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## 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 learning.  
**Au2** 32 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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