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How Marxist History of Science Can Inform a Pedagogy of Science for Social Justice

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The scope of this paper is to examine the perspectives for a pedagogy of science for social justice situated in the framework of Marxism by proceeding to an analysis and a contemporary evaluation of the work of the scholars who are considered as the initiators of the Marxist history of science. In this paper therefore, I review N. Bukharin's and B. Hessen's seminal papers as presented in the 2nd International Congress of History of Science and Technology in 1931 in London. This Congress was marked by the appearance of the Soviet delegation influencing a generation of radical scientists in Britain with the most prominent figure being J. Bernal. I present J. Bernal's views as developed in his most important work "The Social Function of Science" with an emphasis on his writings on science education and the role of science teachers for the emancipation of society. Finally, I present the work of the Austromarxist and member of the Left Vienna Circle E. Zilsel on "The Social Origin of Modern Science" contemplating on his work as an adult educator in the period that Vienna was governed by the Austrian Social Democratic Workers Party. Emphasis is placed on the role of science and education as a vehicle for raising proletarian self-awareness. The analysis of the legacies and works of these scholars of the Marxist tradition in the history of science shows that it can form the basis for a Marxist pedagogy of science that can change society and its practices in our epoch when education in science and pedagogy of science are considered one of the most important pillars of contemporary science policy.

Keywords: marxism, history of science, Bukharin, Hessen, Bernal, Zilsel

Что марксистская философия науки может сказать о социальной справедливости в преподавании науки

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Целью данной работы является изучение перспектив преподавания науки для поддержания социальной справедливости. Проблема рассматривается в контексте работ представителей классического марксизма, а также современных родоначальников марксистской истории науки. В этой статье анализируются ключевые работы Бухарина и Гессена на Втором международном конгрессе по истории и философии науки в 1931 г. в Лондоне. Этот Конгресс был ознаменован появлением советской делегации, которая оказала влияние на целое поколение радикальных ученых в Великобритании. И наиболее заметной фигурой здесь был Дж. Бернал. В статье анализируются взгляды Дж. Бернала, представленные в его самой важной работе «Социальная функция науки». Особый акцент сделан на его трудах о научном образовании и роли ученых-преподавателей в процессах социальной эмансипации. Также в статье представлена работа австрий-

ского марксиста и «левого» представителя Венского кружка Е. Цильзеля «О социальном происхождении современной науки». Особое внимание уделяется роли науки и образования как средств воспитания пролетарского самосознания. Анализ наследия и трудов этих ученых-марксистов показывает, что философия науки может стать основой преподавания науки, способной изменить общество и в нашу эпоху, когда научное образование считается одним из важнейших столпов современной научной политики.

Ключевые слова: марксизм, история науки, Бухарин, Гессен, Бернал, Цильзель

Introduction

The relation between Marxism and the history of science has been a topic with a long history. From the very first appearance of the Soviet delegation headed by Nikolai Bukharin at the 2nd International Congress of the History of Science in London in 1931, till the second decade of the 21st century a substantial body of literature exists that studies this topic, which is full of ambivalent issues.

This is not only due to the variety of approaches on the subject but also has to do with inherent problems both in the interpretation of Marxism and the methodological issues in the history of science, mainly the "internal" vs "external" debate.

As it has been explicitly stated in our previous papers [Skordoulis, 2008; Skordoulis, 2015], Marxism cannot be considered as a unified body of work. The dichotomy between critical and scientific Marxism of the previous decades has given in nowadays its place to a renewed dichotomy between the various post-Marxism(s) (postmodern, cultural etc.) and scientific Marxism [Harvey, 1990; Eagleton, 1996; Callinicos, 1989]. The key issues in this renewed dichotomy are the social construction of knowledge and historical determinism [Meiksins-Wood, 1997]. I will further analyze these two issues with relevance to the nature of science and its historical development.

