HOW COULD VYGOTSKY INFORM AN APPROACH TO SCIENTIFIC REPRESENTATIONS?

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In the quest for a new social turn in philosophy of science, exploring the prospects of a Vygotskian perspective could be of significant interest, especially due to Vugotsky 's emphasis on the role of culture and socialisation in the development of cognitive functions. However, a philosophical reassessment of Vygotsky's ideas in general has yet to be done.

As a step towards this direction, I attempt to elaborate an approach on scientific representations by drawing inspirations from Vygotsky. Specifically, I work upon Vygotsky's understanding on the nature and function of concepts, mediation and zone of proximal development.

I maintain that scientific representations mediate scientific cognition in a tool-like fashion (like Vygotsky's signs). Scientific representations are consciously acquired through deliberate inquiry in a specific context, where it turns to be part of a whole system, reflecting the social practices related to scientific inquiry, just scientific concepts do in Vygotsky's understanding. They surrogate the real processes or effects under study, by conveying some of the features of the represented systems. Vygotsky's solution to the problem of the ontological status of concepts points to an analogous understanding for abstract models, which should be regarded neither as fictions nor as abstract objects.

I elucidate these views by using the examples of the double-helix model of DNA structure and of the development of our understanding of the photoelectric effect.

Key words: Vygotsky, concept, mediation, zone of proximal development, scientific representation, models.

ПРИМЕНЕНИЕ ИДЕЙ ВЫГОТСКОГО В ИССЛЕДОВАНИИ ПРОБЛЕМЫ НАУЧНЫХ ПРЕДСТАВЛЕНИЙ

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В контексте нового социального поворота в философии науки рассмотрение преимуществ подхода, предложенного Выготским, может представлять значительный интерес, поскольку здесь особое место в объяснении процесса развития когнитивных функций субъекта уделяется роли культуры и социализации. Между тем философское осмысление идей Выготского в этом ракурсе все еще не было осуществлено. В качестве первого шага предлагается подход к проблеме научного представления, основанный на концепции Выготского. Автора интересует понимание русским психологом проблемы природы и функции понятий, опосредования и так называемой области проксимального развития. Автор полагает, что научные представления, опосредуя научное познание формируют специальный контекст, в котором становятся частью целой системы, отражающей социальные практики в их отношении к научному исследованию. Выготский считает, что такова функция научных понятий. Они заменяют реальные процессы и эффекты, передавая свойства репрезентируемых систем. Предложенное Выготским решение проблемы онтологического статуса понятий указывает на аналогичное понимание им абстрактных моделей, которые следует рассматривать иначе, чем абстрактные фикции, или абстрактные объекты.

Ключевые слова: Выготский, понятие, опосредование, область ближайшего развития, научное представление, модель.

Introduction

In the quest for a new social turn in philosophy of science, exploring the prospects of a Vygotskian perspective could be of significant interest.

Vygotsky has been more or less ignored in Western philosophical and scientific debates for a very long time. The main reason for that is that he was a Russian Marxist in the Soviet era; therefore there is/was an obvious political bias. Moreover, Western philosophers and scientists use(d) to pay little attention to the role of culture and socialisation in the development of cognitive functions.

The majority of philosophers who have dealt with Vygotsky's work tend to either draw comparisons with other philosophical currents (i.e. pragmatism), or to discuss it in the light of recent debates in the cognitive sciences. In other fields (i.e. pedagogy) there have been attempts to reconstruct the philosophical implications of Vygotsky's views (i.e. about cultural influence in concept acquisition). However, these debates have not yet drifted in "mainstream" philosophy. It seems, then, that a philosophical reassessment of Vygotsky's ideas in general has yet to be done. As a step towards this direction, I attempt to elaborate an approach on scientific representations by drawing inspiration from Vygotsky.

Perception, activity, and scientific cognition

In accordance with Wartofsky, I consider representations to be perceptual artifacts which we do not perceive, but by means of which we perceive real objects or processes [Wartofsky, 1973/1979: 194]. Our ability, as cognitive agents, to represent actions by symbolic means generates representations as a distinctive class of artifacts.

However, it seems that the majority of the approaches which have been proposed so far on scientific representations, regardless of their specific features or the trend they belong to, are ground–ed on the epistemological view that knowledge is the result of observation-description. This amounts to commitment to a certain variety of views on the problem of perception.

