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Marxism in Vygotskian approaches to cultural studies of science education

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Abstract In this paper we initially address the main categories of Marxism, illustrating how Vygotsky has appropriated them as mediational meta-theoretical tools for building concepts for his psychological approach. In order to investigate the influence of Marxism in cultural studies of science education, we make an account of how current research, sustained by Vygotsky's original and successor theories, has been appropriating meta-theoretical categories of dialectical materialism. Once we identified *Cultural Studies of Science Education* as a journal that would probably concentrate papers that follow these perspectives, we decided to take it as the context of this study. In the process of selecting the corpus to be reviewed from the editions published from 2006 to 2011, we have found that 16 % of the articles that matched keywords denoting frameworks related to the Vygotskian tradition developed and appropriated the categories of dialectical materialism. The quality and originality of contemporary development of CHAT denote that this framework has been playing a very important role in recent expansion of Vygotskian approaches to research in science education. Among the papers that we considered to develop and appropriate Vygotskian frameworks, incompletion in the appropriation of meta-theoretical categories of dialectical materialism and the misusage of dialectics intertwined with dialogism were highlighted. Our findings suggest that overcoming these limitations can enhance political analysis of sociocultural phenomena in the context of science education. It also represents a strengthening of the role of dialectical materialism in

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expanding sociocultural perspectives toward a better articulation between individual and institutional-centered analyses.

Resumo executivo Embora as raízes marxistas da tradição de pesquisa vygotskiana raramente sejam negadas, a centralidade do materialismo dialético para a abordagem sociocultural nem sempre é devidamente explicitada por pesquisadores em educação científica. Assim, o presente artigo tem início apontando alguns traços principais do *materialismo dialético*—fundamento filosófico e metodológico do programa de pesquisa marxista—que podem ser facilmente encontrados nos textos mais lidos de Vygotsky. São destacados aqui cinco traços ou categorias meta-teóricas fundamentais: (1) tese, antítese e síntese; (2) unidade de análise dialética; (3) história e processo; (4) revolução; e (5) materialismo. Com efeito, uma análise atenta dos textos de Vygotsky permite demonstrar que essas categorias foram ferramentas meta-teóricas eficazes para que o autor pudesse construir os fundamentos de sua psicologia sociocultural. Em seguida, com o propósito de investigar a influência do marxismo nos estudos culturais da educação científica, o presente artigo parte para uma revisão crítica de como pesquisas contemporâneas baseadas nos escritos de Vygotsky e de seus principais sucessores têm se apropriado das categorias do materialismo dialético para resolver os diversos problemas teóricos e metodológicos com os quais se deparam. Ao identificarmos *Cultural Studies of Science Education* enquanto uma revista que provavelmente concentraria artigos que seguiriam estas perspectivas, decidimos considerar este periódico como contexto do estudo. Foram considerados para revisão todos os artigos publicados nessa revista até o ano de 2011, incluindo aqueles publicados no modo *online first*, com referência a pelo menos uma das seguintes palavras-chave: *Marx*, *Vygotsky*, *Leont'ev*, *Activity Theory* e *Wertsch*. Dos artigos selecionados, uma grande parte apresentava referências periféricas a Vygotsky e somente em 16 % foram empregadas as categorias do materialismo dialético. Os artigos em que o materialismo dialético mostrou-se mais fundamental foram cuidadosamente analisados e discutidos. A qualidade e originalidade dos desenvolvimentos contemporâneos da Teoria da Atividade (*Cultural Historical Activity Theory*) denotam que esse referencial tem realizado um papel muito importante na expansão contemporânea do programa vygotskiano no campo da pesquisa em educação científica. Ao longo da revisão, destacamos também as situações em que o materialismo dialético é apropriado de maneira incompleta, contribuindo para que seja feita alguma confusão entre dialética e dialogismo. Nossos resultados sugerem que superar limitações da apropriação do materialismo dialético pode ser importante para desenvolver análises políticas contundentes no contexto da educação científica e expandir as perspectivas socioculturais em direção a uma melhor articulação entre análises centradas no indivíduo e análises centradas em instituições.

Keywords Dialectical materialism · Marxism · CHAT · Vygotsky · Science education

Recent advances in science education research have addressed human development as related to language, culture and society. Despite the diversity and disconnectedness of perspectives that face this endeavor, their theoretical underpinnings frequently stem from or can be related to Lev Vygotsky's studies. We argue that a more connected perspective could hardly be built without understanding the philosophical basis of Vygotsky's human psychology, which is, in its turn, rooted in the Marxist research program, as he himself has argued:

> I want to find out how science has to be built, to approach the study of the mind having learned the whole of Marx's method. In order to create such an enabling theory-method in the generally accepted scientific manner, it is necessary to discover the essence of the given area of phenomena, the laws according to which they change, their qualitative and quantitative characteristics, their causes. It is necessary to formulate the categories and concepts that are specifically relevant to them—in other words, to create one's own capital. (Vygotsky *in* Cole and Scribner 1978, p. 8)

Although it is accepted that Cultural Historical Activity Theory (CHAT), which can be considered as originating in Vygotsky's cultural-historical psychology, is sustained by Marxism, or more precisely, by dialectical materialism—which is largely recognized as the basis of the philosophical and methodological underpinnings of the Marxist research program—(Engeström and Miettinen 1999), the relations between Vygotsky's studies and Marxism are often left overlooked. Most western appropriations of Vygotsky's work subjected his Marxist philosophical commitments to attend liberal and neoliberal political systems since the first translation of his work (Duarte 2001). Elvira Lima (1990) reports that according to the translator of the French edition of *Thought and Speech*, American translation has reduced two-thirds of the Russian text, eliminating key passages and most of its references to Marxism. Since the access to Russian psychology was mediated mostly by American publications, this reduction has spread worldwide.

In an overview of science education literature, it is not difficult to make an incorrect assumption that Marx's quotations of Vygotsky are not fundamental, but only a constraint of the political context where he lived. In certain periods of Soviet history the need to tailor the research to policy trends actually occurred. However, it is a mistake to interpret the inclusion of Marxism in experimental psychology from the 1920s as a reflection of political pressure. According to Michael Cole (1979), a hallmark of research at this time is its enthusiasm and optimism about the development of the dialectical materialist approach to psychology. As any other research program, Marxist framework constitutes a body of knowledge which has vast and complex theoretical and methodological commitments, as well as characteristic jargon and styles of language.

The main purpose of the theoretical enterprise reported in this paper is to investigate the role of dialectical materialism in research carried out in science education under the Vygotskian framework. We initially discuss some categories of dialectical materialism, illustrating how Vygotsky appropriated them as mediational meta-theoretical tools for building concepts and arguments for his new psychological approach. Once these categories are introduced, we report a review of selected papers from *Cultural Studies of Science Education*, which did explore and develop a Vygotskian framework. These papers have been critically approached from the perspective of the presented categories, leading to an account of how dialectical materialism has been influential and appropriated.

Marxism in Vygotsky

The appropriation of Marxist categories by Vygotsky was not a mechanical bond, but it results from a construction itself developed from readings of Georg Hegel, Karl Marx and Friedrich Engels (Freitas 2003). These categories can be traced back to *The German Ideology* (Marx and Engels 1932), which discusses the first developments of dialectical and historical materialism. In the following sections, we discuss the main meta-theoretical categories of dialectics that inspired Vygotsky's studies, illustrating how he appropriated

the Marxist stance in his work as to build the concepts he needed to approach human development from a historical and cultural perspective.

