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Making explicit some tensions in educational practice: science education in focus

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The relevance of Science Education to the modern world nowadays is the subject of many authors. There are a lot of expected outcomes and also a lot of different perspectives that teachers, researchers and educational policy makers have been using to grasp teaching-learning process and to plan/conduct educational activities in science classrooms. Most of these perspectives are grounded in a logic that is incapable to deal with contradictions reinforcing dichotomies and most of them are unable to properly analyze controversial social issues that are more frequently introduced in science educational practice. The main consequence of this framework is the emerging apparent oppositions between individual and collective; ontology versus epistemology; alienation versus emancipation. Bearing in mind these circumstances we understand the necessity of a dialectical approach. In this paper we address some of those emerging tensions analyzing its consequences to Science Education considering Cultural Historical Activity Theory. To deal with those oppositions we propose three analytical categories for tensions: a) the subject of activity; b) the content of activity; c) the outcome of activity to fully understand the dialectical nature of contradictions.

Keywords: Tensions, Science Education, Activity Theory, Alienation, Emancipation, Formation of the Individuals.

Introduction

There seems to be no doubt about the relevance of Science Education to the modern world nowadays. A large literature, plenty of books, research papers and official documents point out the importance of specific disciplines like physics, chemistry, biology, and interdisciplinary approaches to the school. Beyond understanding natural world, it is expected that Science Education can promote scientifically literate individuals, i.e. supposedly reflective citizens that are able to engage not just scientifically but also politically in science related issues [19, p. 23] and "contribute to decision-making about issues that have a scientific dimension, whether these issues be personal (e.g. relating to medication or diet) or more broadly political (e.g. relating to nuclear power, ozone depletion or DNA technologies)" [12, p. 703].

On the other hand DeBoer [4, p. 591] summarizes other expected outcomes for Science Education (i.e. teaching and learning Physics, Chemistry, Biology and other Natural Sciences) such as: a) teaching and learning about Science as a cultural force in the modern world; b) preparation for the world of work; c) teaching

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and learning about science that has direct application to everyday living; d) understanding reports and discussions of science that appear in the popular media; e) learning about science for its aesthetic appeal; f) preparing citizens who are sympathetic to science; g) understanding the nature and importance of technology and the relationship between technology and science.

Given such variety of objectives attributed to Science Education, there are also a lot of different perspectives that teachers, researchers and educational policy makers have been using to grasp teaching-learning process and to plan/conduct educational activities in science classrooms. But most of those perspectives are grounded in a logic that is incapable to deal with contradictions reinforcing dichotomies, and they may be unable to analyze properly controversial issues that are more and more present in educational practice. Some of the paradoxes come from dichotomies that could be presented as typical questions that science educators have been making during the last years, such as: Must we teach scientific methods or scientific results? Must we teach general science or specific topics related to everyday life? Is (Science) Education responsible only for reproducing existent knowledge or also to create new one? Why people are increasingly less interested in Science even defending its importance?

In this paper we address some of those questions making explicit the tensions they express and its consequences to Science Education. We propose three analytical categories for tensions: a) individual versus collective; b) epistemology versus ontology; c) alienation versus emancipation, grounding our analysis on Cultural Historical Activity Theory.

Cultural Historical Activity Theory

Roth *et al* [20] have pointed out that despite the growing interest in Cultural Historical Activity Theory its potential has not been completely achieved in Science Education. He argue that part of the difficult to adopt this framework arise from its materialistic dialectic ontology that cannot be easily absorbed into non-dialectical thinking that underlies great part of Western research tradition, which use to address Science Education under formal logic. We are interested in to explore the Activity Theory dialectical logic base to deal with contradictions that emerge from human activities, particularly in Science Education activities.

Activity Theory origins re-mounts philosophy and economy and more recently psychology, anthropology and sociology becoming a multidisciplinary corpus that aims to understand human development into his dialectical conditions within the world. "In activities, humans develop their skills, personalities, and consciousness. Through activities, we also transform our social conditions, resolve contradictions, generate new cultural artifacts, and create new forms of life and the self" [21, p. 1].

According to Leontiev [15], human ontological development is only achieved by a special process of appropriation of socio-historical experience, unlike animals whose faculties are given by nature as result of the specie's phylogenetic development that guaranties performing adaptations into a specific environment. To human, appropriation exist because another special human process "of objectifying their faculties as objective products of their activity" [15, p. 264]. Thus, humanization should be understood as a dialectical process between appropriation and objectification [5], by which humans humanize natural world and humanize themselves, producing and reproducing humankind — going beyond biological condition becoming cultural-historical beings.

