How invent.
Thoughts on the methodology of scientific work

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In 1960, I sketched theses on the method of "discovery." These are sketches for myself to streamline the initial ideas about technology of scientific creativity. The outline remained unfinished, distracted by work on ARIZ. Almost 20 years have passed, but it seems to me that these thoughts are not outdated and can be used by TRIZ teachers in the classroom on scientific creativity.

In the works and articles of G. Filkovsky and I. Kondrakov, technology of creativity is considered in solving problems of "discovering new theories". Meanwhile, there are "discoveries of new phenomena" (discovery of radioactivity, etc.). Therefore useful up the presentation of the "theory of the discovery of new theories" to give an overview – this will help outline.

G. Altshuller, 1979-08-22

A. What is the difficulty of resolving the problem

1. Difficulties in creating a methodology of scientific work – compared with the methodology inventions – consist in the fact that circumstances play a big role here, complicating the main circuit. Such circumstances exist in inventive creativity. But in discovery they are present in great concentration. it no longer reservations or exceptions to fairly universal rules, but constantly operating "distorting factors" that must always be taken into account.

2. The first such factor is the historical development of scientific methods. In modern inventions still coexist peacefully at tricks that arose at different stages development. In discovery – a more rigid change of methods. Therefore, it is necessary to carefully argue with examples taken from different eras.

3. The second factor is the uneven development of scientific methods in different fields of science. This phenomenon is also observed in invention, but in science it is expressed more strongly.

4. The third factor is the relatively large role of the case.

B. Classification of Openings

5. All discoveries are divided into two groups, so significantly different in all factors that one wonders how they are united in one word. The first group is discoveries consisting in the establishment of a new phenomenon.

Example:

- discovery of X-rays by X-rays,
- discovery of superconductivity by Kemmerling-Onnes.

6. I would call this group of discoveries DETECTION, for the essence of the new phenomenon does not open at all; a new phenomenon is just first discovered.

A subgroup of discoveries consisting in establishing a concrete fact. These are geographical discoveries. This also includes most discoveries of observational astronomy, geological discoveries (new deposits - denia), the discovery of new species of plants and animals. For this subgroup it is characteristic that its discoveries (in contrast to the discovery of phenomena) require no explanation.

It is interesting to note that this is spontaneously reflected in terminology: discoveries phenomena (as well as the opening of the second group, which is discussed below) sometimes called scientific discoveries, involuntarily emphasizing their difference from simple establishing a specific fact.

In the future, we will consider in the first group only the main core - discovery of new phenomena.

7. The second group – discoveries, consisting in the establishment of patterns. In this case new phenomena do not open, the discovery is manifested in the explanation of already known phenomena whose essence was previously incomprehensible or did not fit into the existing explanations.

Example:

- explanation of the photoelectric effect by Einstein,
- explanation of the evolution of plants and animals in the struggle for existence.

8. By no means should the first group be identified with the experimental ones, and the second with theoretical discoveries. On the contrary, in each group there are discoveries made experimentally, and there are discoveries made theoretically. So, in the first group: experimental discovery of radioactivity and theoretical discovery of electro- magnetic oscillations by Maxwell. In the second group: experimental discovery Coulomb's law and the theoretical discovery of the relationship between mass and inertia.

9. If we give a simplified scheme, then we can say this: the discovery of the phenomenon is the new quality QUALITY of matter, the discovery of regularity is the establishment QUANTITATIVE RELATIONS. Even simpler and rougher: in the first case the result of creativity is new information, in the second – a new formula.

10. We must immediately stipulate that there is no blind wall between the two groups. Wherein historically, the "wall power" has been decreasing all the time. At present, often in a single work, an open phenomenon and an immediate explanation (sometimes vice versa: a hypothesis and the following hypothetical discoveries – predictions – of new phenomena).

11. However, a very tangible difference has been preserved to this day. It used to be, as indicated, was even more pronounced. Hence the most important consequence: existed (and in still largely preserved) two groups of scientists, two significantly different types discoverers. The first type is scientists who discovered new phenomena. The second is scientists, established new patterns.

12. Scientists of the second type are much higher (in terms of creativity) of scientists of the first type. One can discover the phenomenon by chance. It is possible and not entirely by chance, but still on free market, trying to discover the phenomenon of five cents, you discover something worthwhile One hundred rubles. The discovery of new laws requires – overwhelmingly - In most cases, focused efforts.

13. In this regard, it is interesting to make the following observation. The fate of scientists of the first type like a lightning fast, but a single flash of a new star: twentieth asterisk magnitude suddenly turns into a star of the first magnitude ... And soon again will return It shifts to its former appearance. It's understandable: the ability to make the discovery of one new appearance does not mean the ability to make another discovery.

Example:

Galvani discovery, Michelson discovery.

