Chapter 5
Humans and Machines: Nature of Learning and Learning of Nature

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ABSTRACT
Old and recent theories stress that any understanding of the processes by which humans can learn requires to fully appreciate the relationships between the “nature of learning” and the “learning of nature.” From a constructivist viewpoint, acquiring knowledge is, like any human activity, dissociable neither from its underlying project nor from the knowing subject. The authors of this chapter relate the lessons from philosophy, psychology, didactics and ethics to their work in computational scientific discovery that aims at empowering learning machines with the task of assisting human researchers (Dartnell, Martin, Hagège, & Sallantin, 2008). The chapter concludes with didactical and ethical considerations.

INTRODUCTION
Reflecting on learning, knowledge and reality is consubstantial with occidental philosophy, from its very origin in ancient Greece, more than two thousand years ago. Since that time and right to the 20th century, philosophy and what we today call “science” – the phusikè of Aristotle (384 BC – 322 BC) – were viewed as one and the same activity. Descartes (1596 – 1650), considered as the initiator of modern philosophy, exposed in his Discourse on the Method of Rightly Conducting the Reason, and Searching for Truth in the Sciences (1637) a way of considering the relationship between on one hand an agent thinking on reality, and on the other hand the preconditions and actions from which true knowledge

DOI: 10.4018/978-1-60566-902-1.ch005
can emerge. He expressed the need to start from a *tabula rasa* by putting into question any previously constituted knowledge or belief. The only piece of certainty one can start with is one’s own existence (“I think therefore I am”). Also one should “divide difficulties into small enough parts to be able to resolve them” and select true statements that appear “clear and sound in the mind” (Descartes, 1637). He so much imprinted our occidental vision of science and our relationship to reality that the inherited “Cartesiano-positivist institutional epistemologies” would constitute the base of “the social contract between science and society, and thus the status of teachable knowledge” (Le Moigne, 1995 p. 8). Paradoxically, such epistemologies are “at the same time individually disputed and institutionally accepted” (Le Moigne, 1995 p. 14). This could be partly explained by the “astonishing lack of epistemological culture of scientific researchers” (Le Moigne, 1995 p. 8) and by the contemporary institutional separation between science and philosophy. It is fair to say that in our work, we attempt to restore this lost unity.

The so-called “Cartesiano-positivist epistemologies”, that we will explicit later on, have thus persisted under different forms until now, while interactions between science, technology and society have been shaping our world and our ways of thinking. For instance, with the advent of the industrial revolution, the transformation of matter into energy has been as much of a reality in everyday life as in theoretical physics. More recently, the advent of the information era has also constituted a big revolution and various scientific disciplines have emerged to model the processes that underlie learning (artificial intelligence [AI] and neurosciences). Together with parts of more traditional disciplines (psychology, philosophy and linguistics), they have been grouped under the generic term of cognitive sciences (Vignaux, 1991 p. 9). Different underlying paradigms provide a variety of approaches to learning and help study the relationships between intelligent machines and human beings.

The aim of this paper is to address the following questions. What scientific models do we use to understand human learning and to produce learning machines? Where do these models come from? What are their scopes and limits? How and why do we choose to use those models? What do they tell us is possible or is out of reach?

In the first section, we will overview i) the models that western societies have recently produced in order to explain the nature of learning and ii) the models that they have developed about the learning of nature, particularly through the prism of so-called “scientific discovery.” In the second section, we will present the general evolution that occurred in the field of AI about assisting human discoveries with learning machines and then introduce the main aspects of our work in this domain. Finally, we will discuss the didactical and ethical dimensions inherent to discovering how learning of nature is performed, and to using assisting machines.

**HUMAN LEARNING**

**Nature of Learning**

After a few preliminary considerations, we review the conceptions on human learning as they evolved in western culture. We then focus on a particular model of the scientific activity, and highlight how the two conceptualisations of “general learning” and of “scientific learning” converge to constructivist paradigms.