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Cases of Interdisciplinarity: Between Habitus and Reflexion [1,2]

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Abstract

Several cases of broadly viewed interdisciplinary research are considered. Discussed are the disciplinary status of natural philosophy in the middle ages; the dispute about witchcraft in the Renaissance; the disciplinary formation of chemistry in the interaction between peripatetics, jatrochemists, spagirists and atomists; and the conceptual shifts in Maxwell's electrodynamics. These debates are analyzed using two major notions—*habitus* and *reflexion*—that differ from those of Bourdieu. Habitus is taken as a methodological attitude based on natural and historically rooted adherence to a theory, or world picture, based on the shared research practice. Reflexion represents a critical and proactionary stance towards a revision of an established theoretical framework, which is irreducible to the logic of rational criticism. Various cases of *habitus-reflexion* controversy provide a valuable source for a typological picture of interdisciplinary research. And this, in turn, helps clarify the nature of interdisciplinarity in general, given the topicality of this cognitive pattern in the contemporary science.

Interdisciplinary interaction in modern science has become a usual phenomenon deserving more serious philosophical and scientific understanding. Why is an epistemological analysis of interdisciplinary research significant? The rationale for this attention stems from the nonclassical approaches in epistemology and philosophy of science that emphasize the communicative nature of the cognitive process and, moreover, the essential determination of the content of knowledge by various types and forms of communication.

The epistemological analysis of this field of knowledge involves clarifying the subject matter of the study and its related concepts. A particular distinction should be drawn between *i-interaction* (interdisciplinary interaction) and *i-research* (interdisciplinary research). *I-interaction* relates to the subject matter of science and embraces the relationships within science as a social institution and its relationship to other social institutions that produce knowledge. *I-research* belongs to epistemology and the philosophy of science and expresses the peculiarities of the cognitive process in the

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context of communicative agents that produce and consume knowledge. These two concepts can be likened respectively to the ontological and to the epistemic view of the relationship between the knowledge systems. Therefore, although *i-interaction* can hardly be ignored, it is the clarification of *i-research* on which this given study focuses.

Before posing a question about the specific parameters of the cognitive process in a situation outside any discipline, one needs to "disperse the clouds" in the conceptual space that are essentially laden by current pseudo-scientific interests. Because of the predominance of these interests, which are loosely linked with the objectives of achieving a new true knowledge, scientists (and some philosophers) have given the notion of interdisciplinarity increased importance while, at the same time, making its content vague. Here epistemology is, as it is often the case, obliged to go ahead of the reflective process in science since scientists themselves have nearly no positive results when attempting at least to use, if not construct, this concept. The consequence of this situation is, among other things, the practical impossibility of achieving an adequate self-orientation to the interdisciplinary developments in modern science. The answer to the question—*Is interdisciplinarity an advantage or disadvantage to a research project?*—depends on many unclear issues related to the conceptual area called the "relativity of scientific knowledge".

For example, one can initially presume that the concept, role, and evaluation of interdisciplinarity will be significantly different in relation to modern times, and the present, in basic and applied research; in the humanities and mathematized sciences; in science and the para-sciences; in the paradigm science and cutting edge sciences; and at the different stages of the research (wording an idea, search study, proposing a hypothesis, the process of justification, examination, publication of the results, applications, etc.). Hence, the distinctions among *inter-*, *trans-* and *poly-* disciplinarity do not cover the diversity of relationships outside a monolithic discipline.

The first step of analysis should be to develop a typology of interdisciplinary relations based on Wittgenstein's method of family resemblances or principles of phenomenological description. The types of interdisciplinarity should be understood in terms of a multi-factor determination of their genesis. Further, the epistemic peculiarity of activity and the communication of scientists within each type should be identified and analyzed. In such a case, the concrete conclusions about the role and value of *i-research* for a cognitive situation, a discipline, science in general, and/or an historical epoch might be provided.

Self-Sufficiency of a Discipline?

Discipline and science are not identical concepts, although they should be distinguished in contemporary STS with more clarity (Ogurtsov 1985). What comes first, science or discipline? represents a topical question. There are sufficient reasons to believe that mature theoretical knowledge usually exists in a special organizational form of disciplinarity, ensuring its accumulation, transfer, and modification. Theory and discipline are two sides of the same coin with the characteristics of a developed thinking on one side, and the activities in the context of communication on the other side. But they

are not simply complementary—there is a genetic causality between them. If thinking is a product of activity and communication, then discipline gives rise to theory. Hence, the primacy of disciplinary organization takes place in scientific research in general and in relation to the theoretical knowledge. Although theory as a form of knowledge appeared long before the emergence of science in the modern sense, no difference was drawn in antiquity between theory and science. "Theory" referred to "to look at, view, behold" by Herodotus or was "of the mind, to contemplate, consider, observe" by Plato (Liddell and Scott 1889). Furthermore, science (*episteme*) was identified not only with mathematics, philosophy, geography, and medicine, but also with astrology, alchemy, and magic. This leads to the idea of independence of disciplinary form from cognitive content.