I adopt a Vygotskian stance on perception, according to which we perceive a thing where it is, its properties in relation to itself and its relations in the context of its localization with respect to other things. Human perception turns to be a social activity, depending on and determined by cognitive artifacts (such as language and signs), concepts, and so forth, which are produced and employed in social terms. In this context, perception, sensation and cognition are all considered to be functions of action (for further discussion, see [Vygotsky, 1978; Hyman, 2009; Zaporozhets, 2002]). On these grounds, I contend that in the analysis of cognitive processes human activity should be at the epicenter; to know means to manipulate the object of knowledge, to transform it into a tool of action. In this context, scientific representations should be construed as active representations of reality, functioning as tools for scientific cognition.

The social aspect is inherent in scientific representation. As Hessen famously suggested, social practice determines the problems science is dealing with and therefore the direction of scientific inquiry and the formulation of scientific concepts and theories; those of them that fail to correspond to social needs inevitably dissolve [Hessen, 2009]. Hence, even before it is given birth, a representation bears significant history, since, obviously, the scientist who created it is not a blind-deaf child in an empty, sealed room; rather, s/he is a social product. Moreover, from the very first moment of its employment in a scientific inquiry, it is loaded with an enormous amount of social by-products, such as the social needs which foster the scientific inquiry, the socially formulated lenses through which the results of the inquiry are evaluated, or even the material artifacts used to conduct the specific inquiry in the research laboratory, that came out of social production and so forth, not to mention the social relations within which every single scientist who employs a specific representation in his/hers research lives and works.

Scientific representations and Vygotskian concepts

Following M. Wartofsky, I maintain that models and theories are representational cognitive artifacts that function as means of self-consciousness of human as social being. On this ground, they could be conceived of as being putative modes of action, representations of prospective practice(s), or of acquired modes of action.

This view echoes Vygotksy's understanding of concepts (for a detailed discussion, see: [Vygotsky, 1987: ch. 6; John-Steiner, 2007; van der Weer, 1994; Wells, 1994; Berger, 2005]). Vygotsky describes concepts as parts of a system of representation which contains different levels of abstraction and degrees of relatedness to our understanding of reality via other concepts.

In this multifold representation, there are interrelated hierarchies based on already formulated concepts to facilitate the introduction of new ones. In a concept, the bonds between the parts of an idea and between different ideas are logical and ideas are part of a socially-accepted system of hierarchical knowledge. According to Vygotsky, we are conscious of external reality and the whole system of internal experiences in a system of concepts [Vygotsky 1998: 127]. Our cognitive confrontation with reality is not subservient to sense-data but a tendency to interact, to actively participate in its phenomena.

According to Vygotsky, concepts arise within some specific social practice in the form of a problem and a solution [Vygotsky, 1987: P. 123, 127]. There could be cases in which it could be argued that the discovery of a solution gives rise to the identification of the problem. In any case, though, a concept always names a situation and arises in the course of an effort to solve a problem, which arises within a definite system of social practices.

Let me attempt to elucidate the relevance of what has been said thus far to our discussion on scientific representations by an example taken from the history of physics. I will be dealing with the development of our understanding of the photoelectric effect and its role in advancing our understanding of the nature of light and the development of quantum physics[1]. During his experiments that confirmed Maxwell's electomagnetic theory in 1887, Hertz observed that, by shining ultraviolet light onto metal electrodes, he could lower the voltage needed to make sparks hop between the electrodes. This observation obviously implied that light had some electrical effect but Hertz could not explain the phenomenon.

Two years later, J.J. Thomson showed that when ultraviolet light falls onto a metal surface, it triggers the emission of negatively charged particles. It should be noted that some years later Thomson introduced his atomic model, according to which atoms are uniform spheres of positively charged matter in which electrons are embedded. Thus, the photoelectric effect seemed to happen because electrons inside the atoms in a metal's surface were vibrated by the oscillating electric field of light waves falling on the metal. Due to these vibrations, some of the electrons eventually were tossed out altogether.