Thesis, antithesis and synthesis

Dialectics is a philosophical system through means of which it is possible to analyze opposite or even contrary elements together in unity (Hegel 1977). In general, a dialectical relationship is a tension between two antagonistic entities that puts a larger and more complex whole in movement. Particularly, a dialectic relationship may be found in a debate situation as a statement (thesis) faces its negation (antithesis). This confrontation is dynamic and full of tension so that the internal opposition is precisely what sustains the debate. Eventually the dialectical relationship is overcome and the debate ends producing a synthesis—which should not be regarded as a summary of—neither an intermediate position between—thesis and antithesis, but as a result of (dialectically) overcoming the original tension that constituted the debate. Hence, the *dialectic method* may be referred here as a method for reaching synthesis from contraries.

Throughout the books *Thinking and Speaking* and *Mind in Society*, Vygotsky has conducted literature reviews for the introduction of his ideas using variations of this dialectical method. The author organizes most of the works of its research field around two opposite and extreme positions—such as thesis and antithesis. In the simplest version of this dialectical argument, the author stresses the incompatibilities and limitations of the two polarized positions. In cases where a binary categorization was not sufficient to account for diverse research perspectives, Vygotsky added other categories in conflict, remaining always as the strongest candidate for the synthesis of the debate.

One remarkable example of Vygotsky's reaching synthesis from contraries may be found in his memorable presentation to the 2nd All-Russian Congress on Psychoneurology. In this presentation, Vygotsky (1925) draws from the opposition between reflexology, which is a more behavior-oriented research field, and experimental psychology, which used to be more oriented toward mind as a subjective phenomena, to argue against both these fields that *mind without behavior is as impossible as behavior without mind*. Actually, Vygotsky presents his proposal so that it does not seem to be just another idea among many others. His goal is not to coexist with different theoretical positions, but to overcome their contradictions. Using this dialectical method, and assuming that the reader will accept the same evaluative criterion of dialectics (the preference for synthesis), he introduces his theory one step ahead of his peers. The following excerpt is a prototype of what occurs in several passages of Vygotsky's text:

> A look at the results of former investigations of thought and language will show that all the theories offered from antiquity to our time range between identification, or fusion, of thought and speech on the one hand, and their equally absolute, almost metaphysical disjunction and segregation on the other. Whether expressing one of these extremes in pure form or combining them, that is, taking an intermediate position but always somewhere along the axis between the two poles, all the various theories on thought and language stay within the confining circle. (1934, p. 2)

Vygotsky rejects both the idea that thought and speech are the same as the idea that they are distinct and separate. In his theory, Vygotsky asserts that thinking and speaking are distinct, though mutually related psychological functions: the speech becomes thought and thought becomes speech (Vygotsky 1934). Thus, the argument transcribed in the excerpt above, which is presented at the beginning of the book, prepares the reader to agree that

Vygotsky's approach to speech and thought sets out a revolution in the context of human psychology. On the other hand, it is possible to notice that the core of this argument stems from the dialectical method.

Dialectical unity of analysis

Dialectics is not restricted to the strategy of argumentation. The profound adherence to the categories of dialectical thinking implies an ontological stance for which reality is considered to be dialectical. Hence, to produce a dialectical theory about anything, one must adopt a unit of analysis, which is complex enough to include processes in competition. Only then, the object of study can be characterized by the conflict between comprised antagonistic parties, enforcing attention to tension that is typical of the dialectical thought.

The unit of analysis of any theory that adopts dialectics in the meta-theoretical level must be composed of parts and relations (of tension) between these parts. From these considerations, it is possible to observe that dialectics is necessarily opposed to reducing the object of study to its minimal elements (the so-called atomistic analysis). Thus, the strong opposition to atomistic analysis developed by Vygotsky emerges from his philosophical commitment to Marxist dialectics. This stance can be seen in the following fragment:

> Interfunctional relations in general have not as yet received the attention they merit. The atomistic and functional modes of analysis prevalent during the past decade treated psychic processes in isolation. Methods of research were developed and perfected with a view to studying separate functions, while their interdependence and their organisation in the structure of consciousness as a whole remained outside the field of investigation. (Vygotsky 1934, p. 1)

To illustrate his opposition to reductionist atomistic thought, Vygotsky puts forward an analogy with the chemical analysis of water into hydrogen and oxygen. Isolated, these elements have properties that are not found in the whole (water) and the whole has properties that are not present in its elements. That is, the whole is qualitatively distinct from its isolated parts and analyzing the latter does not substitute an analysis of the former.

History and process

Besides adopting a minimally complex unit of analysis, it should be added to the ontological stance inherent to dialectics that dialectical relations constitutive of this unit are considered to be responsible for putting the whole unit in movement, i.e., these relations are responsible for changing the unit of analysis through time. From this perspective, results a methodological focus on history and process.

For Vygotsky, only a historical theory of inner speech can handle the problem of thinking and speaking. In fact, elaborating a historical theory of psychological phenomena requires adopting research methods that focus the history of one's unit of analysis. Hence, Vygotsky outlines his methodology for psychological research in these terms:

> In summary, then, the aim of psychological analysis and its essential factors are as follows: (1) process analysis as opposed to object analysis; (2) analysis that reveals real, causal or dynamic relations as opposed to enumeration of a process's outer features, that is, explanatory, not descriptive, analysis; and (3) developmental

> analysis that returns to the source and reconstructs all the points in the development of a given structure. (1978, p. 65)

The zone of proximal development, which is often considered Vygotsky's most remarkable contribution to educational practices; possibly for being an easy-to-grasp concept with very straightforward implications; is also intimately connected to the experimental-genetic method and is deeply rooted in the need of addressing psychological phenomena as an always developing process (1978).

Revolution

Researchers committed to dialectics tend to approach complex and ever-changing phenomena through adequate process methodology. But what does dialectics assert about the history of dialectical processes? Are dialectical processes always-continuous transformations or may they eventually turn into turbulent and discontinuous revolutions?

This question may be answered through considering what happens during a debate situation. Eventually, the tension that relates thesis and antithesis is dialectically overcome, i.e., a synthesis that resolves the conflict is produced. The process of producing the synthesis cannot be considered continuous, since it qualitatively changes the debate situation from conflictive to non-conflictive. In this sense of *qualitatively transforming the situation* we can say that the production of synthesis represents a *revolution* in the argument.

Dialectics is a meta-theoretical stance opened to revolution, i.e., revolution is acknowledged in dialectics as constitutive to the process of being. For this reason, researchers inspired by dialectics tend to stress, in the historical development of his object of analysis, some revolutionary discontinuities.

Vygotsky advocates the idea of revolution in understanding human psychological development. The main property of psychological tools is revolutionary in that it completely changes the flow and structure of psychological functions. From this perspective, mediational tools are not only aids, but they transform the mental functioning qualitatively. Hence, the very notion of mental development of Vygotsky includes revolutions as development is not made of a steady stream of quantitative increments, but it fundamentally comprises qualitative transformations (Wertsch 1985).

According to Vygotsky, it is the speech—or more precisely, the changes that speech brings to thought and action—that makes us specifically human and qualitatively distinct from other animals. In various passages of *Mind in Society*, Vygotsky (1978) argues that there are qualitative differences between men and animals. For example: for him, the internalization of social activities is specifically a human feature; the ability to perceive meanings and perform operations with signs affects the whole of higher mental functions and is also characteristic of human being. At last, the ideas of revolutionary human development and distinction between human and animal are in the core of Vygotskian thought.