Mikhail Petrov (1991) identifies the following eight components of any discipline:

> 1. A disciplinary community—the living generation of actual and potential creators and actors.
> 2. An array of actual contributions—results saved and inherited from previous activities and living generations of members of disciplinary communities.
> 3. Mechanism of socialization—a recognition of contributions (future results) that introduces them to an array of actual results (publication).
> 4. The disciplinary mechanism for the reproduction of participants by attracting new generations to the array of available results and to the rules of disciplinary activities (university).
> 5. The disciplinary activity that accumulates results and reproduces the discipline throughout generations. The activity is implemented in four main roles: that of researcher, historian, theorist, and teacher.
> 6. The rules of disciplinary action are defined by each of these roles, including the leading role of a theorist who founds the paradigm.
> 7. The integration of actual results in a citation network provides the backbone line continuity.
> 8. The subject matter of discipline is the field of search for new results determined by the actual disciplinary paradigm in terms of the description pattern of the possible product.

According to Petrov, the ancient philosophy and science that existed in local societies did not yet have a good half of these characteristics. The first disciplinary matrix arose in the Middle Ages in the form of Christian theology. While leaving aside his interest in the process of accumulation of empirical knowledge and skills within the framework of a prescientific craft and practices, Petrov holds out a straight line from theology to modern science. This stance is partly justified by the desire to trace the logic of the development of discipline in the natural sciences; this was not so much historical research as it was a bird's eye epistemological perspective on science. Among other things, scientific discipline, even in the second half of the seventeenth century, still had not purchased the entire set of disciplinary properties.

Therefore the scientific community, Petrov asserts, hardly existed even a century later. The community of combined agents of scientific activities knew no clear distinction

among professionals and amateurs. A university education (in England, for example) often gave way to self-education, and the predecessors of contemporary scientific journals were the archives of the private correspondence of Marin Mersenne or Samuel Hartlib. Even in the eighteenth century, there was no clear disciplinary boundary between physics and chemistry or between the different earth sciences or life sciences. This means that until the nineteenth century, the scientific discipline was an exception rather than the rule and had not yet set the basic parameters of the image of science.

An active rise and differentiation of sciences in the first half of the nineteenth century owes much to the deeply rooted view about the levels and types of reality and, consequently, of the basic differences between the objects of various sciences. This view was developed by Auguste Comte and then was picked up by many, including Karl Marx and Friedrich Engels in the works published under the general title *The Dialectic of Nature.* These special scientific pictures of the world (Stepin 2005) were a necessary precondition of mature disciplines before they develop the paradigm theories. And while in the mechanics the emergence of such theories took place in the seventeenth century in the writings of Newton, the chemistry of Lavoisier and Dalton made this possible only at the end of the eighteenth century.

All of this raises a question: Is the discipline that expresses an existence of science as a social institution important for the production of scientific achievements? A discipline is a condition of intensification of a collective scientific activity by attracting numerous people in science, learning, and socialization. Discipline is the cognitive factory where knowledge is produced to certain standards, tested, packaged, and sent to the consumer. Discipline is also, and perhaps above all, the condition of science funding within the state budget and the allocation of financial resources for the scientific directions; it is a form of scientific expert bureaucracy. In this sense, discipline is a necessary social representation of science as a sphere of professional production, distribution, and use of knowledge in our time.

How is all of this consistent with the ideal of scientific knowledge in terms of novelty and truth? What roles do abilities, aptitude, and talent play in the production of knowledge? What is the relative importance of formal and informal communication in scientific achievements? Is the increase in the number of talented scientists and real scientific discoveries proportional to the multiplication of publication units? Is the discipline the socio-civilizational, or the cultural-historical dimension of science?