The most vivid illustration of constructivist epistemology is the claim that science is just a knowledge system of the West, an expression of the imperialistic and oppressive principles on which Western society is based. The thesis for the social construction of knowledge traces its roots to the tradition of the sociology of science that includes figures such as K. Marx, K. Mannheim and R. Merton. The crucial difference between these prominent figures of the past and the social constructivist epistemology is the issue of realism. None of them ever denied that science, despite being situated in specific social contexts, provides knowledge of reality independent of our social practices.

For social constructivism, reality itself is socially constructed and therefore we cannot distinguish between the knower and the known. Social constructivist epistemology confuses the forms of knowledge with its objects. It asserts that not only the theories of science are a historical construct that has taken different forms in different social contexts but that natural entities themselves are also socially constructed. This is the consequence of the epistemological position that human knowledge is totally and inescapably enclosed within particular cultures and social interests and therefore humans cannot comprehend reality.

Marxists reject the view that science can be adequately understood in abstraction from the social and historical context in which it develops and at the same time, reject the currently fashionable view that science is merely a social construct lacking any objective validity.

The author of this paper adheres to critical scientific Marxism, a notion introduced by the Marxist economist Ernest Mandel [Mandel, 1986] and supports the view that science possesses a certain degree of cognitive autonomy independent of the social and cultural context in which it develops.

Unlike the internalist rationalists who believe that science can be understood as a self-contained body of ideas with a fixed method that guarantees its rationality and objectivity, critical scientific Marxists argue that science is a socially embedded practice and that its basic concepts and methods have changed historically. Unlike the social constructivists who conclude that because science is a social practice with no fixed canon of methodological principles, its findings have no objective validity, critical scientific Marxists claim that science is a way of discovering the world's hidden causal structure and that the development of science may help to undermine assumptions which reflect the dominant ideology of the particular social formation.

The issue of historical determinism touching upon Marx's theory of history is equally important. Marx employed a materialist conception of history which he combined with a dialectic of emergence and contingency. Marx's materialism is not contained within the critique of capitalism but it is Marx's critique of capitalism that is contained within a materialist view of history, constituted by the "materialist conception of history," on one hand, and the "materialist conception of nature" on the other.

There can be no greater distortion of historical materialism than to conceive it as leading to a strict determinism that then becomes a pseudo-scientific basis on which to prophesy historical developments before they happen.

Indeed, Marx's theory of history looks at societies as totalities where change happens because of internal contradictions in those societies. Historical 'truth' is in the process of change, not in any individual part or event, or even in the end result. The 'outcome' of events is not determined in advance [Meiksins-Wood, 1984].

Far from a mechanical materialism, Marx advocated a materialism grounded in an anti-teleological conception of "evolution as an open-ended process of natural history, governed by contingency but open to rational explanation" [Foster, 2000, p. 15–16].

Recent research in Marxist theory of history has focused on the notion of historical contingency. Historical contingency is not antithetical to Marxism but is of its very essence. History has no end; and the present as history is always both constrained and contingent [Gasper, 1998]. An open-ended, non-teleological outlook is characteristic of historical materialism as opposed to the notion of "the end of history" of the postmodernists.

This paper is structured as follows: in the Introduction I give a brief exposition of the two main issues occupying the central scene of the debate between Marxists and various forms of postmarxism describing the characteristic features of an open critical scientific Marxism of our epoch.

In Section 1, I analyze Bukharin's paper presented in the 1931 London Congress which articulates a Marxist theory of science based on the concept of social practice arriving at the conclusion that science is political and that the idea of the self-sufficient character of science ("science for science's sake") is naïve.

In Section 2, I review the Hessen Theses as outlined in the 1931 London paper giving emphasis on the interaction between science and technology and on the difficulty to apply a demarcation criterion between the two disciplines.

In Section 3, I give a brief exposition of J. Bernal's ideas on science education as outlined in his "The Social Function of Science". I make special reference to his ideas about "Science for all" and about the role of the science teachers.