Materialism

Despite its roots in ancient history, modern dialectics is considered to be developed by Hegel (1770–1831) and became a mainstream framework to German philosophy in the 19th century. Before being appropriated to Marxism, Hegelian dialectics was profoundly reviewed by Marx and most differences between Marxist and Hegelian dialectics fall under the concept of materialism. The materialist stance in Marx is developed in opposition to

Hegelian idealism and is fundamentally related to the negation of autonomy of abstract entities (such as ideas, mind, consciousness, the self, knowledge and language) over concrete social life.

> We do not set out from what men say, imagine, conceive, nor from men as narrated, thought of, imagined, conceived, in order to arrive at men in the flesh. We set out from real, active men, and on the basis of their real life-process we demonstrate the development of the ideological reflexes and echoes of this life-process. (Marx and Engels 1932, p. A)

Several implications to social sciences have been developed from this materialist statement such as: (1) consciousness (along with language, mind and the self) should be considered originally a social phenomenon; (2) collaboratively changing the world through labor should be considered central to the production and reproduction of human conditions of existence; (3) being able to produce and reproduce their own material conditions of existence (rather than being conscious, religious, moral) is what distinguishes man from other animals.

In the Marxist worldview, individual consciousness is shaped by the material conditions of social life and the first fact of human existence (rather than individual thought) is human transforming reality through labor. For Marx, "life is not determined by consciousness, but consciousness by life" (Marx and Engels 1932, p. A). This materialist stance has influenced Vygotsky's work in various ways. In his criticism of Jean Piaget, Vygotsky rejects the idea that the development of thought corresponds to the socialization of originally egocentric mental states. He points out that, before existing as egocentric speech, language is experienced as a form of social relationship, and, then, internalized: "every function in the cultural development of the child appears on the stage twice, in two planes, first, the social, then the psychological, first between people as an intermental category, then within the child as a intramental category" (Vygotsky 1978, p. 55). In fact, the concept of internalization implies that every mental function has its origins in concrete social phenomena (1978, pp. 52–57). On the other hand, the concept of zone of proximal development is related to the idea that learning from concrete social experience is always some steps ahead of individual development (1978).

Vygotsky's research project relies on the fundamental Marxist idea that one becomes human through labor. In this sense, the role of material tools was considered fundamental in the task of transforming the natural world (Marx and Engels 1932). Vygotsky emphasizes the role of tools in human activity, exploring the psychological role of mediational tools (instruments and signs). Thus, Marxist materialism underlies the work of Vygotsky both in his idea that higher mental functions are originally related to concrete social phenomena and in his approach to mediational tools as a main element for human activity. These contributions, which Vygotsky develops carefully throughout his work, are valuable to the understanding of human psychological phenomena and constitute the legacy of dialectical materialism.

Developing Vygotskian tradition in science education

Concepts and ideas that constitute Vygotsky's sociocultural psychology (e.g., the dialectical relationship between thought and language, the study of psychological processes as a whole, the zone of proximal development, the communicative function of language as a human specificity, the general law of cognitive development from the social to the

individual), which arise from and are supported by meta-theoretical categories of dialectical materialism, have been appropriated in various ways by educational research since the 1980s.

A remarkable change in research in science education related to Vygotsky's ideas is the shift from a pre/post-test methodological paradigm to more developmental qualitative analysis of students learning science at school (such as discourse analysis of students interacting with teacher and peers). Vygotsky has privileged school as a scenario for psychological studies, criticizing those who did not take account of inherently social aspects of the scholarly environment (Freitas 2003). School, as a locus of reproducing and transforming society, is fundamentally responsible for the development of higher mental functions as children learn to master and appropriate cultural mediational tools through interactions with teacher and peers. Even though Vygotsky did not show clearly how these interactions are related to reproduction and transformation of large scale social structures (such as the school itself and the educational system), dialectical materialism has played an important role in recent developing sociocultural theories that focus on broader contexts.

Even though activity itself is not explicitly approached in Vygotsky's work, contemporary researchers have been considering it as the first generation of a wider research program called CHAT project (Engeström 2001). After Vygotsky, CHAT has been further developed into a second generation theory by Aleksei Leont'ev (1981), which explained the difference between individual action and collective activity, relating the Marxist concept of labor to psychological phenomena. Aiming to formulate a Marxist psychology, Leont'ev (1981) considers that activity depends on social context and elects labor as the paradigmatic form of human activity.

Contemporary CHAT (third generation) has been developed by many scholars both in the former socialist countries and in western nations with the purpose of explicating the dialectical interplay between individual agency and social structures. It takes the object-oriented, artifact-mediated collective activity system as its unit of analysis. Without reducing the multivoicedness of contemporary activity theory, CHAT analysts often draw from Yrjö Engeström's (1999) model for the activity system, which articulates subject, object, mediational tools, rules, community, division of labor and the activity's outcome. It is important to highlight that every constituent of the activity system is dialectically interconnected to the individual-others and to the whole in the sense that these tensions tend to bring revolutionary qualitative transformations to the activity system.

Another successor framework stemming from Vygotskian tradition is James Wertsch's (1998) theory of mediated action, which shares the same purpose of articulating individual psychology to include broader sociocultural context. However, Wertsch's focus on action (rather than on the activity system) brings distinct features to his theory. He considers human cognition and mind as mediated action (such as thinking, remembering) and, hence, never completely individual as actions depend on subject's mastering and appropriating certain cultural tools as mediators. Under his approach, it is possible to demonstrate that mind is not limited to one's brain, but rather distributed since mental actions are often performed with the help of cultural tools and more capable peers (Wertsch 1998).

Review procedures

In order to investigate the influence of Marxism in cultural studies of science education, we make an account of how current research, sustained by Vygotsky's original and successor theories, has been appropriating meta-theoretical categories of dialectical materialism.

Once we identified *Cultural Studies of Science Education* as a journal that would probably concentrate a significant number of papers that follow these perspectives, we decided to take it as the context of this study.

We adopted a two-step procedure for selecting papers from the universe of 382 published in CSSE in the period of 2006–2011 including the Online First publications. First, we entered, one at a time, the following keywords in the research engine, which denote frameworks related to the Vygotskian tradition: 'Marx', 'Vygotsky', 'Leont'ev', 'Activity Theory' and 'Wertsch'. Second, every paper (original article or forum paper) found was briefly analyzed and separated into two categories: (1) peripheral citations of the keywords, i.e., papers that cite one or more keywords without showing a theoretical commitment through all the steps of the investigation; (2) development and appropriation of the frameworks in the sense that we could identify explicit relationships with the meta-theoretical categories. The number of papers found and classified through this procedure is presented in Table 1. One might observe that lines do not sum up to total in Table 1 because different keywords have often occurred in each paper.

Finally, every paper considered to develop and appropriate at least one of the frameworks denoted by the keywords has been reviewed and critiqued in the light of the previously discussed categories. In the section 'Quasi-appropriation of dialectical materialism' we summarized five papers that we could not classify strictly as 'Peripheral citations' or as 'Development and appropriation', highlighting research elements that could be more consistently discussed with a deeper appropriation of dialectical materialism.