In 1902, Lenard, one of Hertz's earlier assistants, went on to study the photoelectric effect and made the first quantitative measurements about it. He found that higher frequency light increased the kinetic energy of the electrons, while changing the light intensity had no effect on the kinetic energy. These findings could not be explained by classical physics, according to which, when light shines on a surface, it slowly transfers energy into the substance. This increases the kinetic energy of the particles until finally, they give off excited electrons. Thus, it was expected that increasing light intensity, regardless of frequency, would result in photoelectrons with higher kinetic energies. In addition, since the substance must first reach a critical temperature before it can begin ejecting electrons, it was expected that the photoelectric effect would not be observed immediately.

One should recall that in the meantime, Planck had introduced energy quanta, by arguing that electromagnetic energy could be emitted only in quantized form. Lenard's observations and Planck's theory could be seen as arrows pointing arguably to the same direction. However, it was

[1] This is a rather rough sketch of the actual story, for the sake of my argumentation. Wheaton (1978 & 2009) discusses the issue in detail.

only in 1905 that Einstein applied quantization, not to blackbody oscillators as Planck had previously done, but to the actual radiation that is emitted or absorbed. Thus, he came to realize that light itself is quantized and explained the photoelectric effect mathematically by proposing the concept of light quanta, or photons. This conclusion runs counter to the classic understanding of physics and is better understood in the context of wave-particle duality. If one reads what has previously been said about concepts by changing “concept” to “scientific representation”, s/he could get an apt description of the aforementioned episode. Let me clarify that I do not equate scientific representations with concepts; I just use Vygotsky’s understanding of concepts in order to build analogies with my understanding of the function of scientific representations.

Let us return to the Vygotskian understanding of concepts. According to him, scientific concepts have four distinctive features: generality, systemic organization, conscious awareness and voluntary control. Scientific concepts are not primarily distinguished from spontaneous concepts in respect of the fields to which they apply; rather, it is the way in which they relate to experienced reality. Spontaneous concepts are related to the world of experience in a direct but relatively *ad hoc* manner. On the contrary, scientific concepts are both more abstract and more general. Their primary relationship is to other concepts within the relevant system and only indirectly to the particular objects and events that they subsume.

A new scientific concept ultimately enters into the discourse of the relevant social practice and could make its way into the language and subsequently participate in restructuring the relevant social practices. A scientific concept is consciously acquired through deliberate inquiry in a specific context, where it turns to be part of a whole system, reflecting the social practices related to scientific inquiry, just as scientific representations do.

Word meaning and the function of scientific representations

Let me now turn to the relation between concepts and Vygotsky’s conception of *word meaning*. According to Vygotsky, *word meaning* is the unit of analysis for the study of verbal thinking. A word is a sign for a concept and meaning is an act of both speech and thinking. Thus, *word meaning* is an act of indicating a concept to another person or oneself. Just as word meanings develop, concepts develop, both ontogenetically and historically. In this sense, word meaning is a “*complex and true act of thinking*” [Vygotsky, 1987: 169] which develops and the psychological form of the concept which is indicated by the word meaning is itself also developing. Since a word does not itself have any meaning, people make meaning and use the word for the action of meaning-making. Thus, the concept is represented by word meaning. In Vygotsky’s words, “[i]t is a functional use of the word, or any other sign, as a means of focusing one's attention, selecting distinctive features and analyzing and synthesizing them, that plays a central role in concept formation [Vygotsky, 1987: 106]. The parallelization with my understanding on the function of scientific representations in scientific cognition should be obvious.

This parallelization goes even further, as, according to Vygotsky, a concept exists objectively, albeit implicitly, in our activities and the social properties of the artifacts we, as human social beings, use. However, word meaning is not simply objective. As an action, it is both subjective and objective — in other words, it is an expression of the dialectical unity of objective and subjective. It is through word meaning that concepts are manifested for the person psychologically and become true concepts in the course of cognitive development. We now have in hand the Vygotskian solution to the problem of the ontological status of concepts. This solution radically differs from views according to which concepts should be regarded either as mental images (or any other kind of internal representation) or as something objective, which inhabits the world. This solution pinpoints to an interesting answer to metaphysical concerns about the status of abstract models, which should be regarded neither as fictions nor as abstract objects. The philosophical underpinning could be given by E.V. Ilyenkov's approach on the concept of the *ideal* [Ilyenkov, 1977]; however, a further elaboration of this idea is beyond the scope of this paper.

