Science and Scientific Discoveries

Through the Lens of Critical Pedagogies

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Abstract

In this article, a thorough presentation is attempted on how Critical Pedagogies could be used as a basic instruction tool to teach the history of science and the "evolution" of science to students of all levels. Science is usually taught as a series of inventions, or as one scientist builds over the works of the previous ones. Seldom do educators refer to the central aspects of scientific evolutions such as: the existence of relations of power within them, the use of science to facilitate war or domination, the social necessities that order the scientific discoveries in many cases, the role of women in science, etc. Little importance is given to the evolution of non-Western, non-White science (Chinese science, Arabic science, etc.) as equivalent and equally important forms of scientific expression. Critical Pedagogies can provide answers to these thoughts and are discussed in this article. Traditional wisdom (as is *eco-wisdom*) is also compared to science in a balanced discussion through critical pedagogical arguments and the fight of both pseudo-science and the refutation of science (e.g., the avoidance of vaccination) against rational science, are discussed here, always in educational settings.

In the final part of the article, there are suggestions on how teaching history of science and scientific evolution could be applied within the classroom by means of Critical Pedagogies, thus teaching praxis could also be affected by the views suggested here.

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Introduction

It is common practice in education worldwide, to teach Science and the Evolution of Science under the perspective of a series of discoveries, one superposing the other, or under contemporary views, as is the School of Edinburgh or the Latourian views of competition among scientists (Barnes, Bloor, & Henry, 1996; Latour & Woolgar, 1986). All these methods of instruction, as well as the very well scrutinized view of Tomas Kuhn (2012), referring to the so-called Kuhnian "paradigm," have, with no doubt, certain grains of truth within them, but what is suggested in the current work is that forms of Critical Pedagogy could provide a more solid and generalized framework in order to teach such a field, like evolution of science.

When teaching Physics, Chemistry, Biology, Geography and Geology in contemporary classrooms (both Primary and Secondary or even university—Tertiary—classrooms) the teacher usually presents scientific discoveries and/or the elucidation of certain phenomena, as something that actually *just happened***,** because the specific scientist was gifted or because a large amount of knowledge was accumulated, leading naturally to a new discovery. One realizes that this accumulation of knowledge (the "banking" approach) is already contrary to the ideas of Paulo Freire (1990).

It is clear, however, that science does not work nor evolve in this way. Science has been produced—in many cases—in order to strengthen the exploitation of people by groups of specific interests, or for advancing warfare. The advance of Computer Science, for example, has been strongly related to area bombing in World War II (Williams, 1999; McCartney, 1999). We believe it would be good practice—to state to students, the reasons behind any advancement of science, which is very closely related to specific human interests, having, in many cases, very little to do with the common good.

Another strong point that would be beneficial for teaching, would be that all the forms of production of science are considered as equivalent: Science is equally well-produced by women, non-White people, First Nations or Native Americans, Chinese, Arabic peoples and other. This point is definitely missing from contemporary instruction practices.

Also, of major importance, is to ask *what kind? and what aspect?* of science is of importance and relative to the context for the audience. As educators, our ways of teaching science—(teach scientific discoveries and scientific evolution) are totally irrelevant to the lives of people—the students—hearing them. Once more, it is argued here, that Critical Pedagogies have suggestions to make, in order to change these issues.

A final point, is that it would be a mistake to consider all the aforementioned characteristics of science, as taught today as reasons to avoid science and, consequently, turn to pseudo-science or the negation of science itself. Arguments such as the Greenhouse effect *does not exist*, that we should avoid vaccination or that the Earth is flat, would be totally wrong to prevail over the rational, human-made

science. Those who provoke such arguments, have usually other ideas and interests behind them—knowing it or ignoring it—who deliberately want to keep the population in a state of fear and to a refusal to change. Critical Pedagogy certainly never refuses the concept of science as a human concept and enterprise that—when in proper use—changes our lives for the better.

