



Theory Construction

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2 Theory Construction

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7 Synonyms

8 Scientific discovery

9 Definition

10 Theory construction is a process, i.e., a set of state changes
11 by an autonomous agent, or by an organism composed of
12 several autonomous agents. In the first case, we may recall
13 the approach of Pierce (1931) that considers three logical
14 operations (inference rules) on a knowledge base, i.e., a set
15 of propositions asserted to be valid: abduction, deduction,
16 and induction. *Abduction* generates new hypotheses from
17 which *deduction* derives predictions to be confirmed by
18 experience. The confirmed hypotheses are structured by
19 *induction* into laws of general validity. A similar way to
20 describe the life cycle of theory construction within
21 a single agent is to say that the real world asks the agent
22 for a concrete solution in a *single instance case*, then the
23 solution is *abstracted* in order to identify laws that are
24 more general; finally the abstracted solution is applied to
25 other classes of instances of the abstract problem, i.e., it is
26 *generalized*. The interplay of these operations in one single
27 autonomous (artificial) agent is widely modeled in the
28 work on machine learning.

29 The second social scenario – communicating agents
30 learning by exchanging messages – is less easily formalized
31 but probably more realistic when describing human learn-
Au2 32 ing. In this article we give support to the conjecture that
33 the process of construction of knowledge in science
34 (theory construction or scientific discovery) and human
35 learning is an interactive human process of a social nature
36 that presents profound similarities and relations with each
37 other so that we may profit from advances in one domain
38 to infer properties of the other one and the reverse. In this

approach we are strongly influenced by constructivism 39
(Piaget 1970) and social constructivism. 40

Theoretical Background 41

The previous century has been characterized by 42
a *constructivist approach to science* (Zalta 2011). Knowl- 43
edge construction in any science was strictly associated to 44
proof and validation (Popper 1959). Obviously, proof and 45
validation in history, for instance, is not the same as in 46
mathematics and, in turn, not the same as in physics or 47
biology. Nevertheless, all these proof-and-validation pro- 48
cesses require to possess a critical mind as well as to 49
exercise a critical approach knowing that proofs and val- 50
idations *have to be accepted* by others. Theory construction 51
is then the result of a *social game* that enables the historical 52
development of newborn theories that progressively focus 53
their own validation domain. In more general terms, the 54
scientific activity is considered as a social activity 55
influenced, as all the other ones, by pressures of the con- 56
temporaneous leading powers (Kuhn 1962; Latour 1987). 57

The end of the previous century is marked by an 58
evolution of *reductionism*. Reductionism can either mean 59
(a) an approach to understanding the nature of complex 60
things by reducing them to the interactions of their parts 61
or to simpler things or (b) a philosophical position that 62
a complex system is nothing but the sum of its parts, and 63
that an account of it can be reduced to accounts of indi- 64
vidual constituents. Problem solving is not considered 65
anymore just as consisting of decomposing each problem 66
into a finite set of subproblems and composing the solu- 67
tions. Rather, the *holistic, situated* approach to problem 68
solving requires one to integrate (or make interoperable) 69
the partial results validated by different scientific disci- 70
plines. Reductionism and holism seem today complemen- 71
tary approaches. For instance, understanding and 72 **Au3**
forecasting phenomena related to the global warming 73
problem requires to consider the planet and model *simul-* 74
taneously, for example, their physical, chemical, biological, 75
and social properties. A regulation rule influencing human 76 **Au4**
behavior acts modifying the actors thus the observed 77
system. According to the pioneer ecologist Francesco 78
Di Castri, for instance (Di Castri and Hadley 1988), 79

80 one of the major scientific bottlenecks to natural
81 resource management was the lack of a holistic approach
82 bridging ecology (in fact, according to his views, social
83 ecology with a strong emphasis on human impact) and the
84 natural sciences. We are facing what people call a complex
85 system with feedback. From a practical viewpoint, reduc-
86 tionism supports human learning by disciplinary subjects
87 and toy problems, while a holistic view supports learning
88 by solving realistic inter-, trans-, and multidisciplinary
89 problems.

90 **Important Scientific Research and Open** 91 **Questions**

92 Scientific knowledge is built and communicated by means
93 of *interactions* among scientists and between scientists and
94 all other human beings. Several interaction communities
95 are formed and dissolved each having properties that are
96 different one from another. A scientist does not process
97 his/her theories *alone*, but rather he/she is guided by critics
98 of his/her pairs on a scientific production offered as
99 a contribution to the solution of problems identified
100 within a scientific context where publications already
101 exist. A well-trained researcher should be able to enact
102 successfully a problem-solving process on old and new
103 problems within a scope limited by the discipline of exper-
104 tise. The training requires exercise but training and prac-
105 tice are intertwined all life long, not separated in temporal
106 phases, so that we may treat scientists as lifelong students
107 and teachers at the same time.