In Section 4, firstly I review the Zilsel thesis about the social roots of modern science highlighting the relation between the scholar and the craftsman and secondly following Zilsel's career as an adult educator during the period of "Red Vienna" I give an exposition as of how the popular education movement tried to fulfill the task of raising proletarian self-awareness thus making a significant contribution towards the education of the working classes.

Finally, in the Epilogue, I combine the conclusions of the four sections in outlining the main features of a Marxist pedagogy of Science based on the notion of social justice.

Bukharin

In his early years, Bukharin sided with the mechanists of Stepanov against the dialecticians of Deborin in the debates within the Bolshevik Party. In his *Personal Confession* written in July 2, 1937 he admits of having *"a certain heretical inclination to the empirio-critics"*[1]. He believed that Marxists should study the most advanced work in the natural and social sciences and cleanse it of the idealism inherent in the Hegelian formulations.

In *Historical Materialism* [Bukharin, 1969], he interpreted dialectics in terms of the "concept of equilibrium"[2]. For his schema, Bukharin was criticised by those Marxists educated in the classical German philosophy who saw the origins of Marxism in this intellectual tradition.

Reading *Historical Materialism* in his prison cell in Italy, Antonio Gramsci [1971] wrote an extended critique of Bukharin, whom he regarded as the embodiment of a positivistic tendency within Marxism.

Georg Lukacs, associated with a neo-Hegelian interpretation of Marxism, also criticised Bukharin. Lukacs' critique of Bukharin is exhibited in his article: "Technology and Social Relations" [Lukacs, 1966]. In this article, Lukacs does not confine himself to a purely philosophical critique but examines crucial areas of the Marxist interpretation of history in order to combat the evolutionist determinism which descended from the Second International and replace it with a theory of revolutionary action.

Lukacs was highly critical of Bukharin because of his preoccupation with Natural Sciences. According to Lukacs, the closeness of Bukharin's theory to scientific materialism derives from his use of science as a model thus allowing positivism to enter into the study of society.

Later in the '30's, Bukharin studied Engels's *Dialectics of Nature* and Lenin's *Philosophical Notebooks* but paid also great attention to the writings of Hegel. In his writings in the 1930s, Bukharin came to a new understanding of dialectics and to the relationship of Marxism to Hegel. This new approach to dialectics appears explicitly in his paper: "Theory and Practice from the Standpoint of Dialectical Materialism" [Bukharin, 1931].

In 1931, Bukharin led the Soviet delegation to the 2nd International History of Science and Technology Congress in London. Bukharin was already the Director of the newly founded Institute for the History of Science and Technology of the Soviet Academy of Sciences[3].

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1 Nikolai Bukharin "Avtobiografiia" p. 55, cited in Cohen, op. cit. p. 14.

2 ie. the conflict of opposing forces causes a disturbance of equilibrium, a new combination of forces leads to the restoration of equilibrium.

3 The Soviet Union was the first country in the world to establish a specialized institution for the study of the history of technology and science. In 1921, the Russian Academy of Sciences organized the Commission on the History of Knowledge, which in 1931 was transformed into the Institute for the History of Science and Technology under the direction of Bukharin. The institute published in 1933-36 several volumes of the *Archive*

In 1933, Bukharin edited *Marxism and Modern Thought,* a collection of essays with important discussions on Marxism and the Natural Sciences. The collection was published by the Academy of Sciences to commemorate the 50th anniversary of the death of Marx. In his paper, "Marx's Teaching and its Historical Importance", Bukharin took greater note of the Hegelian roots of Marxism and he engaged in a polemic with other philosophical trends of the times: logical positivism, pragmatism, gestalt, neo-Kantianism, neo-Hegelianism etc. These were the themes he took up again in his prison cell in 1937 in his "Philosophical Arabesques" [Bukharin, 2005].