Science produced in Conditions of Rivalry

It is a usual characteristic in the production of scientific knowledge, that discovery is produced many times, in conditions of rivalry. For example, the rivalry of Louis Pasteur and Robert Koch over anthrax led to significant discoveries in microbiology and the causes of diseases, but has always been the center of many scientific debates (Ullmann, 2007), the debate of the first to discover/understand the theory of evolution in biology, Alfred Russell Wallace or Charles Darwin (Costa, 2014) is also well known, with Darwin gaining the recognition in the future. The history of science is full of such cases, but usually are not revealed nor discussed in class, the scientist that prevails is the one the teacher teaches to the students. In shaping the image of the scientist for the contemporary audiences, it would be important to focus on human aspects of those who shaped the history of science and their tremendous drive and desire to make a difference through science.

It is a central characteristic of the evolution of science that—apart from the role of social surroundings in it (Shapin, 1982)—a very strong or even unscrupulous personality prevails and gains all the recognition for the discovery over the other(s). A typical case, though a genius, was Sir Isaac Newton. One should not forget to wonder that Galileo Galilei may have been restricted to his home for the rest of his life, *what would his fate have been?*, if he had not had strong relations with the Pope and the Catholic Church?

Science as a tool for war and for restoring relations of Power

Another major aspect in the production of scientific knowledge throughout history is the knowledge that science was employed as a means to facilitate winning wars. The discovery of the atomic bomb—a weapon of mass killing and destruction—pushed forward atomic physics (Rhodes, 2012); many inventions involving computers were associated with bombing and other activities in World War II (Rees, 1980). Also, science has been used as a means to impose power and exploitation between nations or races, even between different groups of people (Aronowitz, 1988). The famous *Manifesto of the Ninety-three* signed by prominent German scientists in order to justify what Germany did in World War I is a basic example (Norton, 2008). Another famous instance was Trofim Lysenko, the Soviet biologist and how Stalin used his ideas to impose his views (Stanchevici, 2012). The validity tools that science and scientific communities possess by definition, have been used for political reasons or reasons of exploitation, this

certainly gives us a different/new perspective of and a characteristic that it is a human creation, devised through channels that must be examined regarding their intentions. As Pierre Bourdieu noted, science is produced in the context of society and the groups that handle society's behavior are also striving to manipulate science (Swartz, 2012; Bourdieu, 1990).

Science as a multicultural enterprise with no barriers

The contribution of various civilizations to the evolution of science is little—even discussed in everyday classroom discourse. Focus is always given to the contribution of the West and of White men to the scientific evolution. However, the Chinese, for instance, have made great discoveries, the compass as an example, many discoveries before the West; Arabic peoples discovered the system of arithmetical digits used worldwide today. Insisting on science as always a product of Western civilization product, omitting its Eastern and African origins, makes it more difficult in classrooms of today to accept and appreciate global science discoveries. Science and its importance is often hidden to the notion of civilization *as a whole.* Possibly the most dangerous ramification reveals colonial and imperialistic views on the explanation of scientific evolution and discoveries.

Another major aspect of science is its trans-class production. Many of the scientists that made major discoveries belonged to poor or lower classes, like Michael Faraday, and even though science needed in many instants, the aid of rich patrons in order to flourish, those who produced it were often very poor. We must reflect with our students that class should, in no way, be considered an obstacle in producing science.

The notion of science and feminism in the treatment of history of Science, is also essential. Many women contributed to science, and—in several cases—their contribution is neglected. We have the example of Rosalind Franklin in DNA-strand elaboration (she was forgotten in the Nobel Prizes), Lise Meitner in Atomic Theory, and Jocelyn Bell Burnell in the discovery of pulsars, the latter losing her initial recognition, due to her supervisor. The role of women in the advancement of science is a major issue to be discussed in school and university classrooms, it is of the utmost importance to reveal science's multi-dimensionality and the absence of any kinds of barriers in it. Science also must accept those who were traditionally marginalized in their era, with Alan Turing, whose non-accepted homosexuality led him to commit suicide, being one of the most prominent examples.

