knowledge on the „second nature". Humans realize their cognitive activities within the framework of technology (technical objects) and various technological processes (production and other processes, technical as well as non-technical ones, e.g. biological processes). This has brought many specific branches into existence (agriculture, forestry). The market with various products initiated the birth of economy.

The number of these scientific branches is increasing strongly nowadays; we can mention not only all the traditional technical, technological, agricultural and economical sciences, but also bioengineering ((Janicek, 2007, p.82), e.g. bionics, biorobotics, biomechanics, genetic engineering, etc.).

It is evident that many man-constituted scientific branches apply the knowledge of the basic scientific fields to discover new facts and patterns within themselves.

Note: Those, who feel the notion "man-constituted scientific fields" to be a forced newspeek, can replace this notion by the more common „engineering sciences"; it corresponds to the original meaning of the word „engineer" (lat. „ingenium" means creation, creativity). Then engineering scientific branches are those used in creation of the second nature and to solve its problems.

6.3. Humanities and social sciences

These scientific fields deal with human beings and their society. Philosophy as well as philology plays a general role among these sciences. For illustration, social sciences comprehend sociology, psychology, politology, demography, economy,etc. Also cultural sciences belong to this cathegory, such as archeology, ethnography, anthropology, aesthetics, linguistics, etc.

6.4. Formal scientific fields

The title „formal" relates to the fact these fields use formal language (symbols, icons) in their expressions. They belong to supporting fields in the sense they support cognitive activities in the basic as well as in man-constituted branches; these scientific fields are general, applicable in all branches. This category comprehends mathematics (the language of natural and social sciences) and logics (the language of all sciences, but especially humanities). Mathematics and logics are also denoted as abstract sciences. Philosophy plays also the role of a supporting science partially, it can be understood as a methodological and critical basis of the other fields or as integration of all specialized fields and branches (theory of science).

6.5. Complementary scientific fields

These scientific fields complement not only the above mentioned cathegories of sciences, but various other professional activities as well. The following scientific branches can be included into this group: geodesy and cartography, environmentalism, technology of measuring and illumination, information systems, technical cybernetics, forensic engineering, technology of wood processing, amelioration of waters (flood protection, morphology and regulation of rivers, lakes).

Naturally, the grade of importance and scientific significance m_v of new pieces of knowledge acquired in all the listed branches is very different, higher or lower. It is extremely difficult to define the scale between more and less scientific, the authors have no ambition to be arbiters in this sense. A strict division by an exactly defined boundary line is probably even not possible.

All of the listed scientific fields, basic ones as well as man-constituted, formal and complementary, belong to concrete scientific branches.

7. Characteristics of scientific activities – what is scientific?

The comprehensive characteristic of science presented in chapter 3 has been created with the following aims:

① To offer an understandable characteristic of science, formulated with a commonly used terminology, to most individuals from all of the above scientific branches, except for „philosophers of science".

② To formulate general characteristics of scientific activities. They are important for making decissions what activities and corresponding branches can be considered to be scientific. And similary, what of them are not scientific.

③ To formulate characteristics of scientific pieces of knowledge. They are important for making decissions whether a certain paper (a written description of methods and results of some cognitive processes) can be considered to be scientific or not.

7.1. Characteristics of scientific activities

The characteristics of scientific activities (processes) defined below are based on the definition of the science in chapter 3. These characteristics can represent ***„attributes of scientific activities"***:

Basic characteristics of a scientific activity

① A scientific activity is a predominantly durable, targeted, structured, organized, individual or collective activity, having a form of investigation and cognition.

② A necessary condition of a scientific activity is its **actual novelty** in the sense of:

+ acquiring of a **novel piece of knowledge** (a primary piece of knowledge at the given time)

+ **completition** of an existing knowledge with **new facts**.

③ **Targeted motivation** for a creative seeking for new pieces of knowledge.

④ Application of the **scientific methodology** in the investigation; this can be the systemic methodology.

⑤ **Verity** of the acquired piece of knowledge confirmed by testing processes, or a scientific hypothesis including ideas about testing procedures and ways of their realization.