In particular, the choice between the civilizational and cultural optics is of particular importance in connection with the second feature of discipline marked by Petrov—discipline as an array of actual contributions, or results saved by previous activities and living generations of members of disciplinary communities. To what extent is the discipline open to the pre-disciplinary stage of development of this field of knowledge? Does not a discipline raise peculiar criteria for the demarcation the mature, proper disciplinary knowledge from immature, pre-scientific, "pre-paradigm" knowledge (Kuhn 1970, 147-148)? Should Archimedes and Euclid be deleted from the history of physics or mathematics on the grounds that, at the time, the relevant discipline did not exist and these scholars (intellectuals, academics, philosophers) could not be described as

"physicists" or "mathematicians," respectively? Or, on the contrary, should the concept of discipline contain a mature picture of its genesis? Petrov evidentially had not planned to exclude the history of science from itself, for he singled out the common role of a "historian" within the disciplinary community. However, his definition of disciplinary community as "the *living* generation of actual and potential creative actors" makes the role of the historian meaningless without reference to the number of generations making the whole history and pre-history of discipline.

Thus, what is necessary is either a narrow and rigid ("civilizational") notion of discipline confronting the historical reality of i-science or another ("cultural") definition that actually diffuses current disciplinary boundaries—these are the options the scientist or philosopher of science faces.

Disciplinary Imperialism or Interdisciplinary Democracy?

In his keynote article "Epistemology of Interdisciplinary Relationships", Jean Piaget distinguishes *the multidisciplinarity*—as a unilateral addition of one discipline to another—*the interdisciplinarity*—as an interaction of disciplines—and *the transdisciplinarity*—as constituting the integrated structures (for example physics not only of inorganic nature, but also the physics of life and the social physics, and the physics of all, physical imperialism) (1972, 139). Clarifying this typology, we distinguish three corresponding types of cognitive systems.

First, there are *multi-* (or *poly-*) disciplinary systems of knowledge—biophysics, physical chemistry, animal physiology, social semiotics, general theory of communication, etc. These systems are characterized by the application of some disciplinary ontology and the methods of another discipline or set of disciplines. Interdisciplinary borders remain strict within the framework of multidisciplinary systems and distinguishing objects, methods, and results of interacting subjects are a prerequisite for success. For example, the morphology of the layers in geology, on the one hand, and the regional distribution of the flora in paleobotany, on the other hand, are subject matters of the independent disciplines, a connection of which allows for the study of the evolution of geological deposits within geobotany.

The second type of the cognitive system results in i-interaction, such as space research, country-specific studies, science studies, and political science. They are distinguished by combining disciplines to create new ontologies and methods for working with objects. These systems of knowledge are characterized by less clear interdisciplinary borders. Geography, sociology, economics, civil history, linguistics, history of culture, and political science complement one another within the framework of international relations research, for example. They interact with the purpose of establishing a coherent "picture of the social and regional reality". This picture, in turn, gives a semantic interpretation of the facts in each separate resource discipline and provides their relative integration even before a mature "civilization theory" or "theory of international relations" are construed.

Finally, transdisciplinary knowledge systems claim an absolute universal ontology and propose methods that keep no disciplinary certainty. These include the system theory, the

theory of self-organization, information theory, and catastrophe theory, which set a fundamental disregard for the disciplinary borders. Naturally, these theories have emerged as a synthesis of some disciplinary concepts in biology, chemistry, and mathematics. However, they broke away from their roots and began to develop on their own theoretical basis. Their validation and assessment result from application in other areas of knowledge.

Types of Interdisciplinarity: Criticism, Borrowing, Synthesis

When, and under what conditions, does an i-interaction cause or result in the creation of a new discipline? To answer the question the interaction between, or beyond, disciplines should be differentiated as an end in itself, on the one side, and as a means of developing the disciplinary knowledge, on the other side. This distinction tacitly presumes the priority of discipline over communication, which is typical of modern science of science (Kuhn). We would like to justify the shift to the significance of communication and to draw a distinction between the two main forms of scientific communication about the production and consumption of knowledge—*habitus* and *reflexion.* Here, we utilize Bourdieu's concept habitus. Bourdieu defines habitus as a system of "durable, transposable dispositions" which is generated from the structures of the social world (Bourdieu 1977, 72), while "each individual system of dispositions may be seen as a structural variant of all the other group or class habitus, expressing difference between trajectories and positions inside and outside of class" (Bourdieu 1977, 86).

In the methodological framework of philosophy of science, we shall reinterpret habitus as "a common sense of science", which is immediately derived from the routine practice of "normal science" (Kuhn). Habitus only partly overlaps with paradigm for the former is in no way grounded in the textbooks, but rather represents unarticulated, tacit experience and elementary mentality of the knowing agent. Habitus cannot be reduced to the agent's *practical faith* in theories, methods and patterns of experimental work that are accepted within the scientific community. Much more, it is a special mode of an informal communication (e.g., the coffee break in the lab), commonly shared presuppositions and discursive structures (e.g., a common language) that make a member of the community easily recognized.