In 1936, Stalin accused the Institute of the History of Science and Technology of being the center of an anti-Soviet conspiracy. Bukharin and a number of other scholars prominent in the field were arrested and executed, including the author of the famous 1931 essay on Newton, Boris Hessen. The Institute of the History of Science and Technology, which had pioneered the field worldwide, was abolished and not re-established until 1944 [Graham, 1973, 2001].

Bukharin's "Theory and Practice from the Standpoint of Dialectical Materialism" outlines the epistemological importance of the problem of the relation of theory and practice and examines the relation between theory and practice from a sociological viewpoint setting the basis for a social history of science.

In his paper, Bukharin attempts to base the development of human history and consequently of the history of science in the interrelation between theory and practice. He explicitly states that both theory and practice are steps in the joint process of the reproduction of social life.

Bukharin then elaborates that the interaction between theory and practice develops on the basis of the *primacy of practice*: the sciences «grow» out of practice and the practice of material labour is the constant motive force of the whole of social development.

For Bukharin, the external world is not static but has a history. The relations between the knowing subject and the knowable object are historical. Linking the process of knowledge with the economic base of production (mode of production) through their historicity he arrives at the statement that the "modes of production" and the "modes of conception", are historical.

Consequently, "truth" can be understood historically as a process and this means that at any given time we know to a certain extent. Therefore, one cannot talk on the basis of absolute truth. Truth is always approximate.

Truth is associated with science and the function of science, according to Bukharin is primarily the "*function of orientation in the external world and in society, the function of a peculiar struggle with nature, with the*

*of the History of Science and Technology***,** devoted to the elaboration of a Marxist approach, with strong emphasis on socioeconomic analysis. After the arrest and execution of Bukharin, this field of scholarship was reestablished only on Stalin's personal intervention in 1944.

elemental progress of social development, with the classes hostile to the given socio-historical order". Science and society are inextricably linked. Science functions in society by extending and deepening practice. The function of science in society is therefore political. Science is a weapon against capitalism in the same way that Enlightenment and the French revolution has used science and science education as a weapon against aristocracy and the feudal order. Therefore, the idea of the self-sufficient character of science ("science for science's sake") is naïve.

Hessen

Boris Hessen (1893–1936) studied physics at the University of Edinburgh (1913–1914) and then at the St. Petersburg University (1914–1917). He joined the Red Army and became member of the Revolutionary Military Council (1919–1921). He graduated from the Red Professor's Institute in Moscow in 1928. He became a physics professor and the chair of the Physics Department at the Moscow State University in 1931. In 1933 he was elected a member of the Russian Academy of Sciences.

From 1934 to 1936 Hessen was a deputy director of the Physics Institute in Moscow headed by S.I. Vavilov. On August 22, 1936 Hessen was arrested. He was secretly tried by a military tribunal, found guilty on December 20, 1936 and executed by shooting on the same day. On April 21, 1956 he was rehabilitated.

In 1931, Hessen delivered his famous paper "The Socio-Economic Roots of Newton's Principia" at the 2nd International Congress of the History of Science and Technology in London, which became foundational in the history of science and led to modern studies of scientific revolutions and sociology of science.

Hessen's paper provides a detailed analysis of the way in which classical physics was rooted in the economic and technological developments of the 17th century, decisively refuting the 'individual genius' view of the history of science. Hessen focuses on the period of the English Revolution of the 1640s and examines the impact on theoretical physics of factors such as communications, water transport, mining, armaments and ballistics.

But Hessen does not offer a crudely reductionist view. While economic and technical factors play a crucial role in shaping the development of science, they are not the whole story, and Hessen also discusses the influence of philosophical and political ideas, arguing that it is necessary to analyze more fully Newton's epoch, the class struggles during the English Revolution and the political, philosophical and religious theories reflected in the minds of the contemporaries of these struggles.

Hessen's outstanding essay remains to this day the high watermark of 20th century Marxist analyses of science, expertly tracing the way in which a major scientific theory emerged from the interplay of material and ideological factors.