The analysis of the 17 papers considered to develop and appropriate the Vygotskian frameworks led to an account of how dialectical materialism has been appropriated in contemporary research in science education. For presenting the review, commentaries on each selected paper have been grouped into sections that are related to the content of the papers and to the meta-theoretical categories.

Six papers (Candela 2010; Johnson and Tippins 2007; Treagust and Duit 2008; Brayboy and Castagno 2008; Brown and Kloser 2009a) did not match the keywords but were included in the review because of their importance to understanding forum papers that matched one or more keywords. These papers were not counted in Table 1.

Quasi-appropriation of dialectical materialism

The following reviewed papers draw on Vygotskian successor theories and as such, appropriate dialectical materialism meta-theoretical categories as long as they constitute the core of these theories. We considered them as quasi-appropriation in the extent that we could not identify how those categories have been assumed as commitments to the point of impacting research design, analysis and findings.

In an ethnographic study of a third grade science classroom, John Reveles, Gregory Kelly and Richard Durán (2007) focus on how a teacher has helped his students acquire

Table 1 Selection of papers to be reviewed

	Marx	Vygotsky	Leont'ev	Activity Theory	Wertsch	Total
Peripheral citations	20	55	6	46	23	87
Development and appropriation	2	8	0	8	1	17
Total number	22	63	6	54	24	104

psychological tools for learning to think and engage in scientific practices. The concepts of human and symbolic mediators, activity system and psychological tools sustain this analysis and stem from third generation CHAT, although sociocultural theory is mentioned in general as the theoretical framework and attributions are made to Leont'ev, Vygotsky and Wertsch (in Reveles et al. 2007). Some theoretical aspects presented in the forum (Scott, Mortimer, Lee and Engeström 2007) helped us to consider how dialectical categories could perform to make the sociocultural framework more consistent in the research. One of them is related to the nature of the data presented in the first part of the analysis, which are not in line with the sociocultural assumption that learning is a material phenomenon that happens first in the social level and later in the individual level. The dialogues presented in the two episodes, constituted mostly by the teacher's or the ethnographer's utterances, fail to give evidence of the co-construction of community knowledge. The same incongruence related to the lack of description of the social relationships that occurred in the classroom—e.g., the science practices that the teacher intended to teach.

Another aspect that refers to a dialectical category is related to the idea that mediated action should be treated as the unity of analysis which means that it should include the tension between the agent and psychological tools and focus on the process of development. The data presented by the authors to examine the ways the tools were internalized and appropriated by the students to construct scientific knowledge does not show tensions lived by the students during the process of learning, but only the final result of the process. The dialogues the students have with the ethnographer seem to be carried out in an absolute climate of acceptance of everything that they were taught without tensions or conflicts.

Sylvie Barma (2011) examines how a science teacher makes an effort to change her practices as she plans and implements new teaching and learning situations based on a subject considered relevant to the students (an awareness campaign on the risks of tanning salons) in the context of a curricular reform in Quebec. This reform overlaps concerns among European and North American reforms as the growing focus on developing competencies and the implementation of an interdisciplinary practice grounded in current problems having relevance for students. Drawing on third generation CHAT, for which subject, object, mediational tools, community, rules and division of labor are dialectically related, the author describes how changes in the teacher's practices (considered the subject of the activity) are related to changes in the other poles of the activity system. By using activity theory, Barma (2011) presented a chronology of how the pole 'subject' has evolved over a short period of time and how a teacher (Catherine) has engaged in a project she thought was innovative and in line with reform. The teacher's practice trajectory was investigated by autobiographical narratives, semi-structured interviews and field observations. In a forum contribution, Carlos García (2011) points out some controversies concerning Barma's analyzes and approach to activity theory, claiming that not only teaching practices are socioculturally anchored but science curriculum reform as well. Conceiving curriculum reform as a field of cultural production, the author calls attention to the fact that this field is frequently a curricular standardization towards employability. Any curriculum reform, beyond their ideals and objectives for change, is also a field of cultural production and reproduction in which the social aims can no longer be seen as isolated from economical goals. In this sense, García claims that Barma (2011) overlooked curricular reform itself (along with the policy makers that produce these curricular standards). Hence, García (2011) stresses that activity theory is not only biographical, but also historical and social as he claims that Barma (2011) missed in her analysis the tensions between teachers and the (often vertical and authoritative) curricular reforms and

reformers. In general, García contended that Barma did not effectively articulate the situated issue of one's changing of her own teaching practices owing to a curricular reform to the institutional forces that tend to inculcate these reforms.

Drawing on dialectical arguments, García also points out that the dialectical relationship between the actors involved in the activity system investigated by Barma (2011) are not explored to the extent that the position of the teacher in the field of reform is considered practically equal to Barma's (the researcher and one of the formulators of the reform) and the tensions between positions are not explicated. In this sense, García has addressed that the teacher, the researcher, the students, the school principal, the laboratory technician, other teachers and health professionals, along with public policy proponents and activity theorists appear to be similarly active in the construction of this specific reform. The community and division of labor in an activity whereby different positions (often defined by a hierarchy of power and status) are created for each system participant are not considered in Barma's investigation although it is a crucial feature in the activity theory framework. Since the process of verticalization in an activity system was not considered, dialectical relations between its poles were not relevant to problematize the division between manual and intellectual labor.

The CHAT-IT theory, which is a combination of CHAT and Institutional Theory (Ogawa, Crain, Loomis, and Ball 2008), has been used by Ajda Kahveci (2010) in his forum on Antonia Candela's (2010) ethnographic study concerning the academic trajectories of undergraduate Physics students at a Mexican university. Jan Nespor's (in Candela 2010) conceptualization of learning in which it is 'first, being able to move oneself and, second other things (as cultural tools), through the space–time networks of the discipline' is the principal theoretical framework of the study. Her findings suggest that Mexican students are more autonomous in constructing their own itineraries in Physics while north-American students are forced to focus on a rigid formal training. Besides, Mexican students seem to take initiative and develop power as they are more in charge of the construction of their itineraries than are Physics undergraduate students in the US (Candela 2010). She also has found that there is a general orientation toward work in groups by the Mexican students in order to accomplish academic tasks. In his forum, Kahveci draws on CHAT-IT theory to highlight the institutional elements that inevitably constitute the social context of learning (Kahveci 2010) and should be taken into account of what happens in Mexican and US undergraduate Physics classrooms. From the CHAT-IT perspective, Kahveci stresses that it is important to "understand the historical development of the Mexican university as an educational organization and the institutional influences on this development" (p. 741). The notion of transformation, central in activity theory, could be used to analyze the role of Physics professors in Mexico as agents whose practices could contribute not only to innovative didactical changes but could become a critical and transformative one in the context of formal educational organization. The understanding of the differences between undergraduate Physics students from these two countries by recognizing the cultural features also should take into account the history of the Mexican University and the economic role of Physics and technology within a dependent country.

History and revolution: Toward an activist transformative stance

In expanding the notion of responsibility suggested by Wolf-Michael Roth (2007), Anna Stetsenko (2007) claims that human development is an *activist project* not only imbued with dialogism and interrelatedness but also "grounded in answerable deeds ineluctably

colored by visions and commitments to particular goals for and versions of social life" (p. 749). As a way to substantiate her argument, the author elaborates on a merger of Mikhail Bakhtin's ideas and those of Vygotsky, who was "a visionary and committed activist" (p. 748).

