Division of cognitive labor: phenomenon, models and policy

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1 Introduction

The Science, now, is a big "industry" produces knowledge. This "industry" involves multiples amount of people, infrastructures, technologies, financial services and more. Science over the last century has become a social phenomenon, in the sense that in addition to epistemological context which determines how scientific knowledge is obtained, there is a social context, which describes how society shapes the subject of scientific knowledge, the manner in which one or the other scientific theory becomes dominant and so on. In additional, science become governable: by acting in various ways on the scientific communities one can encourage the development of particular areas.

Involvement of huge amount of people in scientific activities gave rise to the phenomenon of cognitive division of labor. The simplest example of such a division of labor is the variety of scientific disciplines. Physics and chemistry, biology and computer science - different disciplines, different specialties, different groups of scholars and different scientific issues.

At the same time there is a cognitive division of labor within a single discipline. For example, any scientist always has choice: try to develop existing research areas established by previous researchers, or create his own. In other words, the cognitive division of labor is a phenomenon that, how the choice of research areas is performed by scientists, in a depends on the existing ones.

The mechanism of the selection of the research areas influence on the whole context of the research activity and the future of a non-scientific results of the research, such as social and economic outcomes. The personal rewards, such as recognition and credibility in the scientific community also depend on the choice. One can assume, that the creation of a new scientific area inside one scientific discipline will bring more intangible rewards, than the extension of existing ones.

The Choice of a scientific direction is also important in the organization of scientific research of catching-up developments, where scientific culture is lost or unformed, and it is important to

organize scientific activities in a short period of time, and then, in a limited time range obtain measurable results, for example, as cited publications in scientific journals. In this case, the choice of research direction is determined by the strategy of scientific activity, which in turn is supported by a set of policy. For example, when creating a new university academic council generates a set of advanced scientific fields, and in accordance with them they are looking teachers and professors.

The correct selection of the direction of scientific research is not enough to obtain in future leader position in such scientific area. Within one and the same discipline one can use different strategies, for example, aimed on discovering of new issues, or aimed on extension of existing, as described above by phenomenon of cognitive division of labor. From my point of view, the policy should not only prescribe/stimulate research in special direction, but also defines research strategy, that is the way in which research topics are chosen inside a scientific discipline.

In this essay, I would like to consider several models of cognitive division of labor, and to develop the policy, which stimulates research in accordance with one model.

2 Epistemic landscape

The process of choosing a scientific topics can be represented using conception of Epistemic Landscape [1]. Weisberg and Muldoon describe [1] notion describe Epistemic Landscape with three components:

The first one - Research Topic - engages a group of scientists. Example of research topic be easily described by set of articles published in specialized conference or advanced monograph. Existence of such conference means, that there is a scientific community, there is a research topic (which is the subject of conference, obviously) developed enough for create conference. The conference should be small enough to have a community, but not broad as to have a sub-topics.

The second component - approaches - specifies how scientists investigate the Research Topic. This entity has a broad understanding, and it is based on current epistemological understanding of science, i.e. scientific method. It includes, first of all, the entire set of research questions related to the research topic. Second, a set of instruments used for the study and study of research topic. Furthermore, codified information about research topic and research questions obtained by use of such instruments is a part of this group too. Third, the set of methods of data analysis is a part of approach. And in the fourth, set of the dominant paradigms, axioms, scientific concepts that are used to explain the results is a part of approach. Each research topic may be accompanied by any set of approaches.