108 The interactive view does not assume that each of the
109 interacting partners have the same knowledge, language,
110 goals, plans, strategies, tactics, intentions, preconceptions,
111 assumptions, misconceptions, etc. In order to hopefully
112 converge to an agreement, arguments and counterargu-
113 ments are discussed and exemplified in a *social, interactive*
114 *negotiation*. Communities exchange messages according
115 to patterns and rules that historically have been studied
116 in sociolinguistics: *pragmatics*, which is the science of
117 understanding the relations between messages and the
118 state of the actors producing and receiving those messages,
119 and *rhetoric*, which is the art of convincing a partner about
120 an argument or evoking emotions into a partner, are the
121 disciplines that deal best with human interaction. In the
122 most interesting case, the rhetoric game of interacting for
123 negotiating meaning occurs between and among actors
124 belonging to different viewpoints/disciplines, thus
125 offering inter-, multi-, and transdisciplinary scenarios of
126 *collective intelligence*. Recently, emotions and personality
127 traits have entered the scene as a mean to understand
128 individual intelligence; thus we expect them also to be at
129 the core of phenomena of collective intelligence.

Formal theories of interactive *learning* study different
approaches of knowledge construction and their effective-
ness. It is usually hard to say that one approach is correct
and the other ones are wrong; often it is the case that they
are complementary. Let us consider foreign language
learning by practice: after a while, the learner's perfor-
mance improves and his/her mistakes diminish. This
learning is accelerated if the instructor confirms (or not)
the correctness of his/her sentence, or either when the
instructor shows the apprentice the incorrectness of
a grammatical form by showing a counter example. Such
training *by practice* is also common in learning of sports or
in learning of artistic skills when the trainee is required to
adopt complex practices without necessarily justifying
them as theories. Any learning needs practice: the trainer
should define the exercises adequate for the learner to
untie the body and the mind. Similarly, the researcher's
work requires a practice to learn how to be creative. But
practice and supervised learning without creativity and
autonomous rational thinking seem to concern only
a minor part of the complex knowledge and skills required
for coping with realistic problems.

Where does *creativity* come from? Sometimes it
emerges from a coincidence; often it is the fruit of
a surprise (unexpected event) assuming the mind is well
prepared to that event. The history of sciences is full of
discoveries emerging from chance, manipulation errors,
even from the innocent viewpoint expressed by a novice.
Such *serendipitous events* look quite similar to learning as
a side effect of interaction: something that happens even if
we can neither forecast its occurrence nor explain its
origins.

We will reinterpret *multi-, inter-, and transdisci-*
plinarity as modalities of collective behavior of the social
game of theory construction that we claim to be similar to
human learning. Assume a "service-oriented view" of such
a social interaction: the one actor *produces* a statement and
the other one *consumes* it, either for progressing in his/her
own scientific construction, or for demonstrating/refuting
the validity of the proposed statement. Under the hypoth-
esis that the two actors come from different disciplines (or
sub-domains of knowledge) one may have several com-
posite situations – interaction patterns – that explain the
nature and complexity of the holistic view previously
identified to be a foundation of current scientific progress
as well as modern learning processes.

At the basis of each of those situations there is the fact
that "Real-world problems may not respect discipline
boundaries" (Popper 1959) while scientific communities
are made of actors that mainly master a single discipline,
including the lexicon and the methods. Here is the crucial

181 challenge for the future of science as well as innovation
182 and, simultaneously, human learning: How to exploit
183 disciplinary convictions, viewpoints, rules, and jargon
184 when many of them should interact synergically. Hereafter
185 is a simple, though significant preliminary classification
186 that adopts the above identified classification criteria.

187 *Multidisciplinarity*: each actor uses statements proved
188 by his/her (multidisciplinary) community in his/her own
189 problem's statement and argumentation.

190 *Interdisciplinarity*: each actor exploits in her/his proof
191 statements proved by another community. The principle
192 of interdisciplinarity is to admit as axioms some results
193 proved by other communities that one cannot prove by
194 himself. An interdisciplinary approach is required when
195 there is no discipline omniscient and omnipotent able to
196 solve the problem without intervention from others.

197 *Transdisciplinarity*: actors propose some hypothetical
198 statements to other communities that trigger inter- or
199 multidisciplinary work (Piaget 1970).

200 Each of these interaction scenarios may be mapped to
201 many concrete situations (called also business processes)
202 of theory construction and scientific discovery, but also of
203 technological innovation. In human learning, similarly,
204 the game of collective construction of knowledge is very
205 clearly influenced by synergies between and among actors
206 each representing different disciplines, viewpoints, and
207 interests.

208 Finally, the interactive construction of scientific theo-
209 ries can be viewed as an activity intertwined with two
210 kinds of learning: one is supervised by the teacher or

master and implies the acquisition of practical skills; the
211 other is unsupervised as it is concerned with the commu-
212 nication of knowledge in the form of documents that have
213 to be evaluated by pairs. 214

Since both the process of creative discovery in science
215 and learning in all its facets present those quite similar
216 properties, we may assume that they are related to each
217 other, so that advances in understanding each of the two
218 may be profitable for the other one and the reverse. 219

Cross References 220

- ▶ Abductive Reasoning 221
- ▶ Advanced Learning Technologies 222
- ▶ Learning as a Side Effect 223
- ▶ Networked Communities 224

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