At first, Stetsenko (2007) contends both naturalist and social constructionist perspectives in that they fail to provide an adequate understanding for the ethical nature of life and relation to the other. She claims that "turning to primordial experiential reality that later on becomes extended by cultural constructions through language and other semiotic means does not offer a viable anchoring to the problem of ethics" (2007, p. 749). From this statement on, Stetsenko turns to the discussion of commonalities between Bakhtin's and Vygotsky's ideas. She claims that, although he never used the terms 'otherness' or approached dialogism as Bakhtin, Vygotsky clearly attributed much value to the role of others in the psychological development.

> The role of dialogicality in Bakhtin's works and sociality in Vygotsky's are well understood and integrated in today's interpretations of their works. The point to note so far is simply that the two scholars are clearly very close in their viewpoints at a very deep, metatheoretical level of analysis in that they both adhere to a relational ontology of a shared world as the source and fulcrum for human being and development. For both scholars, unavoidable and profound interconnectedness of human beings constitutes the deepest and most significant feature of all human life in all of its expressions. On this score, their positions are closely compatible and complementary, each strengthening the voice of the other. (p. 752)

Stetsenko (2007) also asserts that both Bakhtin and Vygotsky stem from the same tradition of Russian philosophy (which inherits and constitutes Marxist philosophy) since they both follow on with the long established tradition of Russian philosophy that revolved around the notions of "unity, communality, and sociality of life and being" (pp. 752–753). In contrast to Bakhtin, Vygotsky does not develop an understanding of ethics and responsibility explicitly. However, Vygotsky's understanding of how human subjectivity emerges from shared actions with others (to never completely break away from these actions) is "indicative of the same meta-level understanding of Being as *an active project of becoming* that stems from and is constituted by communal, shared forms of doing" (p. 755).

In another paper, Stetsenko (2008) plants a contribution to overcome the current fragmentation within sociocultural approaches in psychology, education, and other neighboring disciplines. After recognizing the need for an integrated perspective in sociocultural approaches, understood by her as often committed to social justice and equity issues that explore the effects of culture and society in human development, the author focuses on the common foundation that is tacitly present in John Dewey's, Piaget's and Vygotsky's theories of human development: so-called *relational ontology*. The analysis of these three theoretical perspectives on human development is an intermediate step to deeply understand Vygotsky's research project, planting the notion that collaborative purposeful transformation of the world is the core of human nature and the grounding for learning and development.

The author explains that relational ontology is a stance that emerges in opposition to the essentialist perspective that takes phenomena in the social world as thing-like entities that exist separately from each other and also to the Cartesian split between subject and object, knower and known. Stetsenko (2008) shows that, Piaget, Dewey and Vygotsky elaborated

approaches to human development that are consistent to a relational ontology stance, despite the differences between these authors.

The author points out that Piaget, Dewey and Vygotsky agree that human action is in the core of the relations between persons and the world and that they constitute human development. This attention to human action is itself an opposition to the spectator stance – that stands for the idea that human development is mainly a passive process. However, the activist transformative stance defended by Stetsenko (2008) suggests that people come to know themselves and their world as well as ultimately coming to be human in and through the processes of *collaboratively transforming the world* in view of their goals. Hence, all human activities are profoundly imbued with ideology, ethics, and values.

The activist transformative stance is regarded as a solution for many theoretical problems posed by sociocultural theories since it cuts the gaps (1) between individual and social and (2) among ontological, epistemological, and moral–ethical (ideological) dimensions of human activity. Finally, Stetsenko (2008) asserts that Vygotsky's CHAT project advances toward this view and is distinguished from Dewey's and Piaget's theories as it sustains the foundations of an activist transformative stance in human developmental psychology.

As an attempt to 'operationalize' the discussion put forward by Stetsenko (2008), Colette Murphy and Karen Carlisle (2008) illustrate relational ontology and the activist transformative stance in the everyday context of coteaching and cogenerative dialogue. These authors argue that coteaching and cogenerative dialogue provide "expanded opportunities for transformative action in learning and development through shared contribution, collective responsibility, expanded agency and the active promotion of each other's agency" (p. 505).

Dialectics and dialogism

Drawing from the life history case study of a science teacher named Anna, Konstantinos Alexakos (2007) demonstrates that her moral beliefs, perceptions, experiences and interests dialectically frame and mediate her views of science teaching. This author claims that, in the 'transmission' of cultural capital, Anna enacts not only the role of a cultural mediator, but she enacts "an organic entity that contributes to how culture is created, recreated and exchanged in a science classroom" (Alexakos 2007, p. 883). As such, Anna is described as an organic link. Besides, as Anna brings her personal philosophy of teaching and learning to her science classroom, which is, in its turn, rooted in her life history, she also brings in her own identity. Alexakos (2007) claims a dialectical relationship between teaching philosophy and identity in these terms:

> Anna's experiences and her own sense of self frame her teaching philosophy, and yet, in turn, her philosophy continually shapes and reshapes, informs, influences, modifies and transforms her subsequent experiences and reshape and transform her sense of self. (p. 885)

Consistent with his commitment to the dialectical meta-theoretical framework, Alexakos (2007) also argues that "the total of what science teaching is exceeds the sum of its commonly "measurable" parts" (p. 883) such as content and pedagogical knowledge. Not only in these fragments, but throughout the whole paper, Alexakos's dialectical claims embrace mostly two features of the dialectical framework: (1) unity—for which the unit of analysis of any dialectically-oriented theory must be composed by parts and tension relationships between these parts; (2) history and process—for which the dialectically

related parts of a whole are ever changing and developing due to the tensions that relate between these parts.

However, other commitments originally constitutive of the dialectical materialism framework, such as the idea of producing qualitative revolutionary transformations from conflicts, are underexplored by Alexakos (2007).

In critically discussing Alexakos's findings, Amy Johnson and Deborah Tippins (2007) claim that the idea of science teacher as an organic link would be better articulated under a dialogical (rather than dialectical) framework. They ascertain that what Alexakos is dealing with "is not so much the dialectic aspects of Anna's identity construction, but the dialogic aspects of Anna's identity development as a science teacher" (Johnson and Tippins 2007, pp. 913–914). From these reviewers' perspectives, "seeking resolution to tensions is not necessarily the goal; instead, what is most important is recognizing the complexities within the tensions and seeking to understand how we can best work within the constraints of those tensions" (p. 913). Arguing for dialogism instead of dialectics, these reviewers explicitly put aside the orientation toward revolution that features dialectics.

Dialectics in theorizing operations, actions and activity

SungWon Hwang and Roth (2007) provide a remarkable example of how dialectical materialism may be put to work as a tool for consistently theorizing science education. In their paper, the authors present a dialectical theory that contributes to the understanding of how students come to learn science through hands-on activities. They depart from CHAT's distinction between motive-directed activities, goal-directed actions and contextually conditioned operations (Leont'ev 1978). As one might acknowledge from activity theory, changes in human practices must be driven by objective contradictions (i.e., relations of tension that constitute the inner forces of acting). However, Hwang and Roth advance in highlighting that, for producing *conscious* transformation of human action, contradictions must be experienced from a first-person perspective. This subjective experience of contradiction is defined as resistance (Hwang and Roth 2007).

The authors argue that resistance and contradiction exist in dialectical relation "because any resistance is the expression of inner contradiction, and all inner contradictions express themselves through resistance, the two terms presuppose each other" (Hwang and Roth 2007, p. 429). Put in these terms, the authors suggest that being *mutually constitutive to each other*—which is equivalent to satisfying *relational ontology* (Stetsenko 2008) or the meta-theoretical category 'Dialectical unity of Analysis' (as it is named in this paper)—is sufficient to pose a dialectical relation.