In the quite recent book of Freudenthal and McLaughlin [2009], the three theses developed by Hessen are briefly presented as:

> The first thesis concerns the relation of economic and technological developments in the early modern period and the relation of these two to the emergence of modern science: Theoretical mechanics developed in the study of machine technology.
>
> The second thesis draws the converse conclusion: In those areas where seventeenth-century scientists could not draw on an existing technology (heat engines, electric motors and generators) the corresponding disciplines of physics (thermodynamics, electrodynamics) did not develop.
>
> The third thesis concerns the ideological constraints placed on science in England at the time of the "class compromise" or "Glorious Revolution" (1688): Because of this compromise Newton drew back from fully endorsing the mechanization of the world picture and adapted his concept of matter so as to be able to introduce God into the material world.

Hessen's topic is the Scientific Revolution that culminated in the seventeenth century, which according to Freudenthal and McLaughlin [2009] had been prepared by developments since the thirteenth or fourteenth century.

Hessen views mechanics and not cosmology (e. g. the Copernican Revolution) to be the core of the scientific revolution. This is in itself significant in as much as he focuses not on the conflict between a geocentric and a heliocentric worldview, but rather on the mechanization of the world picture, in which natural phenomena are explained, like machines, by mechanical laws of motion only.

Such correlations do not yet present a thesis on the emergence of modern science. The correlations have to be explicated and explained. There would seem to be two alternatives to explain the correlation. The first takes technology to be the goal of science and perhaps the motive for pursuing science in the first place. The second takes technology to be the precondition of science [Skordoulis, 2012].

This can be summarized in the following two theses:

> A. Technology was developed in order to facilitate economic development, and science studied the particular problems that it studied in order to improve technology.
>
> B. Technology was developed in order to facilitate economic development, and science developed by means of the study of the technology that was being applied or developed.

Hessen is not asserting that our distinct disciplines existed at the time but rather that these disciplines are what arose out of the study of these problems to technology. Is technology the goal of seventeenth-century science or rather its subject matter? The first expresses the position usually attributed to Marxist historiography of science while the second explains why the rise of technology also gave rise to a new conceptualization of natural phenomena, why these new concepts did indeed find reference in the real world by way of technology, and finally also why this conceptualization of nature seemed plausible within certain strata of society.

Hessen's essay initiated a new field of study that has been subsequently called "social history of science".

Hessen's paper has been studied extensively by Western historians of science. Without endorsing Hessen's approach, Western historians of science applied his logic to explain the origins of his views. When publishing the "socio-political roots of Boris Hessen", Graham [1985] characterized Hessen's paper as primarily a response to the contemporary situation in the USSR and in particular to the suspicious attitude of Soviet Marxists to Einstein's relativity theory.

Hessen, a physicist himself, tried to defend Einstein's theory. According to Graham [1985], Hessen wished to differentiate between the social origins of science and its cognitive value. He knew that he would have an easier time convincing Soviet Marxists that Newtonian physics had enduring value despite its bourgeois social origins than he would demonstrating that the still little understood relativity theory also must be valued despite its social origins in capitalistic central Europe.

One has also to note that in the flourishing field of Science Studies (or Science, Technology Studies – STS) the contribution of Marxism in the field is not disputed and research is to a large extent based on Marxist methodology. Introductory textbooks such as those of Hess [1997] and Ziman [1984] make lengthy favourable references to the Hessen's theses on the interaction of science and technology.

Bernal

Tragically, the period of intellectual vitality which had begun with the 1917 October revolution, come almost at an end in the late 30s. Bukharin and Hessen, among many others, were to become victims of Stalin's purges.

But "Science at the Crossroads" [Werskey, 1971] influenced a generation of radical scientists in Britain who turned to Marxism and became excellent popularisers of science and promoters of science education.