The relation between habitus and the objective social structures is described by Bourdieu as a form of a positive feedback with the help of the notions "internalization" and "objectivization", which evidentially represent a transfer of the similar concepts from psychology (Vygotsky 1956; Uznadze 1966). In terms of the philosophy of science, we reinterpret the relation between habitus and the scientific community in the same way. The former is an interiorization of the latter, while the latter is an objectivization of the former. Thus, the institutional structures of the scientific community taken diachronically, in their evolution are gradual embodiment of informal communicative structures. And habitus, in turn, is a mental structure shared by individuals, a gradual result of the formal scientific training, and an apprenticeship under the guidance of a master. This mental structure makes possible theory choice and "blind" adherence to certain scientific theories and facts.

While Bourdieu diagnosed a sharp gap between habitus and rational reflexion, the given study focuses on the mixed forms, which combine habitual, unconscious elementary discourse, on the one side, and intentional, goal-oriented, critical thinking, on the other side. The source of "mental gaps" should be seen in the clash of the objective social structures, the confronting interests and practices.

So, the phenomena of disciplinarity and interdisciplinarity might be more fruitfully seen as results of specific types of communication in science and beyond. In the following considerations, we will analyze several cases of i-interaction and give evidence for typological generalizations. To do this, we will introduce the concept of the "goal-providing discipline" (the initiator of i-interaction) and "resource discipline" (the staff of i-interaction), as well as their main relation—"i-exchange" (the transfer of meanings from one discipline to another).

A Reflexive Revision of Habitus

Case 1. Philosophy as a Servant of Theology

Here we consider i-interaction as a reflexive operation with habitus, which represents the use of resource discipline for the goal-providing discipline by limiting the development of the former.

In antiquity, it is probably hopeless to look for the interdisciplinary types of communication for a variety of reasons. This is not a time when people could talk seriously about division of scientific or other disciplines. Platonic or Aristotelian classifications of sciences, pointing to the various types of knowledge, draw rather fuzzy boundaries between them. To be a mathematician and philosopher for Plato, or physicist and biologist for Aristotle, is one and the same. In the Middle Ages, in the context of the "personal-professional type of social coding" (Petrov 1991), theology became a model of discipline, characterized by a special form of cognitive communication. The science of the time, which often existed under the name "philosophy", is designed to discreetly serve theology with empirical evidence, not claiming to own the truth. The main departments at the medieval universities were theology, law, medicine, and philosophy, along with faculties of liberal arts and natural sciences in general (sometimes and partly overlapping with philosophy and medicine). So there was a hierarchy among departments and fuzzy boundaries between many of them, although education usually began with the trivium of the "liberal arts" (grammar, rhetoric, and dialectic) and ended in jurisprudence, medicine, or theology. In the early Middle Ages, the trivium was directed almost exclusively at the service of four main faculties. The "advanced studies"—quadrivium (arithmetic, geometry, astronomy and music)—had a similar status with philosophy and ancient literature studies.

When discoursing in this context on medieval scholarship, one has to be aware of the peculiarity of taxonomic thinking of the time, which is captured in the Borges' essay "The Analytical Language of John Wilkins" (a quote from which opens *The Order of Things* by Foucault). The "Chinese" strangeness of the medieval classifications is reflected in the classification of medieval science, leading to the confusion of i-interactions in that epoch.

Generally speaking, modern taxonomic principles establish neither equivocal relations within science nor between the science and philosophy of the time. The trivium could be taught within or outside philosophy. The quadrivium sometimes included medicine, geography, or cosmology, or it could exist independently. Philosophy was sometimes identical to the natural sciences or differed from them, etc. Certainly, the nature of logical and conceptual thinking in the Middle Ages was different than today. And yet we know that the theologians of the time focused on laws of Aristotelian syllogism in building their arguments. Interestingly, the premises with which they operated often appear senseless and absurd in modern times. One should also keep in mind that the medieval taxonomy is given to us in time and space in the process of spontaneous differentiation and integration of disciplines, and the observer's eye grasps their changing parameters as if they are stable.

