



Towards a Pedagogy of Complexity: Responsibility, Critical Thinking and Complex Systems in Science Education. Review of the Science and Humanities Program in the National Autonomous University of Mexico (UNAM).

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Abstract

What responsibilities does the scientist (as a teacher and researcher) hold to social problems? What is the role of humanities and the sciences of complexity in the formation of new scientist? What functions should the public university have in the context of economic, political and ecological crises? Since 2011 these and other questions have guided the birth of the Science and Humanities Program in the Faculty of Sciences of the National Autonomous University of Mexico. The objective of this program has been to contribute to a science education that includes ethical, historical and empirical issues, i.e. approaches to science complexity and transdisciplinary research. To achieve these goals, the program has focused in three areas: 1) the recovery of more than four decades of work in philosophical, ethics and political education that exist on the Faculty and other iberoamerican spaces, 2) to expand anti-reductionist perspectives (non-racist, non-sexist, non-colonialist) linked to complex science and systemic thinking in biology, physics, sociology and philosophy, and 3) the innovation of teaching and learning methodologies in order to improve student participation and to create links between the university and the needs of people. Through courses, symposia, conferences, seminars, publications and virtual spaces on the Internet, the Program has made steps towards a pedagogy of complexity that includes ethical, critical thinking, and a transdisciplinary agenda where philosophers, biologists, physicists, mathematicians and historians can talk, teach and produce knowledge and models that contribute to a more just and environmentally responsible society.

To the memory of Richard Levins and Flavio Cocho Gil.

1. Introduction

What kind of sciences and what kind of science education are required in countries of low human development, high disparity and high violence as in Mexico? How to promote a science that recognizes the complexity of biological and social systems while criticizes and goes further reductionism, colonialism, sexism and racism? There are different experiences of concerned scientists that have faced to such questions and practical challenges within their universities and education fields [1]. In this paper we present a brief overview of the work that has been done in the Science and Humanities Program (PCH; acronyms are in Spanish) of the Faculty of Sciences (FC) at the National Autonomous University of Mexico (UNAM), and summarize some of the challenges and experiences that we are facing in order for create what could be named a *pedagogy of complexity* that is concerned and committed to their society and people.

2. Historical Background

During the sixties, in several parts around the world (USA and France for example) emerged various social, student and youth movements that criticized different forms of political authoritarianism and cultural values (Vietnam war, sex conservatism and others) [2]. In Mexico a student movement emerged protesting against political authoritarianism and repressive forms of power. The State's response led to the Tlatelolco massacre of 1968, when hundreds of students were murdered and persecuted [3]. Despite these tragic events, debate and reflection remained within universities, particularly with regard to the role of science and humanities against the violent and illegitimate use of political power, as well as fulfilling the social function of public universities.

Under this background and with the leadership of teachers of scientific fields, the Science and Society Program (PCS) [4] was born in the early 70s at the FC at UNAM. This Program promoted education



and scientific research focused on changing nature of reality, both natural and social. It also worked to create awareness of the hierarchical governing structure and economic policies that support the scientific apparatus.

These efforts materialized in at least five areas:

1. Lines of research were developed in physics, biology and mathematics that focused on the dynamics and nonlinear processes of natural and social systems, which today are named complex systems.
2. Courses and scientific seminars incorporated historical and sociological elements into the history of ideas.
3. Conferences and public debates about contemporary problems of society were created.
4. Assemblies, collegiate bodies and other mechanisms of participation of the university community were implemented towards a more democratic form of decisions within the FC.
5. Work in communities was performed through field practice where teachers and students could learn about the needs and problems of urban and rural communities.

Despite this Program did not continued, there were several victories that remained over the years: i) the incorporation of the seminars-courses "Science and Society" and "Nature and Society" in the curricula at the Science Faculty, ii) a more collegial structure of academic decision within the FC and iii) the Complex Systems Department at the Physics Institute also at the UNAM.

3. Challenges and contemporary works

In 2011, a new generation of teachers took from this history to promote and strengthen the current courses "Science and Society" and "Nature and Society". They also fund the "Nature, Science and Society Coordination" (CNCS), which sought also organize different academic and debates events within the FC [5].

Through these courses and activities CNCS manages to generate and strengthen networks with other academic structures such as Seminar Philosophy of Biology [6], the UCCS [7], the Diploma in Medicine and Complexity [8], Coplt-arXives [9] and other projects linked to the C3 [10] at the UNAM.

The questions and principles that have been guiding the CNCS were related to the responsibility of scientists, as teachers and researchers, in relation to complex diseases, new technologies and political and ecological challenges in the capitalist system. One core idea has been the understanding of the scientific experiences that have resisted subordination to the hegemonic economical and political powers and the transdisciplinary dialogue among contemporary sciences (i.e. complex systems, eco-evo-devo, cultural development, gender) and topics from philosophy, history and sociology of sciences.