On the contrary, scientists of the second type, as a rule, equally fruitfully work in different (sometimes very distant) areas. Examples: Einstein (first the photoelectric effect, then the theory of relativity), Faraday (electromagnetism and chemistry), Schmidt (higher algebra and cosmogony), Mendeleev, Pavlov (first physiology of food- jam, then – the study of higher nervous activity).

B. Initial Construction of the Method

14. The presence of two groups of discoveries means that when creating a MODERN methodology discovery should be based on the presence of TWO GROUPS METHODOLOGY-SKILLS, very different from each other.

15. The purpose of the first group of methods is to lead to the discovery of a new phenomena. Hence, the association in this group of specific search methods. The purpose of the second group is the discovery of new patterns. Hence the union various combination techniques aimed at opening a new combination (i.e., a new explanation) of already known phenomena.

16. The task of the elementary discovery technique is to study separately separate techniques in each group of methods. In other words: give a number of specific and sound recommendations for making discoveries. The ultimate goal of the methodology is to establish patterns in historical development methods of discovery and explore the mechanism of mutual understanding of methods in different fields of science. In the same way, the elementary technique of invention (if to it add the study of historical development and mutual influence) goes into theory development of technology.

D. Basic Receptions for Opening New Phenomena

17. The simplest technique – historically very important – consists (paradoxically simplicity) is to pay attention to already known and different countries – ness of the phenomenon. Briefly – look for an anomaly. At first glance, no one will pass past a strange phenomenon. But during the 11th – 19th centuries this happened all the time. In a number of branches of science, this situation has been preserved to a certain extent in our days.

Example:

At the end of the 18th century, Cavendish, exploring the air, discovered a certain, with nothing connecting part. This fact was well known among scientists, considered an anomaly, but did not attract attention. Only a century later, Ramsay, continuing this study, discovered argon (and the phenomenon of chemical inertness at all). It can be argued that with a focus on the found Cavendish anomalies could have discovered inert gases (and the phenomenon of chemical inertia) 60-80 years earlier.

18. A somewhat more complicated trick is paying attention to white spots within already known phenomena. In this case, anomalies are also sought – within the limits already studied range of temperatures, pressures, distances, speeds, etc.

Example:

In 1772, in Bonn, a book by Tipius "Contemplation of Nature" was published, in which attention was paid to the correct increase in the distances between the planets and Sun and space between Mars and Jupiter. Then another scientist – Bods - stated that there should be an unknown planet in place of the gap. She was found by one of the astronomers who responded to the call "search."

19. The next most difficult trick is to pay attention to white spots outside known phenomena.

Example:

Bridgman's research into previously unavailable high pressures at led to the discovery of new ice modifications.

20. Next in complexity is the assessment of known phenomena from a new point of view.

Example:

Quote from an article in the Literary Gazette of February 6, 1960: "18 years ago to Professor M. Volsky (co-dispatcher) was contacted by a doctor working on his dissertation, asking battle to calculate the perimeter of the trachea, ellipsoidal in cross section. "Having made the calculations, Volsky recommended a number of other calculations and calculate the loss air pressure during its movement. A doctor who has done enough work in the field physiology of breathing, sincerely admitted that with such a question to him never had to meet. Then professor Volsky made the calculations himself and came to completely unexpected conclusions. He proved theoretically that the old concept of breathing is against the laws of physics. For millennia, there is no air in the pleural cavity. The whole theory was built on this. And the conclusions of Volsky testified: there is air in the pleural cavity. Soon this was confirmed experimentally.

21. The discovery of new phenomena by combining the old. In other words: phenomenon A in itself is known, phenomenon B is also known, the discovery consists in the fact that phenomenon B, consisting in the relationship of A and B.

Example:

The frequency of sunspots has long been known; the frequency of phenomena in ionosphere – too; the discovery was that a mutually connections between sunspot activity and ionosphere functions. There may be more complex options for discoveries: the formula A + B gives a new phenomenon B, then B + known G gives a new phenomenon D.

Example:

The periodicity in solar activity is known, the periodicity in clumping colloids too. First, a relationship was established between these phenomena. Then the resulting new phenomenon was associated with the well-known phenomenon, consisting in that the human body is a colloidal system. As a result, the phenomenon of mutual the connection of some processes in the body with the frequency of sunspots.

22. Reverse reception: investigation of phenomenon A in order to establish that it is a co-the combination of two previously unknown phenomena B and B.

Example:

At first, radioactive radiation was generally known, then using magnetic field – found that the rays of radium – a combination of three different rays. So discovered the phenomenon of alpha, beta and gamma radioactivity.

23. Other schemes:

- By analogy. There is a group of phenomena and, for example, there is another more or less similar pressing on her for the second group of phenomena; then we can expect that phenomenon A in the first group corresponds to the still unknown phenomenon A1 in the second group.
- Question self-evident and universally recognized phenomena. On each It's useful to verify the stage of development of the experimental technique ny phenomena.
- Exclusion of a non-universal phenomenon. Suppose phenomenon A combines well a number of factors, but does not explain any one fact. Then it makes sense to abandon phenomenon A or replace it with particular phenomena. Wherein the existence of boundaries between particular phenomena is a new phenomenon in itself.
- Search among mutually contradictory phenomena. Such inconsistency is far not always obvious.