Werskey [1978] has written a collective biography of these famous British Marxist scientists. His *Visible College* includes Hyman Levy, J. B. S. Haldane, Lancelot Hogben, J. D. Bernal and Joseph Needham[4].

P. M. S. Blackett, who became President of the Royal Society and a Nobel Laureate, and J. G. Crowther who is considered to be the first science journalist and was science editor of Oxford University Press were also influenced by the papers of the Soviet delegation in the 1931 Congress.

These scientists founded a tradition that produced a number of influential popular and scholarly works. The most influential single work in this tradition was J. D. Bernal's *The Social Function of Science* [Bernal, 1939]. This publication was followed by a number of books, the most relevant of which are *The Freedom of Necessity* [Bernal, 1949] and the four-volume *Science in History* [Bernal, 1954].

Bernal worked tirelessly for the cause of socially responsible science. He felt that the progress of science was sufficient to alleviate the many problems that confront humankind. He believed that science should concern itself in a planned way to improving the lot of humankind [Ravetz, 1971, p. 312].

With the flux of time his grand design, which seemed so radical in the 30s and 40s now appears to be an essential part of the writings and conference papers which abound on the subject of Science, Technology and Society (STS).

Bernal's view of science is best represented by the following passage from his work: *Already we have in the practice of science the prototype for all human common action. The task which the scientists have undertaken – the understanding and control of nature and of man himself – is merely the conscious expression of the task of human society. The methods by which this task is attempted, however imperfectly they are realized, are the methods by which humanity is most likely to secure its own future. In its endeavour, science is communism* [Bernal, 1939, p. 414].

Bernal was deeply concerned with the state of science education [Bernal, 1946]. His criticisms have been echoed down the decades by others but his suggestions are still relevant. In *The Social Function of Science* he wrote that the chief benefit of science education is that it teaches a child about the actual universe in which he is living, and how to think logically by studying the method of science. He insists that the way in which educated people respond to pseudo-science such as spiritualism or astrology, not to say more dangerous ones such as racial theories, shows that previous years of education in the method of science in Britain or Germany has produced no visible effect whatsoever [Bernal, 1939, p. 72].

[4] Werskey's work refers exclusively to Britain. Well-known Marxists scientists in the anglo-saxon world are also Benjamin Farrington and Dirk Struik. Generations of Marxists scientists and educators appeared and flourished nearly everywhere in the western world with the most celebrated declaration being Albert Einstein's "Why I am a Socialist" (*Monthly Review*, Vol. 1, No. 1).

Bernal devoted fifteen pages of *The Social Function* to "Changing the Teaching of Science". He advocated introducing an element of discovery into science teaching, thus predating the discovery-learning movement. He has also argued for the inclusion of questions of social responsibility in the teaching of science – another contemporary theme. Also of contemporary significance is his call for teaching *Science for All* which would empower citizens through developing their abilities to see that everyone not only has a general picture of the world in terms of modern knowledge, but also appreciates and can use the type of argument on which that knowledge is based, to be able to safeguard themselves from 'anti-rational tendencies which are otherwise at the command of all reactionary forces' [Bernal, 1939, p. 248] and to provide an understanding of the place of science in society to enable the citizen appreciate the impact of science on society.

In making these suggestions, Bernal was asking for radical changes in the science teaching of his day. Bernal emphasized the important role of science teachers. For Bernal, science teachers, with their special knowledge, represented one of society's great resources, and it was important that this resource should be used for the benefit of society. At the same time in addressing practical, and controversial social problems and in giving leadership to their students they would need to be thoughtful, aware that 'anti-scientific and anti-social forces are powerfully entrenched in the school system' [Bernal 1949, p. 143]. He believed that if school teachers knew their job they would be able to convince the society that a rational approach to social problems is not politics but plain common sense [Cross and Price, 1988]. Bernal's general attitude on science teaching is given epigrammatically: "*Science and education are powerful weapons for the defence of democracy, and for making possible the extension and development of democracy in the direction of an ordered, yet free, co-operative community*" [Bernal, 1949, p. 158].