With these pre-considerations, we can go back to the relationship of theology and science. Evidentially, dealing with theology in the Middle Ages was especially prestigious work, an area of high intellectual culture. Public disputes of theologians were based on the legal nature of the biblical text and the close relationship of the Church to the State. The science of law had similar status in regards to Roman and Canon law. Sources, objectives, and methods of learning about God and his vicar on Earth, states were seen as high by nature. In contrast, the naturalists did not garner particular respect in the community. The status of physician and pharmacist was little different from the alchemist, the barber, the executioner, and the manufacturer of cosmetics and poisons; an astronomer as well as an astrologer was regarded as swindler; a mathematician was similar to a mystic-cabbalist. To exist legally, science had to be consecrated to high theological purposes, to knowledge of God and the world created by Him. And the gradual reducing of theological purposes to the everyday life needed, in turn, the treatment of natural sources and rational methods of observation, experience, knowledge, and mathematical proof, designed to reveal the divine order of nature and thus contribute to the proof of God's existence.

My hypothesis about the origin of the differences in the disciplinary status of theology and science (natural philosophy) of the time refers to their modes of communication—exoteric and esoteric, respectively. Exoteric communication, within which theologians debated, not only clearly defined themes but also was the criteria for their discussions that were reflexive in their nature. Scientists did not have their own legitimated methodology and were forced to borrow the historically institutionalized reflexive standards of communication. At the same time, they implicitly used those standards that followed from their habitual practices, though their articulation was prohibited. Hence, the famous slogan of Thomas Aquinas' "philosophy is the servant of theology" was the first formula of i-interaction in the history of knowledge. At the same time, this represented a transfer of a disciplinary matrix beyond theology, which contributed to the formation of the first disciplines in the sciences.

Reflexion vs Habitus

Case 2. A Dispute on Witchcraft

A confrontation of reflection against habitus belongs to the second type of i-interactions. One might encounter such situations in the form of criticism pitting one or more discipline against another. For instance, the disputes on witchcraft, which physicians and lawyers carried out against theologians, obtained not only ideological, but also significant scientific value in the sixteenth and seventeenth centuries (Kasavin 1999; Pruzhinin 1999).

On the one hand, it was, in the words of Walter Scott, the time "when a doubt in the existence of witches was interpreted as equivalent to a justification of their infernal practices" (1912, 178) according to the theological point of view commonly shared since "The Hammer of Witches" (1484). Belief in the harmfulness of witchcraft, as well as of the sorcerers and witches as its speakers, who allegedly signed a contract with the devil, organically formed the part of the everyday consciousness of the epoch. In this sense, the belief in the real effectiveness of any kind of magic was the habitus of the Middle Ages, which was cultivated by the Christian Church and theology and shared by the ordinary believers due to tradition.

On the other hand, magic was a general issue of great concern and even led to confusion for the greatest minds of the time—philosophers, lawyers, doctors, theologians—precisely because it was a *sharp dispute* on the fate of European civilization, on the relationship between doctrines and heresies, law and morality, science and superstition, secular and ecclesiastical authority. The theme of witchcraft was problematized and became the sphere of intellectual and ideological confrontation. And yet, it would be misleading to think that that the issue went beyond theology into the wider scope of ideological confrontation. Legally seen, theology was "the queen of sciences" even if it did not rule, its reigns covered the entire field of knowledge. Therefore, the dispute about witchcraft led to division of theology into conservative and moderate (not identical with the distinction of Catholicism and Protestantism), as well as to the constitution of the idea of "double truth". This was the prototype of a successive secularization of science obtaining an independent philosophical meaning.

The basic i-interaction took the following form in this context. Conservative Catholic theology was taken for granted as a kind of mainstream approach, the most traditional habitus. And the latter has been criticized by some liberal scholars as a false theory and a harmful superstition, the wrong faith, the political engagement and indulgence towards baser tastes of the crowd yearning for bloody spectacles. The considerable courage of reflexive thinking was required on the part of the dissenting intellectuals who positioned themselves as the representatives of a different discipline. These individuals claimed the priority of its objectives and methods over theology. On the one hand, such criticism could happen within a theological discourse and communicative purpose but, on the other hand, it was meant to make theology take seriously if not science as a whole, at least its results and their justifications.[4] Theology defended itself against this criticism, but it did not take into account the crucial argument, i.e., the underjustification of the ontological status of magic. This kind of justification, according to scientists, could not be reduced to

[4] This corresponds to the distinction between precautionary and proactionary approaches (More 2013; Fuller 2014).

the historical references to the Bible where the devil and the mages were mentioned. The scientists required the justification of the current diabolic presence in the world and exact evidence in favor of magic capacities of the accused person manifesting itself in the material world.