The fight between Science and pseudo-Science and/or negation of Science

Another important debate that needs to be treated in educational settings, is the fight between science and pseudo-science. Often guided by ultra-conservative and religious circles, pseudo-science, as well as the refutation of science and its

rationale, seem to be gaining a lot of ground among students, teachers, the media, and the general public. For example, the old debate about the Theory of Evolution vs. the Theory of the Firstborn (Adam and Eve) has revived. A movement has been growing, reviving centuries -old theory that the Earth is flat, absurdities that fly in the face of history, science, and rationality. At the same time, masses of people believe in the "evil eye," believing that the Earth's population is "sprayed" by beings in the air and that vaccination does nothing but harm.

Science suffers in itself by arguments that severely threaten our planet and our existence, such as the vastly supported idea that the Global Warming is nothing more than an exaggeration, and that gases would heat up, in any case, that we cannot change these occurances. Similarly, segregationist theories prevail in certain areas, academic and school environments, which maintain that people of certain races are inferior through DNA and they should not hold academic or political positions.

It is clear that the production of science in itself has not always been *moral* and *just* or inclusive. On the other hand, science is the basic platform we have to interpret phenomena and one of our basic tools in resolving the problems of our daily lives. It would be dangerous, obscurant, and serve inappropriate interests to replace scientific acts, discoveries and argumentation, by pseudo-science and the refutation of science.

Equivalent forms of wisdom, such as eco-wisdom or traditional cultural heritage products, must not be ignored, however. Many would not turn easily to a Shaman to cure a disease; most often an afflicted person would turn to a traditional medical professional. Yet, these forms of wisdom can readily contribute to the evolution of science, and give peace to the patient and the self-guidance, sometimes psychologically necessary, in order to treat a situation. Most important is that, given as granted that the majority among these civilizations (the Native Americans, First Nations, Southern Americans, Aboriginal Australian, Asian and African indigenous tribes etc.) are engaged in severe daily battles to preserve their lands, their water supplies, their natural resources, one thing should be stressed: *we should NOT use their—supposed—scientific inferiority, as a main argument in order to deprive them by all their basic goods and needs.*

Pseudo-science is one position, and traditional cultural and ecological wisdom is another, and a clear distinction between the two must be discussed and taught in our science classes.

Some suggestions through different Critical Pedagogies for the classroom praxis

Critical Pedagogy, or Critical *Pedagogies*, since there are many branches and currents, is, by no means a fixed doctrine. It does not consist of a set of recipes on ***how*** to teach something and what results the educator should have. The understanding of critical pedagogy can give suggestions, through the lens of the world-

view of emancipatory and enlightened educational orientations, as hopefully,this is the point in the case of this article. Our intent is to merely discuss how different critical pedagogies would suggest alternatives for a teacher or an educational system that would wish to teach History of Science and scientific discoveries under a contemporary perspective. Of course, our general suggestions—obviously susceptible to alterations depend on the context within specific educational settings. It is good to teach science as a product of people with their own faults, passions, their drawbacks and dislikes. Teachers would be good to encourage students to search for the situations referring to specific scientists that led to the great discoveries or to the *giant* spiritual leaps in science.

It would be appropriate in the context of critical pedagogies to engage students to the anti-FIDUROD features of Science (Kincheloe, 2008) [F=Formal, I=Intractable, D=De-contextualized, U=Universalistic, R=Reductionistic, OD= One-Dimensional].Working with students to identify these issues within scientific problems or histories extends the students' ability to examine alternative ways of knowing.

Additionally, the audience *does play a key-role*. When teaching science and its history, the specificities we give the students, we address to are very significant. Bricolage and ethnographic techniques (Kincheloe, McLaren, & Steinberg, 2011) are central and important to realize who the audience is we are teaching History of Science to. We ask what is *meaningful scientific knowledge* for them? and what the context of our teaching could be.

As a further step, different critical pedagogies would certainly suggest teaching *inclusive* science, a science that embodies the efforts of women in its progress, the contributions of civilizations other than the Western European and North American; the ecological wisdom, the cultural traditions, indigenous ways of knowing. For example the students could be prompted to find what role black people played in NASA discoveries or to what extend women were hidden from the lights when new scientific findings earned prizes.