24. Probably this list can be replenished. The challenge is to give a clear scheme of receptions. Perhaps some of them are special cases of others, more general tricks.

D. Reception Regulations

25. There may be two cases: either the pattern is established for the first time (for example, Kepler's establishment of the laws of planetary motion), or the task is to overcome difficulties (explain contradictions, exceptions) that the previous theory was nullified.

26. In the first case (historically, the development of any exact science begins with it) The simplest trick is this: you need to increase the number of known facts until the pattern manifests itself. This, incidentally, is an elementary method of scientific research today.

27. In the second case, a characteristic trick is that hypothetical phenomena that remove difficulties.

> **Example:**
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> And before Mendeleev there were various systems of periodization of elements. However, all these systems ran into difficulties, the main of which consisted of in that the periodicity evident at the beginning of a series of elements was then violated. Mendeleev eliminated this difficulty by introducing hypothetical elements. it there was a "stretch" that removed the difficulty and allowed for the first time to hold the principle periodicity throughout the whole series of elements. Roughly speaking, in this case, to open it is necessary to raise the question: "What unknown phenomena or facts must be taken as reliable in order to remove difficulties theory? "- and answer this question. It is important to consider the psychological moment. When some kind of theory that has long served faithfully, suddenly begins to stall, the vast majority of scholars It is possible to explain heretical facts

without changing the theory. Great scientists are great that they leave the hypnotizing effect of the theory and boldly change it, they fret, not worrying that these prohibitions seem arbitrary at first glance extremely unlikely or inexplicable (e.g., final velocity Sveta). Often the most difficult thing is to recognize the leakyness of the old theory and the need for new assumptions. If this is recognized, the assumptions themselves are sometimes quite difficult to find.

28. Every theory is mortal. Therefore, in the period of maturity, theories must be concentrated efforts not only (and in the period of old theory and not so much) to apply it to explanation of new groups of phenomena, but also on the study of weaknesses. Simply put: necessary to develop a theory not where it is strong, but where its weakness is felt. All prep university admissions, all graduate studies, the vast majority of candidates works, in general a significant part of scientific work is based on the application of substantial theory to particular problems (for example, the application of mechanical prin- circuits to the problems of chemistry). We must look for those cases when the theory is just not applicable. neem. We must not expand and strengthen the foundations of the natural sciences, humane tare and social theories (the result of such work at best is hardening theories), and look for cracks.

29. The pace of development of science is largely determined by a combination of various factors, which are far from always possible to influence with the goal of afterburner. However it is possible it is reasonably argued that the average rate of development of science could be noticeable above, if the work on finding cracks in the "well derived" theories today.

It should be noted that in those branches of science that are developing now especially rapidly, they do just that. For example, in nuclear physics the whole story of the last three decades – this is the story of seeking "but" and the desire to introduce new theoretical parcels explaining these "buts." Of course, at the same time using "established" principles to solve various problems, for example to explain the mechanism of chem. reactions. On the other hand, in the branches of science, relatively slow, there is a different distribution of forces: the main efforts sent to the application of existing theories to explain new groups phenomena. This is the case in physiology. After Pavlov, the vast majority The work consisted in the fact that the strengths of Pavlovian theory extended to explanation of new phenomena. And one should energetically look for weak points of learning Pavlova.

Exaggerating somewhat, we can say: study not the laws, but the exceptions to them: namely new discoveries are hiding there.

30. Returning to the methods of searching for new patterns, it should be noted characteristic technique: transferring methods and apparatus of one area to another area.

Example:

The creation of cybernetics (it would be interesting to transfer, for example, "methods and apparatus" of music in geology or nuclear physics).

31. This technique is a special case of this technique: the spread of methods and apparatus (as well as phenomena and facts) to a wider area. The following special case also adjoins

here: the proclamation of a well-known, but considered limited phenomenon, as a universal law.

Example:

Attraction – as a more or less particular phenomenon – was widely known until Newton. But Newton proclaimed the universality of gravity (this led to do that the planets are attracted by the Sun). And then from the previously installed Kepler's third law directly follows the formula of attraction.

32. The opposite method is applied less often: a new pattern is established by limitations of the previously considered universal principle.

33. Another trick: a return to the old theories on a new basis ("alchemical" transformations of elements by nuclear physics methods).

E. General Considerations

34. The development of technology gives science ever more accurate machines and instruments for measuring. Many discoveries are directly an obvious consequence of the new – more accurate – measurement methods.

35. All the techniques described above are elements of scientific work. Cannot be identified discovery discovery with research. Research is a collection of searches for discovery, mechanical accumulation of facts, refinement of measurements, accounting for new ones – made others – discoveries, establishing the relationship between all of the above and Sofsky installations. Thus, research is a much broader concept, than opening.