It was here that many intellectuals came in the arena opposing each other. These individuals included German physician Johann Weyer and German theologians and inquisitors Heinrich Institoris and Jakob Sprenger, along with the reformed Catholic and the professional theologian King James I and the Saxon Lutheran-lawyer Christian Tomasius. A number of other prominent opinion leaders of the time—philosophers and writers—became party to the dispute Bodin, Glanville, Hutchinson, and others. It was hardly surprising that the discussion revolved around such subjects as flying witches, the Devil's physicality, and differences between black and white, natural or diabolical, magic. For educated Europeans of the epoch, these problems were equally relevant with questions about the nature of the State, the power of the monarch, the relation between the person and society—all questions that stimulated the rapid development of the social sciences. This controversy, though temporally remote from us, might be seen as similar to the issues of high concern for the contemporary citizen: social policy, taxation rates, healthcare reform, or fines for violation of driving rules.

It should be noted that i-discussion about witchcraft is irreducible to i-interaction in the form of scientific critique of theology. It represented to a greater extent a certain i-research within science itself and played an important role in the development of the sciences (biology, medicine, sociology, law, criminology), before the conceptual framework of their own was formed. The controversy was initiated by the needs of natural and human sciences seeking self-determination of their subject matter and methods. Discussions of this kind led to the strengthening of the new differentiation of the sciences based on the revised hierarchy of being, in which the scope of the sacred, mystical, political, and legal relations were on one side, and the world of natural elements and qualities were on the other. These existed from this point on independently though parallel. The reflective orientation towards habitus, an attack of the emerging natural sciences against theology under the crisis, resulted epiphenomenally in a rise of reflexive communication between scientists and thus contributed to the emergence of the new disciplines. Yet, this dispute has corresponded neither to external nor to internal needs of theology; it only forced theologians to spontaneously adapt to a new intellectual climate.

Thus, this was a time of constituting of the theoretical content of political science, which was initiated by the questions about the nature of the State, the power of monarch, the relation between the person and society (Machiavelli, Hobbes, Bodin) and led to its formation as a discipline. It was a long way and was deeply rooted in the works of Aristotle. But its proper understanding requires taking into account the i-interactions of the sixteenth and seventeenth centuries, when the disciplines forming the conceptual basis of political science (civil history, law, and philosophy) were released from the direct subordination of theology.[5]

[5] The beginning of political science as a discipline in the modern sense (including training) dates back to 1857, when the Department of history and political science was established by Columbia University

Case 3. Chemistry vs Alchemy

One can find a similar case of the reflexive orientation against habitus in the criticism of alchemy from the point of view of the emerging science of chemistry, upon which Robert Boyle elaborated (Kasavin 2007). One of the important reasons for this criticism was to sort out the contradictory variety of opinions on the nature of chemical elements, compounds, and mixtures, as well as methods for their analysis. The peripatetics, the spagyrists, and the jatrochemists created a dense terminological veil around their concepts. The dispute between supporters of the different concepts only conditionally could be identified with i-interaction or investigation, because even the terms "physics," "chemistry," "alchemy," and "physiology" often meant the same thing, a kind of natural philosophy. The supporters of Aristotle differed from the followers of Paracelsus (spagyrists) in the same way that the followers of pharmaceutical alchemy (iatrochemistry) differed from the chemists. The spagirists and the chemists were new scientists who refused from gold making: the concept of natural elements and qualities was characteristic for both. Yet the former demonstrated a purely applied orientation while the latter tried to discover the basic rules of nature and worked out the correspondent norms and ideals of discourse. The habitual forms of salon discussions shared by educated gentlemen and used by Boyle in the dialogue "The Sceptical Chymist" helped to gradually introduce the new standards for critical-reflexive communication. Clearing the conceptual and terminological fog accumulated over the centuries, Boyle formulated the concept of a chemical element, which was placed at the base of a new scientific discipline. Chemistry asserted itself, therefore, in a dispute with the alchemy (pharmacology) of Paracelsus and the natural philosophy (physics) of Aristotle. Yet the status of the dispute as an interdisciplinary one in the modern sense is under some doubt given the absence of definite boundaries between disciplines.

Case 4. Reflexion vs Reflexion. An Emergence of A New Habitus

The critique of mathematics and physics by George Berkeley in his "Treatise on the principles of human knowledge ..." (1710), his "De Motu" (1721) and his "The Analyst" (1734) has quite a different character. His radical empiricism appeared to be a strong criticism of the scientific revolution.