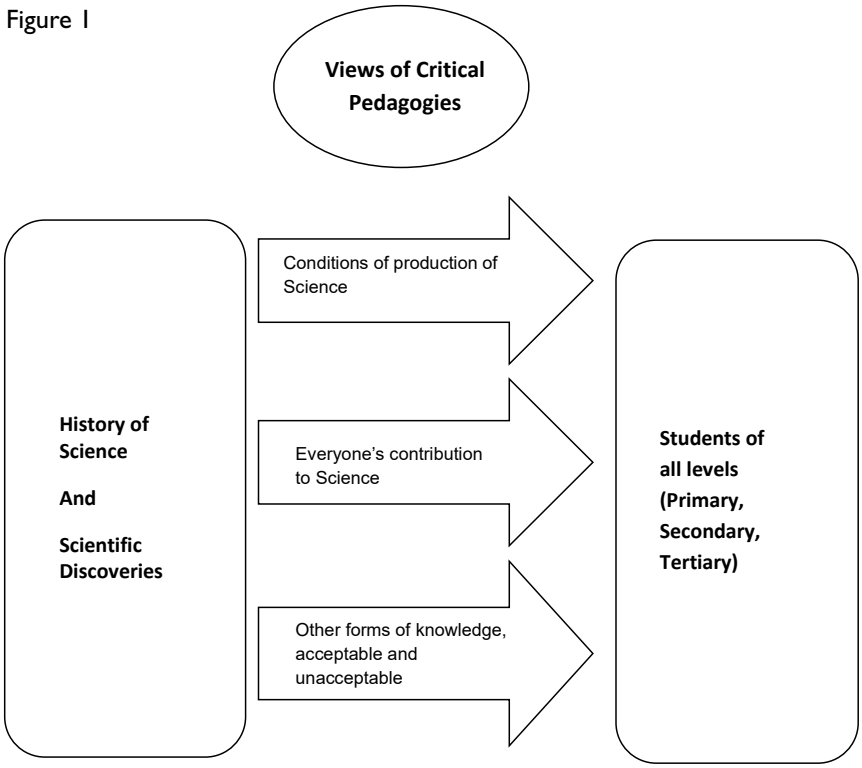
Different critical pedagogies could suggest that the teacher assign student projects or tasks that would help the latter reveal the conditions of production of new things in science, especially those related to war, conflict, or imposing relations of power. How many discoveries (e.g., Archimedes' discoveries on buoyancy) were orders given by tyrants? or to what extend did da Vinci help nobles of his era win wars, kill or imprison people with his inventions?

Another idea would be to relate the instruction of science with different types of justice (social justice, environmental justice etc). A question for investigation which could be of major interest for students in many areas in the world would be: *The government wishes to implant a nuclear waste landfill in your village/city. Among other things, they say that this will create many new job positions in this area, which is severely hit by unemployment. Create and present your thoughts about this issue.*

The fight and the disagreements between science and pseudo-science could be elucidated by the students themselves. The teacher could assign students to organize dialogues in front of the rest of the classroom, where the *"scientist"* and the *"pseudo-scientist"* have a debate over one issue, and the classroom participates arguing, discussing and analyzing the presentations of both sides.

In Figure 1, find possibilities of critical pedagogies suggested for teaching the history of science and scientific evolution:

Figure 1



Conclusion

The history of science and scientific discoveries could be taught under new perspectives, using critical pedagogical suggestions and different ways of viewing the world. This would give students the ability to see science in its proper perspectives and contexts, and to realize the contribution of all peoples in science. Working to create arguments and different scenarios in science, and ways to deconstruct pseudo-science and its refutation of science is important. As is the recognition of diverse (sometimes) equivalent forms of scientific expression like eco-wisdom,

Indigenous knowledges, and/or cultural traditions within science. All aspects stressed by many critical pedagogies, could lead to a critically-thinking citizenry, creating empowered and informed students, those we so need in today's world.

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