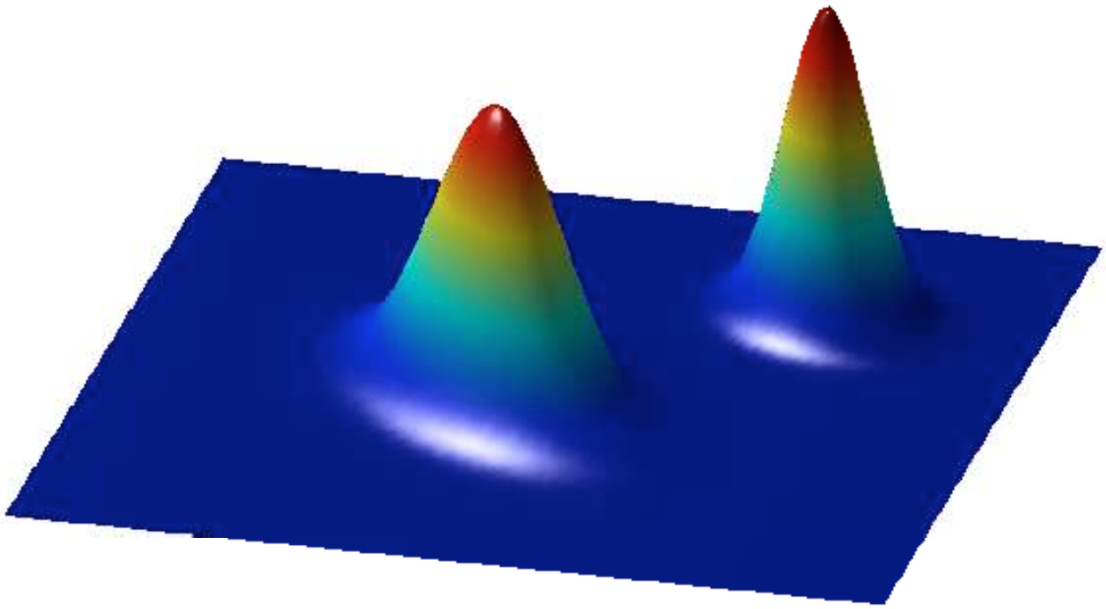

Figure 1: Example of epistemic landscape

Source: Epistemic Landscapes and the Division of Cognitive Labor, Michael Weisberg and Ryan Muldoon

The third component - epistemic significance of the scientific results obtained by use of particular approach [1]. There are several different points of view on the nature of this phenomenon provided by philosophy of science. Someone argues that phenomenon of importance of scientific discoveries inherent in the nature of the scientific discovery. An opposing view argues that the value and importance of scientific knowledge determined by the social, economic or political environment. That means, that importance of knowledge is not part of the scientific knowledge. Also there is an holistic approach. In terms of the concept of epistemic landscape and the development of the policy, at the moment I put out of scope question about the nature of this phenomenon, it is important for me that I can distinguish between the value or importance of scientific findings from some point of view. At a minimum, one can compare the two discoveries, and by use of some algorithm (obviously this algorithm must be provided by the policy) one can define which the discovery is more important and which the discovery is less important.

The Figure 1 demonstrates example of the epistemic landscape. The boundaries of the landscape are determined by the research topic, The x and y coordinates characterize some aspects of the approach, while the z coordinate describes the importance of scientific research [1]. Based on this model, Weisberg and Muldoon modelled and described three strategy of choose of research approach. As in a original research Weisberg and Muldoon, I am using semantic of agents to describing algorithms of search. In additional, examples are provided also.

2.1 First Strategy

This section considers the first search strategy. Weisberg and Muldoon called it "Control" and modeled it by using the following algorithm:

Agent starts with an arbitrary point of epistemic landscape and makes the first move. Next, the agent asks himself whether the investigated region is more significant than the previous one, or not. If this new approach is more significant, the agent takes another step, and again asks such question. If not, the agent asks himself, whether equivalent significant as previous patch. In this case, agent or remains in the selected region (with probability 98%) or a step ahead (c probability 2%). Otherwise, it returns back and steps in any other direction. Each step represents a choice of a scientific approach, or modifying one of its aspects. As mentioned above, the approach includes not only the research problem, but also to apply the tools and methods of data processing.

The main idea of this strategy is that, the if agent found significant approach keep seeking an area where it can make the maximum contribution, or stop and continue to develop existing one. In that case, if the agent found an equal area, there is a small chance that the agent will attempt to advance further in the search area, but in most cases, the agent will stop and continue development of current area.

The behavior of this agent can be described by the following example: There is a research group led by Professor. Professor for a long time engaged in the development of certain areas. When searching for new research problems, he is not interested in other issues and working strictly within its direction. Over time, this topic is becoming highly specialized. And if there is no competing researchers working in the same subject, the number of experts able to assess the result of research, the overall quality of the knowledge will decrease. Then, over time, this can lead to the degradation of the scientific process caused by lack of competition and lack of certification of knowledge. On the other hand, if the certification of knowledge will continue to be made any the degradation of the scientific process will prevented, this scientist and his team can be the owners of rare and unique skills to work with the knowledge that is a certain value to society.

From the perspective of the scientific community and the regulator, such a strategy is not optimal. Firstly, this strategy does not account for other research, because in this strategy there is no division of cognitive labor. There is not tradeoff between specialization and diversity [2]: this strategy is an example of specialization. As mentioned above, a decrease in the communication between the different actors of the scientific community due to specialization leads to a degradation of the quality of scientific work, and most importantly, a reduction of communication adversely affects the other components of the innovation system.