Furthermore, Leontiev [15] also discuss other characteristics of human activities contrasting it to animal activity. He argue that in animal activity there is a fusion of motive (which leads to) with object (for what activity is oriented) while in human activity the relation between motive and object is mediated by the complex relationships between those are involved in the activity. It means that an individual, who have a specific motive, can perform an action that are not directly connected with the motive, but mediated by the meaning of other's action (in the activity). Aiming to illustrate this Leontiev uses his classical example of primitive human hunting. We can say that object synthesizes the motive of activity in a mediated way; individuals, by sharing the same activity, are glimpsing the possibility of satisfying their needs — overcoming contradictions. This is a continuous movement that generates new needs and contradictions, the driven force of human activity dynamics. In this sense we can summarize some key aspects of human activity: it is object-oriented, mediated, collective, historical and has contradictions as driven-force [7].

Tensions in educational practice

One of the central problems in education is meaning negotiation. Particularly Science Education is experiencing a crisis that has its heart on meaning of science. On the one hand teachers prefer contents related to the real world, on the other hand students want contents connected to their daily lives [9]; modern capitalist society expects that students might be more directly prepared for the world-of-work (where even science has its value), developing general skills and being flexible [2], while students want a Science Education that could explain their own world. Students want a scientific education focused on their own interests, giving meaning to their own life and history, instead driven by, *e.g.*, industrial society's or scientific community's expectations. This does not mean that students want to be caged in their own world, but they don't want an education that has no meaning for them [9].

Students seem to fear the imposition of a scientific worldview as the one way to see the world [9]. Duarte [5, p. 218] argued that a negative view about Education may be "consequence of the diffusion of the ideas derived from the so-called theorists of reproduction, like Bourdieu & Passeron, Althusser, Boudelot & Establet, Gintis, and others [...], that has contributed to a negative vision of the role of schooling in social reproduction". Furthermore, it is also due to the widespread idea that learning should be centered on individuals' spontaneous activity [5] that is manifested on Science Education field through unguided or minimally guided educational activities from the post-Sputnik science curriculum reforms (for instance, Biological Sciences Curriculum Study, Chemical Education Material Study and Physical Science Study Committee), which empiricist idea is that "knowledge

can best or only be learned through experience that is based only on the procedures of the discipline" [13, p.84]. Bounded on constructivism this epistemological compromise leads to the idea that knowledge constructed by individuals is more valuable than other forms of knowledge — an overvaluation of individual learning through discovering process.

Historically Science has been conceived through the relation between science products and process or, in other words, between *what we know* (scientific outcomes) and how we know (ways of knowing) [6]. Traditional Science education have mainly focused on what we know in detriment of how we know, emphasizing science results instead their processes. An exemplar of this is experimental physics teaching. Experiments are taught as recipes to achieve previously determined results or as open procedures where supposed determined results could be achieved by any individual by his/her own effort. Science education from this point of view is taught either as an ontology, a description of how thing are in the world or an epistemology, just a way to know something of the world [3; 17].

To better understand these problems we suggest three categories to express the tensions that emerge from science educational practice. In despite we are using science educational examples they illustrate and give some key elements to analyze wider and more complex issue, such as the general educational activity.

Categories

The first category we use expresses the tension between the individual and the collective and comes from the dialectical relation between personal sense and collective meaning of Science (Education). This represents the tension between the individual/local versus collective/general interests. This is a category related to the subject of the educational activity.

The second category makes explicit the tension within the content of the educational activity. It represents the opposition between teaching Science results or Science processes, between teaching science as an ontology or as an epistemology [17].

The third category expresses the tension around the expected outcome of the educational activity. Represents the opposition between appropriation of established knowledge (which many times is associated to an alienating process) and the construction of new knowledge (linked to the construction of a free individuality).

These are not three independent categories of tensions; each of them manifest elements of the other. Furthermore, when planning an educational activity, a specific choice for subject implies also a choice for outcome and content; a specific choice for outcome implies a choice for subject and content; and so on.