For the purpose of reviewing how dialectical materialism has mediated this paper, we focus on their discussion on the nature and function of resistance in design activity. From analyzing several episodes of group work in a science laboratory class, the authors make three claims: (1) the experience of resistance has been fundamental for students to step back from the current situation, to look at themselves and their activity perceiving and resolving systemic contradictions; (2) when the product of goal-directed action is perceived as inconsistent with the motive of activity, resistance resolves into a process that *changes the goals of actions* retaining mutually constitutive relation to the motive of activity; (3) when operations are not consistent with attaining the current goal, resistance becomes salient to the designers in the form of a breakdown and *the original goal disappears temporarily* until a provisional goal appears. In synthesis, Hwang and Roth (2007)

theorize on how contradictions between the adjacent levels of human praxis (activity, action and operations), as experienced by subjects through resistance, lead to one's consciously transforming the goals of their own actions. Thus, the authors provide a remarkable example of how dialectical materialism may be put to work as a tool for consistently theorizing science education.

Maria Andrée (2012) sustains that students' participation in science education can be better understood as engagement in certain activities than determined by socio-economic background, ethnic background, sex or other classification of students on a priori characteristics. The author interprets students' participation based in Engeström's model of activity systems and shows an expansive transformation in the activity system of a particular student (Helena) where the object and motive are re-conceptualized in relation to the prior activity. The contradiction that emerged between a new mediating artifact and the object of formal education opened up for the emergence of learning science as a new activity system. In this sense, the study draws on the dialectical relationships between the nodes of the activity system and turns to the process of transformation generated by a particular episode that occurred in group work. In the description of the process it is possible to note that the division of labor in the classroom changes and can be described in terms of collaboration between experts and non-experts. The activity of science learning instead of the one of completing formal education becomes meaningful for the students, opens up for participation of a wider group of the classroom community and changes the work structure from completing tasks and tests to knowledge production and sharing.

A materialist approach to conceptual change

In reviewing conceptual change research, David Treagust and Reinders Duit (2008) depart from the perspective that conceptions are "learner's mental models of an object or an event" (p. 298). These authors claim that conceptions can be regarded as the learner's internal representations (entities of one's individual cognitive structure) constructed from the external representations elaborated by other people such as teachers and textbook authors. Though developments of conceptual change research have brought new understandings to the nature of conceptions, Gordon Wells (2008) argues that the individualistic cognitive approach from which Treagust and Duit depart has never been completely abandoned in this field of research and students' immaterially conceived cognitive structures are often considered to own conceptions in a very similar way that cases own pencils.

In a forum contribution associated with Treagust and Duit (2008), Wells (2008) articulates the Vygotskian materialist framework to contend the understanding of the nature of concepts underlying most conceptual change research. The first point made by Wells is that scientific concepts are tools, cultural artifacts, elaborated in order to increase human possibilities of action. Because concepts are culturally produced tools for human action, they never become completely an individual property, but may be appropriated in the sense that one may learn how to use them for particular purposes. This shift from the pencil-case metaphor toward the focus on the possibilities of action, which is based on the Vygotskian materialist approach to psychology, may be found in other contemporary scholars' work, such as Wertsch's concepts of mastery and appropriation (Wertsch 1998).

The second point made by Wells (2008) is that, as screwdrivers and hammers are appropriate for different purposes, despite the ambition for universalism often found in

scientific discourse; scientific concepts are not likely to be useful in every field of action. "While a nutritionist may need to use concepts developed in the field of biochemistry to advise on a healthy diet, a supermarket shopper uses less technical concepts in purchasing the ingredients for the family dinner" (pp. 331–332). Thus, Wells argues that scientific concepts are tools developed for the purposes of science and everyday perspectives may be considered 'misconceptions' only in relation to the practical contexts that scientific concepts have proved to be more effective.

The third point made by Wells (2008) is that, in learning their community's language, children everywhere adopt the ways of speaking and thinking that enable them to make sense of the events of everyday life. Since concepts available for children are effective tools for the purposes of their everyday life, attempting to persuade students to 'change' the concepts they use through instruction in school is unlikely to be successful "unless learners recognize that the proposed alternatives are effective in solving problems that they themselves see as meaningful and significant in relation to their own life concerns" (p. 347). These three points, which stem from Vygotskian materialist framework, bring new ways to understand learners' appropriation of scientific concepts.

Ingeborg Krange (2007) aims to understand students' conceptual practices in science education as a cultural phenomenon, which means that the settings are not considered as stable situations, in which participants bring in existing schemas, but faces learning as result of actors' interactions. To make an account of these interactions in changing cultural settings, the author defined the unit of analysis as *mediated action a*nd followed a group of students while they solve a particular scientific problem, investigating how different cultural means were made relevant through their interactions in varying ways over time. The author used Wertsch's (1991) sociocultural view on mediating tools in combination with Pickering's concepts of bridging, transcription, filling, and free and forced moves to investigate how cultural means (the knowledge domain and other tools such as a specific website and a computer-based 3D model of the insulin gene) intersect in productive ways during the students' conceptual practices. According to these frameworks, it also was considered the understanding of the actor's performance as a combination of what one can do and the mediational possibilities and limitations of the tools being used. The basis for the analysis came from video recordings gathered from interactions in the 3D model of the insulin gene. Six excerpts which represented changes in the students' and their teacher's interactions in accordance with the means of mediation were presented.

The analysis shows that both the knowledge domain and the tools mediated students' conceptual practices throughout the problem solving processes. Considering that the means of mediation have historically and culturally inscribed characteristics that must be interpreted and adapted to the particular setting, the author argues that the 3D model of the insulin gene is historically so new that it creates new conditions for the students' and their teacher's conceptual practices in science education. However, while knowledge about the purpose of the design was important for the students to solve the problem, it did not insure a better understanding of the knowledge domain. Acknowledging that "it is in the tension between the students's and teacher's interactions and the intersecting cultural means of mediation that productive disciplinary interactions are defined" (Krange 2007, p. 200), the author calls attention to the role the teacher performed to supplant the problems presented in the tools and to arrange interpersonal relations so that productive interactions occur.

Dialectics in culturally diverse communities

In a forum contribution based on Bryan Brayboy and Angelina Castagno's (2008) original paper on teaching western science concepts to indigenous communities, Marilyn Fleer (2008) argues from Vygotsky's approach to scientific concepts that dialectical logic is more productive to theorize science teaching in culturally diverse communities. This dialectical logic is explicitly elaborated in the claim that "everyday practices and concepts lay foundations for the learning of scientific concepts, and learning in schools also lays important conceptual pathways for raising everyday concepts" (2008, p. 783), i.e., everyday concepts and scientific concepts are dialectically related.

In a hermeneutic study, Alexakos, Jayson Jones and Victor Rodriguez (2011) explore how fictive kinship amongst high school students of color mediated their resiliency, perseverance and success in a college physics class. The authors assert that these kin-like personal friendships contributed to creating a safe and supportive emotional space leading to cooperative competition within the physics classroom and helping students to cope and persevere despite their initial conflicting expectations of their success in this subject matter.