The horizon of this coordination was expressed as follows: "To promote the training of scientists with an awareness of their ethical, social and environmental responsibilities; critical and self-critical reflection on the social implications of scientific work; the inter- and transdisciplinary exchange as well as the defense of human dignity with global dimensions" [11].

Following these ideas in 2014 and supported by more teachers and researchers, we decided to expand CNCS and establish the Science and Humanities Program, as an academic structure that achieved recognition and institutional support for articulating the subjects of science and society, nature and society, and complex systems such as teaching and research lines. This program recognized this genealogy, but posed new lines of work that included a more systematic discussion of the scientific frontiers, as well as an emphasis on the relationship between humanities and natural sciences.

The program has also worked to promote critical thinking in the science education. A key concept is "autogestion académica" or self-organized education [12], which seeks to build self-organized and autonomous teaching spaces by the students and where teachers do not impose the topics, dynamics, or the latest interpretation of scientific arguments and their relationship with social crisis. Unlike the seventies PCS, we have included IT and social networks like Facebook, blogs, Youtube, in order to promote public discussion of texts, promoting outreach. For example, controls reading of the texts appears as blog entries, where other students can see the various possible interpretations of the readings.

3. Theoretical implications and discussions from practices

From this background we have worked in developing what we call a *pedagogy of complexity*: pedagogy because it is a continuous reflection and systematization of the problem of science education, specifically those theories and models of the complex systems and the interactions between scientific disciplines and humanities. The *pedagogy of complexity* aims to build curricula for



training new scientists that take on ecological, political and economic challenges of the contemporary and future world. This education is based on a vision of science where various types of activities are recognized: science as *modeling* and *explaining*, i.e., construction and empirical testing of theories, models of the physical, biological and social phenomena [13]; and science as a *valuing* and *intervening*, i.e., recovering the interpretation and historical character of models, incorporating cultural beliefs and prejudices, as well as its ongoing relationship between science and the productive and power apparatus [14].

This expanded vision of science stems from a continuing study of the categories that have been formulated in philosophy, social studies, and history of science. For example in the case of explanations and models, philosophical discussion includes the diversity of methodologies that exist in science which are not reducible to mathematics or some other formalism, but they have some epistemic and ontological autonomies (e.g. explain the distinctions between biology and physics) . Here we can locate debates about reifications and reductionism, i.e., harmful or abusive scientific practices that conclude concrete realities from scientific abstractions [15]. While recognizing the evaluative and interpretive activities in science, we can open a discussion on the institutional and cultural structures where science is inserted, and how at certain moments in the history, scientific research has been used as mechanisms for the exploitation of nature and of man, and not only for the explanation of questions based on curiosity or ethical goals [16].

The educational aspect is understood here as the challenge of contributing to the education of future scientists who can make responsible and ethical decisions in their various activities such as professional (research, divulgation, etc). The challenge remains to recover the anti-dogmatic character and a creative science to solve concrete problems of the people who finance public institutions. In this context, the complexity sciences, can, with the help of an ethical and historical background, serve as sciences that recognize the dynamic, diverse and transformable character of reality.

In short a *pedagogy of complexity*, would consist of the following elements:

1. Diversity of empirical contents: recognizes an ontology not only entities but processes, which is also heterogeneous and contradictory.
2. Categories, models and various explanatory diagrams. Where no reducibility of science to another, but also the diversity of methodologies, models and ways of understanding the social and natural reality is recognized [17].
3. Valuation and contextual interpretation. Make visible, not only conflicts of interests but differences of worldviews that can emanate from different geopolitical positions, gender, class and race, for conducting science [18].
4. Cautious and limited intervention by ethics. Understand and visualize forms of technological realization of scientific knowledge not only pass the privatization of the means of production of medicines, foods, or other human needs [19].
5. Critical thinking: positioned with human and nonhuman victims of economic exploitation systems, discrimination and violence based on race, gender, sex, or nationality [20].

4. Concluding remarks

In this paper we have presented a experience aimed at the creation of a scientific education for the undergraduates that promotes an ethical and responsible science in order to face the major economic, political and cultural challenges in undeveloped countries like Mexico. Through various alternatives courses, seminars, lectures and textbooks, the Science and Humanities Program of the Faculty of Sciences at UNAM, has made progress in the develop of a pedagogy of complexity, where knowledges and the process of learning are situated historically, where contemporary debates about the uses and abuses of science are analyzed, and finally where critical thinking is promoted inside and beyond the University.

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Acknowledgments

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