Discussion

The subject of activity: individual versus collective

This first category expresses tensions emerging from human practices (also from educational ones specifically) — the opposition between individual and collective, which is object of analysis of many different theories in general, and also object of discussion within the Cultural Historical Activity Theory [22]. By dealing with this issue in a non-dialectical way we attempt to deny one of the poles avoiding the tension. On one hand it is possible to conceive an abstract individual that are completely independent of the collective — collective would be the result of the individual's natural quality to socialize (here lies Marx's critique about the naturalization of the historical [16]). On the other hand individuals can be conceived as simple specimens of an abstract collective with general qualities transferred on them.

Dialectally, the connection between these two poles is never given just by inductive or deductive logic: collective is not simply a set of individuals — collective is qualitatively different of the sum of its individuals since they have generic qualities of the humanity and singular experiences making them up. Humankind cannot be reduced to individual neither individual reduced to humankind. In this sense there are no oppositions between individual and collective.

But in human activity, mediated relationships between individuals give rise to consciousness, which in turn enables more complex relationships and so on. There is here a very thin line: on one hand more complex relationships can improve critical consciousness (humanization), but on the other hand can promote productive relationships in which individuals fail to realize themselves in the product of their activity (alienation). The object of the activity may be completely strange to the individuals. The motive they have to engage in the activity can be completely separated from the real content of their labor, so individuals are deprived of objectifying themselves through their activity, denied of constructing their real free individuality — which can occur as humankind becomes collectively free.

Considering Science Education two retro-feeding hierarchical levels could be addressed. The first one is the Science agenda (related to Science production) that can be allied with social-economic human problems, such as hunger, diseases, poverty, but also many times driven by capital purposes, focused in generating capitalist profit — there is opposition between individuals' real needs and general interests of capitalist society in Science production. The second level is the Science appropriation by the society: even when related to real human needs Science may take the form of commodity, opposing use-value to exchange-value and assuming apparently an independent reality (separated from the human activity — commodity fetishism) serving again as means of oppression and opposition between individual and collective.

The content of activity: Epistemology versus Ontology

This category expresses the tension related to the content of science education activity. Leaning on formal logic the dichotomy is reinforced: science may be presented as a set of results without discussing methods that support them, or presented as a supposed universal method that is independent of particular contexts and results achieved by them; the limits of scientific research is seldom discussed. Despite traditional science education has mainly focused on teaching results, recently there is a growing consensus among science education researchers about the importance of teaching "established ways of thinking in Science" [23], emphasizing processes of knowing enabling students to construct new knowledge: an approach to science education that aims to teach socially established knowledge

and methods, which differs to approaches that concentrates on teaching "scientific truths" [8, p. 919].

Beyond the relation *what we know/how we know* it is also possible to say, quite sure, that scientific results and scientific reasoning many times are not the determinant elements used by students and other people in decision making about science related issues. Nielsen [18, p. 276] argues that "scientific information could never by itself authorize or justify a value-decision; and decisions about societal issues tend to be just that-value-decisions". For example, Gough [10] found that young people, even knowing the risks of smoking, seemed much more concerned with financial issues, defending that nowadays everything is bad for health and claiming that smoking could effectively be used to relieve stress. Yang and Anderson [24] showed that high school students could be easily affected by emotional factors when they are evaluating scientific evidences. Yang [23] argues that students, even young adults, displayed inability to use scientific reasoning about social issues in life context, despite their abilities in specific situations in which subject domain is required; what indicates difficult to generalize and transfer reasoning skills to different contexts. Moreover, many times there seems to be conflicts between scientific reasoning in school and in social contexts. These examples might suggest that Science Education should be conceived beyond the relation what we know or how we know. Bastos and Mattos [1] suggest thinking Science Education beyond epistemology and ontology introducing a dimension of value: axiology, in order to understand the complexity of decision making about science related issues.

The outcome of activity: Alienation versus Emancipation

This tension expresses a fundamental question inside educational practice: some educational approaches advocate many times that appropriation of established knowledge is a process that leads students/people to alienation, that limits individual to become a product from the culture medium without critical consciousness; while emancipation is associated to experiencing all things by him(her)self trying to achieve freedom (that abstract individuality) — a kind of negation of humankind past experience. In this sense knowledge constructed by the individual has value, while appropriation of established knowledge is not valuable or even desirable.