Ergo, to return to the point from which I departed to discuss Vygotsky's understanding of concepts, I contend that, in such a context, a scientific representation is not a mirror-image of reality, but an active representation of it, which functions as a tool for scientific cognition. Scientific representations serve as means for action, given that scientific cognition is an activity of the human-agent. They are instruments of scientific activity that enable us not only to interfere and interact with the world according to our purposes, but also to gain new perspectives in our understanding of the world we inhabit.

Vygotskian mediation and the mediating role of scientific representations

Let me now turn to the mediating role of scientific representations. Several authors [i.e. Morrison and Morgan, 1999; Cartwright, 1983; Knuuttila 2005, etc.] have elaborated approaches on the role of scientific models as mediators in scientific inquiries. However, these authors share a tendency to diminish representation, by arguing that the emphasis on representation does not do justice to the various roles of models in science. On the contrary, I maintain that it is exactly their representational status, properly construed, that allows us to account for their role in scientific practice. I maintain that a model represents its target system, as long as it successfully conveys and/or explains (some of) its features. It is not my intention in this paper to deploy in detail my understanding on the issue of representation in science; rather, I would like to elaborate my views on the mediating role of scientific representations, by drawing lessons from Vygotsky's understanding of mediation.

Mediation is a central concept in Vygotsky's view of cognitive development. It roughly means that human beings interpose tools between them and their environment, in order to modify it for the sake of obtaining certain benefits. It is via mediation that we, as human beings, learn to ascribe meaning and to internalize areas of life that are not instantly relevant to our immediate existence (for further discussion, see: Vygotsky, 1987; Wertsch, 2007; Karpov and Haywood, 1998).

According to Vygotsky, all higher human mental functions are products of mediated activity. The role of the mediator is played by a psychological tool or sign, such as words, graphs, algebra symbols, or a physical tool. These forms of mediation are themselves products of the socio-historical context. Action mediated by signs is the fundamental mechanism which links the external social world to internal human mental processes. Thus, symbolic mediation is characteristic of higher mental processes.

Vygotsky holds that, by issuing activity mediators, humans are able to modify the environment and this is exactly what is characteristic about humans' way of interacting with nature. There are two hallmarks in the mediated way in which humans interact with the environment; namely, the use of tools within social organized activities and the use of language as a cultural form of mediation. In the evolution of humankind, one can trace a motion towards more complex structures of activity, being mediated by more complex tools, which leads to the production of more complex mental structures.

People convert social relations into psychological functions by employing different types of signs as mediators between their minds and their environment. The common feature of these various kinds of psychological tools is that they are acquired through culture, the aggregation of prior generations' acquired knowledge. Vygotsky notes that the most important sign-mediated behaviour that occurs in cognitive development is the use of abstract language, which appears as detached from the individual features of the environment.

Language (and speech, of course) as a mediating tool, is used by the growing child to talk, plan, think. Thus, it becomes part of child's cognitive system. During this process, other symbolic tools are also being internalized, i.e. mathematical, visual thinking etc. It is important to underline that, according to Vygotsky, there are no universal signs, because signs are developed cooperatively within a given culture. If, instead of the developing child, we think of a scientific community that turns to investigate a specific problem or, even broadly construed, works in the same field of inquiry, one could read in the above lines how the acquisition of scientific knowledge is being developed starting from the first, premature and probably at large mistaken scientific representations employed in our inquiries up to the higher level of command of the specific domain of research, that the scientific community eventually hopes to reach. The several models concerning the atomic structure which have been proposed throughout the history of science could serve as a helpful example.

I would like to highlight that the Vygotskian concept of mediation radically differs from any empiricist or positivist understanding of mental representation. Vygotskian mediation does not contradict at all the idea that thought can embrace an independent world, since mediators are not placed in a metaphysically peculiar layer between reality and us[2]. Within the context of my perspective, this is presupposed in the proposal to understand scientific representations as if they mediate scientific cognition in a tool-like fashion. A scientific representation pilots and enacts scientist's cognitive intervention with the object of cognition.

In the abovementioned sense, I contend that scientific cognition is mediated by scientific representations. Following once again Vygotsky's understanding of concepts and paraphrasing it in terms of scientific representations, I propose that scientific representations are introduced when our existing cognitive tools are unable to provide answers to questions which are raised in the course of our scientific inquiries.