Thus, from the viewpoint of the regulator, this search strategy is undesirable, because a) requires additional resources to monitor the quality of scientific activity b) may adversely affect the other members of the innovation process, because of decreasing density of communication of participants, and c) the knowledge concentrated in certain "center", which increases the risk of their loss.

2.2 Second Strategy

This section considers the first search strategy. Weisberg and Muldoon called it "Follower" and modeled it by using the following algorithm:

Agent starts with an arbitrary point on epistemic landscape. When agent selects the direction of step (i.e., some scientific approach), the agent analyzes the possible steps, and selects the one in which epistemic significance higher. If there are a few areas, the choice of the next step makes arbitrarily. If it is impossible to choose new step, that is, all nearby places are the worst, the agent remains in the same place, or stops.

The basic idea of this strategy is that, the in the process of choosing of next scientific approach, we assume, that there are another scientific approaches and choose best of them from the point of view of epistemic significance. This strategy, in the language of landscape, provides ability to quickly detect the peaks in open areas of the map, then quickly identify significance of new scientific approach.

The behavior of this agent can be described as follows: Let us assume, as in the first case, we have a research team headed by Professor. And young researchers coming to his group should create their own research. To do this, they study literature, existing studies, etc, and then, they are faced with a choice - Should they base their research on existing areas or try to create new one? Someone chooses the most promising and new, with a high degree of uncertainty, someone chooses the direction with less uncertainty. After the end of the study, the young researcher face that same question, how to continue own research carrier. They can continue a previous study, and over time, this scientist "turns" in the representative of the first strategy based on the specification and development of a narrow scientific topics. They can re-select the most cutting-edge research areas, and develop them, and "turns" in the representative of the second strategy.

From the perspective of the scientific community and the regulator, such a strategy seems to be more optimal. Firstly, it is present division of cognitive labor, because switching from one approach to another creates mobility as people and knowledge. There is communication, and this communication is intense, as the promotion of a new direction requires substantial cognitive effort.

At the same time, such a strategy may not be effective in terms of resource use. Each switching between research approaches leads to a waste of resources in the attainment of this frontier of science, it takes time, so the research team did not perform at the time its institutional function - extension of certified knowledge [3]. There is no tradeoff between specialization and diversity in this case, because tradeoff is "shifted" in the direction of diversity - a variety of research projects.

At the same time, there is the negative factor of such a strategy. This strategy essentially depends on the presence of someone previously established scientific approach. Assuming that there is no one to create new areas, i.e. all scientific space is represented by followers, then very quickly this space will become filled and the production of scientific knowledge will stop.

Thus, from the viewpoint of the regulator, this strategy is desirable because creates a) a high density of communication, and b) a variety of research projects) stability of scientific environment (through diversity). At the same time, such a strategy depends on the previous achievements, that is, in the truest sense, this is an idea of catching up developments.

2.3 Third strategy

This section considers the first search strategy. Weisberg and Muldoon called it "Maveric" and modeled it by using the following algorithm:

Agent starts with an arbitrary point of epistemic landscape. Unlike follower, where the agent chooses already existing approach with most significant epistemic significance, Maverick chooses approach that never used before. If there are more than one such approach, the maverick chooses any of them. Next, this cycle continues until no approach remains unused.

The main idea of this strategy is to choose scientific approach orthogonally to existing ones. This strategy, in the language of landscape allows you to open the missing peaks on the map, in unknown locations of map.

The behavior of this agent can be described as follows: As in the previous example, a young scientist performs research project, and then he faces the task of choosing of a new direction. We have already seen examples that it can continue to develop the current direction to increasing specialization, or may switch to a new direction which already developed by scientists. In case of maverick strategy, the scientist selects the least-used approach.

From the perspective of the scientific community and the regulator, this strategy looks positive. Firstly, this strategy boost division of cognitive labor and switching to the new challenges boosts mobility of personnels and increase contribution to science. Secondly, this strategy opens up new directions, which is extremely important in terms of "conquest" of the scientific landscape. This

strategy is an alternative catch-up model of followers. At the same time, this strategy does not allow much "to move deeper", in the sense that this strategy is focused on the search for new directions but not on their subsequent development. As with the previous strategy, there tradeoff between specialization and diversity is "shifted" towards diversity.

Thus, from the point of view of the regulator, such a strategy is desirable because creates a) a high density of communication, b) building own research directions c) stability of the scientific environment (by creating new projects). At the same time, such a strategy does not allow for the development of new areas, and thus benefit from them to the community is not as significant as in the case of the strategy of "followers".

2.4 Tradeoff between mavericks and followers

Weisberg and Muldoon after agent-based simulation of each of these strategies, demonstrated, that the in terms of benefits to society, the scientific community must be represent by scientists with two different search strategy: followers and mavericks.