As a consistent supporter of the empiricist philosophy, Berkeley qualifies the concepts of space, matter, and motion as fundamental for Newtonian physics as empty abstractions with no referent in the observable world. Scientific statements that include these concepts may not be verifiable by experiment, and the famous methodological maxim—"Hypotheses non fingo"—turns out to be solely an ideological slogan (Warnock 1969; Winkler 1994). The same applies to the concept of infinitely small quantities as the basis of the differential and integral calculus. Any value, according to Berkeley, should be perceivable with the help of the senses, but infinitesimal is accessible to perception (as a

(United States). The UNESCO Symposium on political science (Paris, 1948) proposed the term "political science" and developed recommendations for the introduction of its teaching as a discipline within the University education.

definite value) and at the same time is not (as an infinite value). Berkeley regarded this lack of logical rigor unacceptable from the point of view of the canons of ancient mathematics; it was a fundamental flaw of the new mathematics (Jesseph 1993).

In fact, Berkeley catches physics and mathematics in a situation where the frameworks of new paradigms are dynamically generated; in this time of "disorder and disarray" (Kuhn), old methodological standards are irrelevant, and the new ones are still in the process of development. The philosophy of empiricism, recognized by many scientists and philosophers of the time as the foundation of a new science, however, is not in a position to perform this function, if it seeks consistence (Berkeley criticizes John Locke exactly for the inconsistencies of his empiricism) and stays in solitude. This applies, in particular, to the justification of new scientific concepts. The norms and ideals of scientific research changed rapidly, and the proponents of empiricism often practice one-sided and contradictory understanding of the nature of theoretical thinking from the point of earlier methodological thought. It is known that scholars did not explicitly take criticism from Berkeley who was genuinely confident that he was working on a new science. However, it would be wrong to assume that it had no tacit impact on the formation of the new natural sciences and mathematics. Scientists still had to develop and adopt new methodological standards, and philosophers were to justify them with greater thoroughness, rethinking the notions of reality, objectivity, knowledge and thinking. In the future, such minds as Mach and Einstein, still give tribute to the strange ideas of the Bishop of Cloyne.

A Reflexive Transfer of Habitus

Case 5. Constructive Transformations in Physics

In this group of cases, i-interaction is treated as a reflexive transfer of habitus in the sphere of physical knowledge. It appears to be a borrowing of the elements of the picture of the world and of theoretical and mathematical apparatus moving then from one discipline to another. It is significant that such borrowing was performed not mechanically, but resulted in significant modifications to the original concepts and models and their subsequent constructive justification using semantic and empirical interpretation.

The story of transfer of atomist views from philosophy to physics and chemistry and the discussions that accompanied it are rather well known. Piama Gajdenko (2000, chapter 5) shows that although the majority of natural philosophers of the seventeenth century commonly shared the corpuscular theory, this did not mean they agreed with atomism as a philosophical concept (given rather low consensus about the nature of atomism). Democritus, Epicurus, Aristotle, Descartes, Gassendi, Huygens, Newton, Boyle, Dalton, Avogadro are authors of different and largely incompatible atomist views. Two main trends in the rethinking of atomism dealt with the nature of atoms (particles, elements, molecules, corpuscles) and the types of relationships (action at a distance, its alternatives, and variants (Hesse 1955).

Mathematicians, physicists, and chemists treated the nature of atoms depending on the requirements in the relevant model views: as infinitely small points with weight; as a diversity of types of small indivisible particles with specific properties; as qualitatively defined particles, of which indivisibility is relative to the type of their interactions. If indivisible and absolutely elastic atoms play a model role in the explanation of properties of light by Huygens, then for Boyle, the relative difference between elements and compounds would be sufficient to interpret the chemical reactions. The formula of the chemical reactions proposed by Dalton could be interpreted as if the half-fractions of atoms are included in the interaction (although the atoms were treated as indivisible). The hypothesis of Avogadro, who had proposed to that time the diatomic structure of gases, was accepted much later (Zubets and Kasavin 1987). Thus, atomism as a scientific program of the seventeenth through nineteenth centuries differed from the ancient atomism due to the former's direct correlation with those phenomena, which are obtained in the experiment or required for mathematical ontology.

Another case became a textbook example through the works of Vjatcheslav Stepin. This case deals with the transfer of theoretical knowledge of hydrodynamics into the theory of electricity. Stepin historically reconstructs this situation (Stepin 2005) as follows. Maxwell initially set out to build a unified system that theoretically described and explained the electrostatic effects. For this, it was necessary to deduce a general equation of electrostatics. The means of deducing the equation was the analog of hydrodynamic model, the main element of which was a singular incomplete tube current of an ideal incompressible fluid. This model made it possible to move the Euler equation for fluid on the electrostatic effects and to use it as a hypothetical expression for a general law of electrostatics. The differential equations for the electrostatic induction law and Coulomb's law were deduced as consequences from the former (Maxwell 1954, 41-44).