Zilsel

The Austrian Marxist Edgar Zilsel (1891–1944) was a mathematician, a physicist and a philosopher, and one of the most interesting Marxist intellectuals of the Vienna Circle.

Against Neurath, Carnap, and even Schlick, he held that there are legitimate, genuinely philosophical problems that can neither be transformed into logical or empirical questions nor be conceived as only problems of language. From the early 1920s, he became absorbed in the investigation of the conditions under which ideas, theories and knowledge arise.

Although many features of the Vienna Circle's philosophy have been re-discovered and re-appreciated during the last quarter of the last century, Zilsel has remained relatively unknown among philosophers until recently, when a collection of his works was published [Zilsel, 2000].

Recent scholarship [Uebel, 2005] presents a revised view of the history and philosophy of a 'left wing' in the Vienna Circle, challenging the conventional representation of Logical Empiricism as politically conformist. Uebel's work is a representative exposition of the Left Vienna Circle (LVC) thesis. Uebel argues that a group within the Vienna Circle, comprised of Otto Neurath, Rudolf Carnap, Hans Hahn, and Phillip Frank, developed a critical and politically engaged early political philosophy of science. According to Uebel [2005], LVC logical empiricism differed from the neutralist logical empiricism later popularized in North America. LVC members believed that by providing conceptual tools to facilitate the progress of science, philosophy may participate in the advancement of emancipatory politics. Describing LVC logical empiricism as 'critical and politically engaged', Uebel implies that Carnap, Neurath and others share common theoretical interests, tools, and questions of present-day social epistemologists, feminist philosophers of science, and others, interested in the possibilities of a political or politically engaged philosophy of science. Uebel focuses primarily on the conviction of some members of the Vienna Circle that philosophy of science has political implications and is part of a larger progressive project.

Zilsel joined the Social-Democratic Workers Party (SDAP) in 1918 and became active in the Workers Education Movement. He did not obtain an academic post and became one of the most active teachers at the Adult Education Centers (Wiener Volkshochschulen) and the Pedagogical Institute of Vienna that played a crucial part in 'Red Vienna's' education program[5].

As well as teaching in secondary school, Zilsel also taught at the Vienna institutes of adult higher education. From the academic year 1922/23 onwards, the school authorities granted him leave of absence so that he could take up a 'teaching assignment for philosophy and physics' at the *Volksheim* (people's institute). Thereafter he worked uninterruptedly in popular education in the city until he was dismissed by the Austro-Fascist regime in 1934.

[5] "Red Vienna", a term describing the city during its political control by the Social-Democratic Workers Party (SDAP) in the 1920s, forms the immediate political context of the Vienna Circle. Led by Otto Bauer, Max Adler, Friedrich Adler, Karl Renner and Rudolf Hilferdig, the SDAP embraced an approach to Marxism that came to be known as Austromarxism, drawing heavily on Marxist, Machian, and neo-Kantian ideas. During the 1920s, the SDAP carried out municipal reforms to aid the new urban industrial working class, instituting libraries, schools, lecture series, vast housing complexes, sports leagues, and free medical care. The SDAP also established programs encouraging 'cultural change' among the working class.

Following Austria's Anschluss in 1938, Zilsel left Vienna for London. In April 1939, he emigrated to the USA. Within a very short time after his arrival in New York, Zilsel was able to establish contact with Max Horkheimer, the director of the International Institute of Social Research (IISR) – the emigrated Frankfurt School. Although the Institute did not have the necessary means to support Zilsel, they did actively assist his efforts to find such.

In 1942, Zilsel published his monumental paper "The sociological roots of science" [Zilsel, 1942]. The project of explaining the emergence of modern science was presented for the first time at the 5th International Congress for the Unity of Science at Harvard University in September 1939, five months after Zilsel's arrival in New York.