Alexakos et al. (2011) have drawn from role modeling tools for understanding individual behavior in relation to the community. Authors claim that each student within the core fictive kinship group became a role model for the others and a dialectical interplay between the individual and the group appeared: each individual became a role model for the collective as the collective became a role model for each individual. On the other hand, beyond the role model interplay of emulating and being emulated by others, students in the fictive kinship group were likely to be mentored and to become mentors for the others as they were likely to look after each other, providing guidance in class (such as making sure their friends understood the scientific ideas in play) and giving advice on personal matters. As the authors argue, this dialectical interplay of mutual affection within the fictive kinship group emerged as an underlying phenomenon in the success and perseverance of these students. Finally, the authors claim that this study expands on the Vygotskian framework in that it describes "how a specific type of close personal bonds affects the space and emotions where learning is to take place" (Alexakos, Jones and Rodriguez 2011).

Providing students with 'authentic' science experiences (i.e., experiences that have some family resemblance to what scientists actually do) has been advocated as an important means to foster students' attitudes toward science and to increase their likelihood to engage with science careers. In their paper, Michiel Eijck and Roth (2009) present a case study of a 26-year old indigenous male student (named Brad) who participates in a scientific internship program. Despite the efforts of bringing Brad into science laboratory and outdoor science-related activities with some relevance to nature conservation (which is one of Brad's major concerns stemming from his original community), the authors claim that the program resulted in Brad explicitly not considering becoming a scientist. Instead, he intended to pursue a career in ethnobotany.

As Pauline Chinn (2009) asserts in her forum contribution, this standpoint of not considering ethnobotany an authentic scientific career might suggest a colonialist perspective. However, we will focus on how Eijck and Roth (2009) develop an approach to CHAT, interweaving their analysis with the dialectical-materialist standpoint. In explaining how the notion of 'authentic experiences' emerged from the scholar concern that much of what students do in their everyday life is unaffected by their school practices, Eijck and Roth (2009) present the following definition of knowledge:

> The fundamental idea at the time [concerning authentic experiences in school] was that literacy (knowledge) has to be understood in terms of practices—the patterned actions people deploy in their private and working lives—rather than as procedural and declarative information stored in their heads that they bring to bear on problematic situations. […] Here, knowledge is equivalent to competent participation in these activities, and learning is recognizable as changing (increasing) competence. (Eijck and Roth 2009, p. 615)

As in Wells (2008), a materialist approach to learning—which takes knowledge as (social) practice, rather than the abstract content of an individual recipient-type mind—is clear and sound in this paper. This materialist stance is implicit in Vygotsky's framework and stems from the original Marxist theory. In explaining the sense of dialectics in CHAT, Eijck and Roth (2009) claim that:

> Activity theory aspires to understand and explain each form of action in its concrete material detail (artifacts, objects), whatever the situation, without losing the connection to the organization of society into systems of activity. The unit of activity is dialectical in the sense that, however, we partition it, each part can be understood only in its relation to all other parts; and each part makes sense only in its relation to the whole, that is, the organization of society. (p. 619)

This emphasis on the meta-theoretical stance that we have named 'Dialectical Unity of Analysis' is clear and sound throughout the whole paper. However, this category alone indicates a partial explicit appropriation of the dialectical framework (from relational ontology perspective). These authors stress further that none of the constituents of activity system (means of production, subject, object, rules, community, division of labor and outcome) can be studied in isolation from one another, but they do not assert that activity systems develop through time, neither that they experience qualitative revolutionary transformations in their process of becoming.

Dialectic Materialism

Under the framework of conceptual continuity, Bryan Brown and Matt Kloser (2009a) conducted a 2-year study with students from a baseball team concerning these students' ways of understanding and describing physical phenomena involved in a baseball match. Through the analysis, these authors have claimed to identify similarities (continuities) between students' conceptual understanding in the informal contexts and canonical scientific ideas.

In critically reviewing Brown and Kloser's paper, Hwang and Mijung Kim (2009) planted a Vygotskian cultural-historical dialectic perspective to assert that Brown and Kloser's approach presupposes the dichotomy between formal and informal language. They discuss that a "Vygotskian dialectic approach shows that people communicate scientific concepts through hybridization, which does not reproduce a self-identical genre; the continuity of conceptual understanding involves dis/continuity" (p. 899).

Drawing from Vygotsky, these reviewers stress that learning science is related to a major dialectic contradiction: speaking the language of science is, at the same time, condition and result of conceptually understanding science. Hence, the former presupposes the latter and one cannot be reached without the other.

Reviewers also contend the procedure of data collection under a materialist Bakhtinian standpoint. They claim that the genre that features baseball training communication is

inseparable from the actual activity in and through which this genre emerges. However, Brown and Kloser (2009a) gathered data through interviews without properly theorizing how these interviews constitute the observed uses of language. Brown and Kloser identify genres mainly by depending on words and word expressions detached from the actual non-verbal context, and, thereby, "separate language/genre from real people speaking language" (Hwang and Kim 2009, p. 901).

Despite being very consistent with and illustrative of the Vygotskian dialectic materialist view, Hwang and Kim's argument had not been acknowledged by the reviewed authors (Brown and Kloser 2009b) and the reason is not very hard to grasp. It is also possible to observe that Brown and Kloser had not expressed any commitment to the dialectical materialist standpoint. For them, there is no problem in reassuring an original dichotomy between formal and informal knowledge. Hence, Hwang and Kim's review did not bring out internal inconsistencies in Brown and Kloser's study.

The dialectics of agency and structure

Maria Goulart and Roth (2010) investigate how 5-year-old children and their teacher collectively design science curriculum. These authors draw on a cultural-historical approach and the dialectics of agency and structure to analyze the events showing the complexity of the activity inside a classroom of very young children in which science curriculum emerges from teacher-student interactions rather than teacher's perspective itself.

The analysis illustrates participative thinking, a form of consciousness that arises from collective praxis and lived experience. From Vygotsky (2003), the authors claim that praxis "constitutes the overarching, all encompassing unit that cannot be further divided into independent elements without losing the phenomena of acting, thinking and speaking" (Goulart and Roth 2010, p. 538). In this way, the authors based their analysis on some praxis-related dialectical contradictions: (1) agency and structure; (2) schema and resources; (3) agency and passivity.

Goulart and Roth (2010) assert that praxis has inner contradictions mostly due to the dialectics of agency and structure (for agency means autonomous acting in a culturally structured world while structure expands and limits one's possible actions and may be transformed by these actions). They bring more detail to structure pointing out that structure itself is made of another dialectical relation between schema (mental, ideal, within-person structures that generate one's perception of the material world) and resources (material, cultural, societal structures in the world that one mobilizes through action). Hence, as schemas generate the perception of resources and resources release relevant schemas, these two entities are interwoven. Both schema and resources are structures that expand and limit one's possible actions and may be transformed through agency. Finally, to understand the power to act, one would have to understand passivity, another dialectical complement of agency. The authors claim that passivity should not be theorized as not being engaged in an activity (because saying 'I don't participate' simply means that one is been agential about his or her non-participation). Passivity would be more related to letting the world impress the agent's senses. Hence, making sense of something by actively mobilizing one's own senses would always involve both agency and passivity.