The analysis of this tension should consider that it is straightly connected with the consumption and production of Science. Science as product of human activity objectifies specific forms of being human and may be a consumed (appropriated) in order to humans be humanized; at the same time science should be produced by humans (objectified) transforming the world and themselves. In this sense appropriation is part of the formation of the individual; objects of the human culture are converted into instruments of individuality. Individuals can only make up themselves by appropriating instruments to act in the world and at the very same time humanization demands the objectification of new instruments transforming them in new objects to be shared by a community — a continuous and endless process that produce and reproduce the singular individuals and the humankind.

But in a capitalist society, capital rules, education serves to reproduce alienated structures dichotomizing production and consumption as well appropriation and objectification, depriving individuals from the elaborated instruments of the human culture that could be used to overcome alienation through emancipation in order to fulfill its human's potentialities — devenire (to become).

Another dichotomic facet of alienation-emancipation is related to assume the fetishized idea that the more abstract elements implies more complex ideas about the concrete reality. As argued by Ilyenkov [11, p. 107]: "To think abstractly meant to be enslaved by the force of current catchphrases and cliches, of one-sided, empty definitions; meant to see in real, sensuously intuited things only an insignificant part of their real content, only such determinations of them as were already jelled in consciousness and functioned there as ready-made stereotypes".

In Science Education it means that the abstraction (and abstract forms of knowledge) becomes an objective in itself never achieving completely "the method of ascent from the abstract to concrete" [11]. Appropriation (internalization) of instruments assumes an abstract form of the object (consumption) without externalizing (producing) it into a more complex concrete form changing the world (emancipating the individual).

Dialectically alienation/emancipation as well consumption/production are faces of the same transformational/conservational process where humans to become humans should reproduce/create humans mediating tools. In this sense to be alienated and emancipated is an eternal human condition — overcoming alienations through emancipations is to deal with a new complexified concrete reality that brings another alienations and other forms of emancipations and so on...

Conclusion

In this paper we made explicit some tensions in educational practice focusing specifically Science Education. We understand the necessity of a dialectical approach such Cultural Historical Activity Theory to grasp them and other controversial/contradictory issues that emerge from human activity. We made a preliminary analysis of these tensions using three categories that are entangled: individual versus collective, epistemology versus ontology, and alienation versus emancipation, without deeply exploring the relationships between themselves — a subject for upcoming work.

We also argued that many dichotomies in science education reflect structural dichotomies from a capitalist society and its form of conceiving individuality, knowledge, education, transformation etc.

Overcoming such dichotomies allows us to further understand how complex human activity and educational processes are. Education (and formation of individuals in general) cannot be conceived as a process by which abstract knowledge is transferred to people's mind (simplistically placed into human head), without any connection to real/concrete existence. More than that, overcoming these dichotomies implies to achieve new forms of being human, as beings of praxis (i.e. reflection and action upon the world in order to transform it), beings that are conscious about their place in the History and able to struggle for a real free individuality, which is only possible as humankind becomes increasingly free.

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Преподавание научных дисциплин: к вопросу о некоторых противоречиях в образовательной практике[1]

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[1] «Science education» (буквально «научное образование») — система преподавания в образовательных учреждениях начальной и средней ступени научных дисциплин, включающих ряд естественных и социальных наук. — *Прим. перев.*

Значимость преподавания научных дисциплин в современном мире обсуждается сегодня многими авторами. Учителя, исследователи и лица, отвечающие за политику в сфере образования, опираются при проектировании и проведении занятий по научным дисциплинам на самые разные подходы к обучению и имеют самые разные представления о конечном результате. Логика большинства этих подходов не позволяет затрагивать в их рамках противоречия, укрепляющие дихотомии, и не дает возможности адекватно проанализировать неоднозначные социальные проблемы, которые всё чаще оказываются в фокусе научного образования. Как следствие, в рамках этих подходов противоречия между такими противоположностями, как индивидуальное/общественное, онтология/эпистемология, отчуждение/освобождение, оказываются неустранимыми. Таким образом, становится очевидной необходимость диалектического подхода. В данной статье мы анализируем некоторые из возникающих противоречий и их значение для преподавания научных дисциплин с точки зрения культурно-исторической концепции и теории деятельности. Для преодоления этих противоречий и более полного понимания их диалектической природы нами предложены три аналитические категории: 1) субъект деятельности; 2) содержание деятельности; 3) результат деятельности.

Ключевые слова: противоречия, преподавание научных дисциплин, теория деятельности, отчуждение, освобождение, развитие человека.

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