One should bear in mind that Vygotsky introduces consciousness as a responsive function; consciousness is the body's capacity to become the stimulus of its own acts through its own acts (Vygotsky, 1925/1997: 71). Therefore, in my approach, scientific representations yield novel ways of thinking and acting, which were unavailable to the cognizing subject, the human-agent prior to their introduction. Hence, scientific representations not only facilitate our engagement in certain, already existing problems, but they also contribute formulating new questions that may guide new forms of practical activity or enable us to unveil new phenomena as objects of cognition. In this sense, each new scientific representation a scientist introduces, does not appear in vacuum; it is based on the 'thought material' that our already existing cognitive apparatus, which was so far employed in the scientific endeavor, provided us. For example, in mathematics, the same mathematical signs could be argued to mediate two processes: the development of a mathematical concept in the individual and that individual's interaction with the already codified and socially sanctioned mathematical world [Radford, 2000]. In this way, the individual's mathematical knowledge is both cognitively and socially constituted.

There is a point I would like to stress. According to Vygotsky, concepts, as well as sign systems, are tool-like or instrumental systems. For

[2] This is a significant reason why I favor this alternative to Cartwright's (and others') conception of the mediating role of models, according to which models occupy the middle space between the theory and the world.

Vygotsky, 'tools' and 'signs' are not interchangeable, but analogical, in the sense that the sign acts as an instrument of psychological activity in a manner analogous to the role of a tool in labour [Vygotsky, 1978: 52]. While both tools and signs are mediating artifacts, they do not mediate the same kind of activities, since tools mediate object-oriented material activity, whereas signs mediate social interactions of various types. By characterizing scientific representations as '*tools* for scientific cognition', I do not renounce Vygotsky's terminology and distinction; rather I attempt to highlight and specify the objective character of scientific representations and their indestructible bonds with reality, in order to juxtapose my views to others, which are popular in the relevant literature nowadays.

In the abovementioned sense, what Vygotsky teaches about the principal role that 'signs' play in mediating the emergence of consciousness and the construction of knowledge on the part of individuals during the course of their ontogenetic development, is analogous to the view I endorse about the role of scientific representations, as '*tools*' for scientific cognition.

Hence, with regard to my main concern in this paper, I maintain that scientific representations mediate scientific cognition in a tool-like fashion (like Vygotsky's signs). Scientific representations surrogate the real processes or effects under study, by conveying some of the features of the represented systems. Thus, they serve as generalized images of reality, with which scientists interact in the course of their inquiries.

For example, when working on introducing the double-helix model, Watson and Crick were striving to make their model comply with experimental data, to embody previously acquainted knowledge in it, to increase its explanatory capacity. In this sense, they were building their model as an investigative instrument, as a workable representation of the actual structure of DNA molecules. It was not the need to establish a structural relation between the model and its target that guided them in their efforts. The representational status of the model was judged and determined in the context of the specific inquiry, since it is proved that it successfully conveys and explains (some of) the features of the target system.

'Zone of proximal development' and scientific cognition

Let me proceed by invoking another Vygotskian concept, the *'zone of proximal development'* (ZPD), in order to shed more light on the function of scientific representations in scientific cognition.

An important aspect of Vygotsky's theory is the idea that the potential for cognitive development is limited to a 'zone of proximal development' — ZPD (for a detailed discussion, see: [Vygotsky, 1978; Chaiklin, 2003; Obukhova & Korepanova, 2009]). Vygotsky proposes "that an essential feature of learning is that it creates the zone of proximal development; that is, learning awakens a variety of internal developmental processes that are able to operate only when the child is interacting with people in his environment and in cooperation with his peers. Once these processes are internalized, they become part of the child's independent developmental achievement" [Vygotsky, 1978: 90].

We can think of ZPD as the area of exploration for which an individual is cognitively prepared, but unable to fully develop without help and social interaction. The individual should be supported in order to evolve understanding of knowledge domains or development of complex skills. *Proximal* indicates behaviors or skills closest to emergence at any given time — not all possible behaviors or skills that will eventually emerge. Thus, ZPD is actually the area between actual competence level and the potential development level. It is based on the mental functions which are not yet mature, but are in the process of maturation.