The idea of the presence of both strategies in the area of cognitive division labor is simple. While mavericks creates new areas, the followers, in turn, develop them rapidly. The balance between the former and the latter is controlled by the policy developed by regulator. In my opinion, only this combination of strategies, supported by special policy can bridge the gap in science, which is impossible to bridge by simple catching-up strategy.

The next section is devoted to development of policy that supports balance between mavericks and followers.

3 Policy

Policy that supports mavericks and followers, as well as to maintain a balance between them should be implement through a special fund which support scientific research. The objectives of such fund are a qualitative and quantitative improvement of research activities achieved through support of research of a special kind. Since scientific activity is directly dependent on funding, the Science Foundation is probably the most effective instrument for implementing the policy.

The main objective of the fund is to support research projects in the format of "Maverick" and "followers", as well as to ensure a balance between them. For each of the formats I've highlighted a few major features that uniquely determine the format to which to attribute this or that project. On the basis of these signs I formulated support mechanisms, and accordingly, control mechanisms.

3.1 Mavericks

As mentioned earlier, the "mavericks" strategy is looking for new scientific approaches, that can be in form of scientific problems, methods of resolving of scientific issues, methods of processing and interpretation of data, and more. It is a key characteristic that differs the Mavericks from other strategies: each following scientific approach differs from the previous ones, both for the research group, and for others on a common scientific space. This means that the type of research is characterized by the absence of large scientific communities, conferences, journals, famous scientific leaders.

In other words, the policy of stimulating of the Mavericks should encourage the emergence of new research directions, that is, encouraging creation of non-existing developed areas, and switching to a new, without further developments. Accordingly, as the requirements for research grants can indicate the need to change direction, and that could be implemented in the form of monitoring of applications for research funding.

Monitoring of the implementation of the research and its relevance to the format can be carried out through measurable characteristics. Such characteristics can be a) requirements for the citation of scientific publications by researchers such as "followers" and scientists with high academic status, b) requirements in creation of a conference with the participation of scientists from high academic status and more.

3.2 Followers

As previously mentioned, the "follower" strategy is devoted to searching of scientific approaches with higher epistemic significance for their subsequent development. These scientific approaches characterized by the presence of a large community, scientific leaders, professional conferences and journals. The inclusion into this research community will be a major characteristic of "follower" policy.

In other words, the policy of stimulating of Followers should encourage to the inclusion of researchers in a special scientific context. The format of these conclusions can be, for example, joint work with the leaders of the scientific research areas, or just research accepted by community.

Measurable indicators of success in this format are articles published in the high-quality conferences, and articles cited by the academic leaders.

Table 1 demonstrates a set of stimulates and metrics for both groups of researchers. As one can see, The Policy stimulates the creation of new research topics, creation of new research commands and relocations for researchers as the main incentive of an initiative for the Mavericks. Control

Mavericks		Followers	
Stimulus	Control	Stimulus	Control
Support creation of new: 1. Research in new area 2. Research team 3. Institutional form of research	Citations Creation of new conferences Ex. Employees that become "Mavericks" Ex. Employees that become "Followers"	Co-funding of joint projects Support of extension of areas developed by "Mavericks"	Publications in tier 1 conferences Citation by scientific leaders.

Table 1: Policy

indicators for this group of researchers are citations, the number and quality of created new conferences and journals, quality of participants in new conferences like scientific leaders (i.e. recognizable researchers with a high contribution to science). Also policy stimulates the emergence of joint projects in the existing scientific areas with scientific leaders, inclusion in the existing project research areas thru funding of research projects of a certain quality, stimulates Followers to participate in projects of Mavericks. The results of the implementation could be controlled through the quantitative characteristics, such as conferences, publications in existing first tier conferences, citation of scientific articles by academic leaders.

4 Conclusion

In this essay I have tried to develop the policy, that stimulates the emergence of a certain type of research. To improve the quality of scientific activities in the absence of scientific environment, it is extremely difficult to create new directions "from scratch" that were created decades ago. In order to "compress" the required time, I think we can use the results of the research in organization of science, in particular in the field of cognitive division of labor. This concept describes how the process of creation and distribution of scientific knowledge is performed. In my work I have used research [1] made by Weisberg and Muldoon. In their work they modeled three strategies for selection of research tasks: "control", "follower" and "maverick". The first strategy is focused on the preservation of the investigated within a single scientific approach, the other two describes the opposite way to determine how to choose new scientific approach from the broad landscape. I have developed a policy that combines two last strategies in order to accelerate the generation of scientific knowledge.

References

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