Why was it possible to interpret hydrodynamic equations in terms of electrostatic values? Stepin shows that the basis for the analogy between hydrodynamics and the electric and magnetic interactions were rooted in Faraday's picture of the physical reality accepted by Maxwell. The picture presented the interaction as a continuous change of forces in space, and, therefore, it allows one to grasp an analogy between continuous media mechanics and electromagnetism. Another key to the discovery is Maxwell's procedure of applying the analog model. It turns out that he justified the model as an image of significant features of all experimentally measuring situations in electrostatics. Then, the tentative interpretation of hydrodynamics values in the Euler equations in terms of electrostatics attained the status of proven hypotheses.

Neither the philosophy of atomism, as it was needed to contribute to the development of all natural sciences in the seventeenth and eighteenth centuries, nor the hydrostatics themselves deserved to promote electrostatics. Both solely performed a function of resource disciplines that work in the science habitually in the form of usual and obvious representations. Supporters of New Time atomism and Maxwell had to generate a lot of imagination and constructive reflexion to see the accessible intellectual resources not as pure cases of science's history, but rather as the prototypes for new theoretical insights. Here, i-interaction appears to be an essential condition for the development of new sciences and disciplines.

Finally, the story of i-synthesis leading to a new science—the sociology of Auguste Comte—might be taken as one more example, which is designed to present i-interactions as a set of reflexive procedures. This case, if considered in detail, unites all previously discussed forms of i-interactions. Here, one can see the exploitation of habitus (interaction of theology and the historical science), the critique of habitus (interaction of rationalist philosophy and metaphysical political science (Hobbes, Rousseau), and finally, the transfer of habitus (the idea of social physics). As noted by Kharcheva, "sociology has formed as an interdisciplinary science based on data from biology, psychology, ethics, philosophy, history and economy" (Kharcheva 2000, 17). Naturally, the detailed reconstruction of sociology as a result of interdisciplinary synthesis is a separate and complex issue that required a further historical study (Aron 1965; Kon 1989).

Conclusion

The main types of communications considered above as i-interactions represent conditions in which i-research is performed. Habitus and reflexion, tradition and critique, and reproduction and creativity are the poles of the interactions of those types and forms of knowledge, which were relevant to the disciplines at different stages of their development. And since i-research is found in the entire history of knowledge, the question arises whether they are indeed linked to a certain type of rationality in a quite specific historical epoch?

I-Research as a Type of Cognitive Process

The cognitive characteristics of i-research, as might be expected, lead us to the next conclusion. These features are similar to the image of science that has been emerging in the post-positivist philosophy of science and later, at the turn of the twentieth and twenty-first centuries. The phrase "discoveries occur at the junction of the sciences" sounds like a platitude, but it means that interdisciplinary is exactly that characteristic of science, in which the context of discovery obtains its institutional justification. This is a feature of cutting edge science, or revolutionary science, unlike mainstream and normal science.

The communicative and semiotic approach that uses the concepts of meaning, situation, and communication is particularly applicable to the analysis of interdisciplinarity. Moreover, it is the i-research that primarily implements the communicative situations of understanding and creation of meanings differing from habitual interactions, in which meanings are already articulated and objectivized, "frozen" in theories and applications (Gutner 2008b). Reflexive communication, as we have seen in some of the examples, accompanies the most problematic cognitive situation related to discoveries and attempts to go beyond the habitual frameworks of a particular discipline. This type of communication is traced not only in science but also in the transdisciplinary relations between scientific and non-scientific types of knowledge.

While thinking about the peculiarities of the cognitive process under attention in unusual situations, taking into account the agents who communicate, produce, and consume knowledge, one is essentially dealing with the analysis of i-interactions. This is a list

(though not exhaustive) of concepts and problems that are especially topical in the epistemology and philosophy of science of the last thirty years: the context of scientific discovery; incommensurability of theories; multi-theoretical description; the conflict of interpretations; the impossibility of radical translation; types of rationality; dialogue; discourse; constructivism. These problems outline the conceptual scope of the prospects of epistemological and methodological reflexion. And this is the case especially when the latter pretends to express the cognitive peculiarity of interdisciplinary research as a specific type of rationality, which nowadays is increasingly gaining reflexive attention.

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