It should be noted that ZPD is a zone and not a point because it covers a continuum from a lower level of a skill to its mastery. However, the actual skill will vary depending on instruction, circumstances, etc. The lowest level is the actual level of development; below that level, the skill has been mastered. The upper level is the potential level of development; everything above is beyond the limits and unachievable for now. Thus, the area between lower and upper level includes everything that can be achieved in terms of current competency. In other words, ZPD contains skills in proximity to the last mastered level. It should also be clarified that ZPD is not limitless, which means that an individual cannot learn anything at any given time; s/he cannot learn skills or behaviors that exceed his or hers ZPD.

It is obvious that each domain of knowledge has its own zone. Moreover, ZPD is a dynamic zone, in the sense that with mastery of one level, the entire zone moves up. In other words, ZPD is not static but shifts as the individual attains a higher level any given time. This process is repeated over and over again, as the individual, within the context of his or hers social interactions, climbs the way to complete acquisition of a body of knowledge, skill, strategy, discipline, or behavior. This also implies that ZPD is different for different areas of development or at different times during the acquisition process; it may even vary in size with respect to different domains.

I maintain that the concept of ZPD could be worked upon, in order to elucidate aspects of the function of scientific representations in scientific cognition. Let me use the term 'zone of proximal development in scientific cognition' (ZPD-SC) in order to set an analogy between the Vygotskian conception of ZPD and my concerns here.

ZPD-SC could be conceived of as the area of exploration for which a scientific community working in a certain research area is cognitively prepared, but unable to fully develop. It is confined due to the restrictions posed by our scientific concepts, models and theories which are embodied in the scientific representation employed in the inquiries of the specific domain. ZPD-SC contains skills in proximity to the last mastered level. It could be argued that these skills are provided due to the effect of misrepresentation. Our scientific representations, as truth-hunters, are forcing us to investigate further within ZPD-SC, in order it to be shifted as the scientific community attains a higher level any given time. This process is repeated in due time, as the scientific community, within the context of its social interactions, climbs the way to acquisition of a body of knowledge or discipline, or behavior.

In other words, the scientific representations a scientific community employs in the inquiries conducted in a specific field in a given era, are pinpointing to the upper limits of the knowledge that can be discovered about the specific research area in their terms. Moreover, they are replaced by others, when a higher level of mastery upon this research area has been mastered by the scientific community (within the potential scope of the 'old' representation). It may be the case that an individual researcher has been able to build a representation that reaches beyond current levels of expertise in terms of scientific community. However, this turns out to be a step which will be completed only when it becomes possible that the community is mature to move towards the next level.

Let us recall the example of the photoelectric effect. It has been under study for some time and the explanation of the experimental findings was limited by the level of mastery upon the nature of light and propagation of energy that the scientific community had reached. However, scientific findings of that time, were already pinpointing to the solution of the problem: Planck had already discovered the quantization of energy. It was about time that the community was mature to overthrow its conceptual and representational machinery in order to conquer a new understanding of, i.e. wave-particle duality, which in turn came to pinpoint to further development of science, i.e. quantum mechanics.

In lieu of conclusion

In this paper, I attempt to elaborate an approach on scientific representations by drawing inspiration from Vygotsky. Specifically, I worked upon Vygotsky's understanding on the nature and function of concepts, mediation and zone of proximal development and tried to build analogies with several aspects and functions of scientific representations, as they are employed in scientific inquiries.

I maintain that scientific representations mediate scientific cognition in a tool-like fashion (like Vygotsky's signs). Scientific representations are consciously acquired through deliberate inquiry in a specific context, where it turns to be part of a whole system, reflecting the social practices related to scientific inquiry, just as scientific concepts do in Vygotsky's understanding. They surrogate the real processes or effects under study, by conveying some of the features of the represented systems.

Furthermore, I propose that Vygotsky's solution to the problem of the ontological status of concepts points to an analogous understanding for abstract models, which should be regarded neither as fictions nor as abstract objects.

Admittedly, this paper offers a descriptive outline rather than a comprehensive approach; however, this should not necessarily be thought of as a fault, since my main motivation was to introduce a Vygotskian perspective to the ongoing vivid debate on the issue and to beget further discussion.

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