What is known today as the 'Zilsel thesis' was one of his most fruitful hypotheses: the assumption that superior artisans and other practitioners had been operative in developing the epistemic principles of causal explanation and methodical experimentation. In order to study the emergence of modern science as a social process, Zilsel suggested distinguishing three strata of intellectual activity in the period from 1300 to 1600: university scholars who focused on rational distinctions and classification; 'the fathers of Humanism' who were interested in accumulation of classical knowledge and mastery of speech and writing; and groups of craftsmen who developed empirical observation, experimentation and research into causes. Among these, the 'artist-engineers' were the most important: they were the immediate predecessors of modern scientists.

To understand the different types of rationality that emerged from these strata of intellectual activity, Zilsel not only showed how they were related to the social and professional conditions under which they were produced, he also drew attention to the intellectual and rhetorical struggles that those social groups were involved in. Moreover, he analyzed the deep impact that symbolic struggles had on social change.

For Zilsel, the rise of the methods of the manual labourers to the ranks of academically trained scholars at the end of the sixteenth century is the decisive event in the genesis of science.

Based on the above account for the genesis of modern science, it is obvious that for the LVC science did not imply a purely theoretical activity, a 'pure' cognition of the world; their experimental / empirical verification of hypotheses essentially meant work, human labour.

In their conception, education did not represent a passive reception of scientific knowledge but meant active participation in the production of knowledge. Since science involves human labour, then there is a material affinity between scientists and the working classes. The division between manual labour and intellectual labour, characteristic of the capitalist mode of production is alien to the conceptions of the LVC.

The popular education movement linked with the LVC was related to the experiences, knowledge and skills of factory workers. This meant that workers did not have to adopt alien "bourgeois" cultural traditions and attitudes but were on the contrary strengthened in their own social identity [Gruber, 1991].

The LVC consistently promoted, on the basis of scientific insights, the development of proletarian self-awareness which must logically lead to the improvement of social conditions for the working classes. This also meant the promotion of anti-authoritarian and radical democratic efforts and the democratic control of the processes of production and distribution, hence a genuine victory over capitalism.

Epilogue

The scope of this paper is to show that the works of the scholars who are considered as initiators of the Marxist history of science can form the basis for a Marxist pedagogy of science that can change society and its practices.

Indeed, Bukharin, Hessen, Bernal and Zilsel did not only lay the foundations for a Marxist history of science but their works are also of pedagogical value and can form a programmatic and theoretical basis for a Marxist pedagogy of science at a period of crisis in science education exemplified by the neoliberal restructuring of education on a global scale [Skordoulis, 2018].

Bukharin's paper presented in the 1931 London Congress articulates a Marxist theory of science based on the concept of social practice arriving at the conclusion that science is political and that the idea of the self-sufficient character of science ("science for science's sake") is naïve.

Hessen theses as outlined in the 1931 London paper give emphasis on the interaction between science and technology and on the difficulty to apply a demarcation criterion between the two disciplines thus initiating the STS approach in science education.

Bernal's ideas on science education as outlined in his "The Social Function of Science" give an emphasis to the nature of science identifying science with democracy and communism. In Bernal's paper, issues of science policy also emerge. Bernal advocates "Science for all" and underlines in this process the role of the science teachers.

The Zilsel thesis about the social roots of modern science highlights the relation between the scholar and the craftsman, the affinity between the scientist and the worker. Following Zilsel as an adult educator during the period of "Red Vienna" we can see in practice how the popular education movement tried to fulfill the task of raising proletarian self-awareness thus making a significant contribution towards the education of the working classes.

Finally, this thread between Marxist historians of science and the Marxist pedagogy of science which shows the intellectual vitality of Marxism has to be further analyzed. This pioneering work of Marxist historians of science precede by some decades what the Harvard Physics Project sought to achieve in the 60s. And this has to be evaluated accordingly.

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