⑥ **Reproducibility** of the results of cognitive process.

⑦ **Approval of the** (scientific-ethic and imaginative) **comunity of scientists** that the investigative processes or their results in the form of pieces of knowledge can be considered to be scientific.

7.2. What is not a scientific activity

It is extremely important to answer this question because persons being in positions of reviewers of any scientific papers, theses, projects or other written outputs need to deal with it; it concerns proposals of grant projects, evaluation of their partial or terminal reports, as well as dissertation, doctoral or habilitation theses.

A general answer to the question in the headline is very simple:

A sufficient condition for an activity not to be scientific is violence of anyone of the characteristics of the scientific activities.

In the end, the individual „attributes of non-scientific activities" should be defined exactly. This has been done by negating the „attributes of scientific activities" in the previous chapter:

Attributes of non-scientific activities

① The activity does **not contain the element** of **„actual novelty“**, namely it does not develop the existing knowledge in any way.

② There is **no targeted motivation of seeking for „something novel“;** seek for novel pieces of knowledge is not the primary goal of the activity.

③ **Scientific methodology is not used** in the activities.

④ The activities **do not aim at verification** of the achieved results; either the hypothesis does not contain the way how to verify them or the piece of knowledge is not verified at all.

⑤ **Activities** are **non-reproducible**.

⑥ The **„community of scientist does not consider“** the concerned activities to be scientific.

Note: Consiously the first paragraph of the characteristics of scientific activities was not negated. It describes their properties, that these activities are durable, targeted, structured, organized, etc. However, it cannot be excluded that a knew piece of knowledge may be acquired by an impulsive one time cognitive activity; also this activity need not to be targeted in respect to the new piece of knowledge, because this may be acquired within the framework of a differently targeted activity as well.

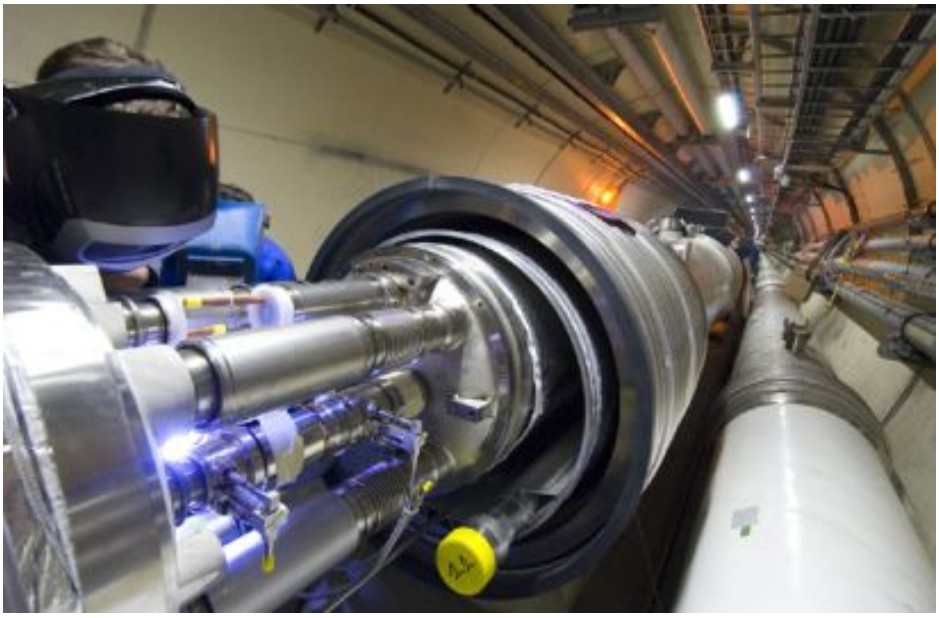

Photo : LHC in CERN (www.ct24.cz).

8. Conclusion

The proposed attributes of scientific activities should not be considered as complete in terms of content and precise scientific terminology. This paper should be considered as an opening of discussion on the issues of scientific activities.

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