In the direction of acknowledging Goulart and Roth's (2010) contribution, Fleer (2010) elaborates a more expansive contextual reading of early childhood science learning and

explores some theoretical features that relate to a cultural-historical approach. Fleer (2010) highlights that the core of Goulart and Roth's (2010) work is in opposition to the maturational view of development. This opposition can be traced back to Vygotsky's critiques of Piagetian theory and their embeddedness in historical-cultural framework. In another review, Katerina Plakitsi (2010) asserts that despite claiming that agency/structure schema brings closely the materialist dialectics to the positivistic western tradition, through the dialectical approach, Goulart and Roth (2010) express an educational monologist standpoint. In an opposite direction, Plakitsi argues that dialectics is not only an appropriate way to interpret natural phenomena (Engels 1979), but it is also a powerful tool for bringing global citizenship into the twenty-first century science education.

Lessons learned

From the results reported in Table 1, it was possible to observe a significant difference between the number of papers that develop and appropriate the original and successor Vygotskian frameworks and the number of studies in which related keywords are peripherally cited. It is important to ask why 84 % of the papers made use of peripheral citations. One possible answer is because in education and in science education research there is a cultural phenomenon of following 'fashion' theories that leads researchers to cite some authors, even if in a peripheral way. Another possibility is to consider peripheral citations of Vygotskian frameworks as a kind of obligatory reference or a first step to approach cultural studies.

The keywords 'Vygotsky', and 'Activity Theory' have been the most cited ones both in the papers that we classified as 'Development and Appropriation' and in the ones classified as 'Peripheral citations'. Besides the number of keywords occurrences, which shows an increasing popularity of these frameworks, the quality and originality of contemporary appropriation of CHAT, which is sound throughout the review, denote that this framework has played a very important role in recent developments of Vygotskian approaches to research in science education.

Prior to reviewing CSSE's papers, it should be acknowledged that dialectical materialism has played a fundamental historical role in developing successor Vygotskian theories such as Leont'ev's approach to activity, third generation CHAT and Wertsch's theory on mediated action. For this reason, dialectical materialism has been appropriated as long as it constitutes the core of these theories even in the papers that we reported as quasi-appropriation. In this sense, what might be considered a major result of this review is that dialectical materialism is a contemporary theorization to sustain cultural studies of science education.

This review illustrates that meta-theoretical commitments to dialectical materialism have been put to work as tools for original theorization in various sensible different situations. Wells (2008) has developed a critical materialist approach to what might be considered the most traditional issue of research in science education: conceptual change. Murphy and Carlisle (2008) illustrated relational ontology and an activist transformative stance in the everyday context of coteaching and cogenerative dialogue. Hwang and Roth (2007) developed an original dialectic theory on laboratory practices and how they might lead to science learning. Alexakos et al. (2011) explored how the dialectical interplay of mutual affection constitutive to fictive kinship groups of high school students of color mediated their resiliency, perseverance and success in a college physics class. Eijck and Roth (2009) theorized on how an indigenous student developed new attitudes toward

science through engaging in different dialectically-constituted activity systems. Finally, Goulart and Roth (2010), investigating how 5-year-old children and their teacher collectively design science curriculum, presented a framework based on a dialectical interplay of agency and structure. Commitment to dialectical materialism is precisely what cuts the gap between these pieces of research and might inspire further original theorizations.

A major contribution toward better understanding the foundations of the Vygotskian project is Stetsenko's (2008) distinction between relational ontology and the activist transformative stance. Along with the meta-theoretical categories of dialectical materialism presented in this paper, Stetsenko's definition of relational ontology has been instrumental for identifying some incompleteness in approaches to dialectics throughout several papers in the review. The widespread usage of dialectics amid educational research does not always reflect a deep appropriation of this framework. Dialectics is often approached as a more general way to designate relation between mutually constitutive things, which leads to leaving some important theoretical possibilities rather unexplored. In Stetsenko's (2008) words, dialectics is often approached as restricted to the perspective of relational ontology. A consequence of this usage is that, in some situations, 'dialectical relation' might be switched to 'dialogical relation' or simply to 'relation' without sensible loss of sense.

Thus, Hwang and Roth's (2007) argument that resistance and contradiction exist in dialectical relation because they are mutually constitutive is leaving out of it the idea of tensions and conflict. The description Reveles, Kelly and Durán (2006) make of science learning equally leaves tensions out and shows full acceptance of what is being taught. They also emphasize more the product of learning than the process, which could be regarded as a tradition inherited from cognitivism. Eijck and Roth's (2009) general emphasis on inter-relatedness between the constituents of activity system misses the consideration of the qualitative revolutionary transformations of the whole system. The notions of historicity and transformation also have been brought by Kahveci (2010) as fundamental tools to analyze the academic trajectories of Physics undergraduate students investigated by Candela (2010) in the sociocultural framework. On the other hand, Andrée's (2011) study succeeds in showing the activity transformation drawing on CHAT.

The materialism as the fundamental assumption of CHAT has been missed in the analysis presented by Reveles, Kelly and Durán (2006), resulting in not presenting the learning process as a sociocultural activity and material phenomenon which happens first in the social level and later in the individual level. In another sense of materialism, Krange (2007) shows possibilities and limitations of a material mediational tool (a 3D model of a molecule simulated by a computer software) in the scientific student's conceptual practices.

In the review of Barma's (2011) study, García (2011) argues that she has failed to consider the dialectical relations between the poles of the activity system, consequently ignoring that the curriculum reform is socioculturally anchored as well. This reductionism leads the analysis to overlook the difference between positions people occupy in the institutional contexts and the relations of power involved.

Although the emphasis in transforming the world through praxis (Stetsenko 2008) was not made explicit by Vygotsky himself, it is possible to assert that this stance is implicit in the original Vygotskian project when we turn to understand its meta-theoretical underpinnings. On the one hand, relational ontology may account for the complexity of human actions; on the other, the dialectical materialist idea that social and natural reality is open to qualitative revolutionary transformations could not be accounted for under relational ontology. The absence of the very idea that men are capable of revolutionary transforming

of the world can be considered a serious reductionism found in the appropriation of Vygotskian (and Marxist) tradition in science education research.

Johnson and Tippins' (2007) critics toward Alexakos's (2007) paper point out some confusion between dialectics and dialogism. In fact, if Alexakos's usage of dialectics is interchangeable by dialogism without much loss of sense (as Johnson and Tippins argue), the very concept of dialectics might be losing much of its important nuances (not only in Alexakos's, but, possibly, throughout the literature on science education). While dialectics may be conceptualized as a method for reaching qualitative transformations through overcoming conflictive relations, dialogism may be related to coexistence of various interwoven entities (Bakhtin 1981), which are neither necessarily in conflict nor evolve always toward revolutionary transformations. Notwithstanding, dialogism often works as a tool for understanding deep interrelatedness without the dialectical commitment to reach synthesis through overcoming/reconciling contradictions.

Our findings suggest that the profound appropriation of meta-theoretical categories of dialectic materialism and a consistent usage of dialectics differentiated from dialogism can enhance political analysis of sociocultural phenomena in the context of science education. In this direction, even though it has not been our focus, this review allowed us to raise concerns about methodological aspects of sociocultural studies as a whole. The missing of complex unities of analysis and the lack of appropriate methods to analyze data (mostly discourse) hinder the proper grasp of development and transformation processes, its conflicts, tensions and resistances, preventing a wide understanding of science education as a sociocultural phenomenon. We believe that the deepening of theoretical commitments and an increasing effort to go forward in the methodological issues could afford more interesting outcomes in cultural studies of science education and would also represent a strengthening of the role of dialectical materialism in expanding sociocultural perspectives toward a better articulation between individual and institutional-centered analyses.

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