Scientific Processes and Social Processes

Wolfgang Balzer[1] and Klaus Manhart[2]
University of Munich
munich-simulation-group.org

Abstract:

We clarify the notions *scientific process* and *social process* with structuralist means. Three questions are formulated, and answered in the structuralistic, set-theoretic framework. What is a scientific process, and a process in science? What can be meant by a non-social process? In which sense a non-social process can be a part of a scientific process in social science? We are specifically interested in social processes. Our answers use the notion of the generalized subset relation applied to set-theoretical structures, and the set of structuralistically reconstructed empirical theories.

Keywords: social process, scientific process, process, theory, structure, neighbourhood.

1 Introduction

The notion of process is probably as old as creatures which speak and move. Even in Greek antiquity this notion was used in different meanings in different areas – for instance the 'process against Socrates' and the processes in physics described by Aristotle. The evolution and specialization of the use and meaning of 'process' goes on to this day. In the 18th and 19th centuries, physical and chemical processes received abstract forms; the notion of a process in law also was formed structurally. In the 20th century the notions of formal, biological, economic, political, and social processes were analysed. In Germany, the biological notion of process even entered into sociology, mainly due to Luhmann.

In our times, two other cleavages have opened. There is a distinction between scientific and non-scientific processes, and another distinction between social and non-social processes. This leads to further distinctions coming from the different scientific disciplines. There are three main groups: natural sciences, social sciences and humanities. In this paper, we subsume all disciplines from these three groups under the term *science*, in order to have a general term available.[3]

[1]balzer@lrz.uni-muenchen.de
[2]mail@klaus-manhart.de

[3]This means that we do not reserve the term 'science' to the natural sciences, as this is done in the Americas. For this narrow referent, we will always use the term 'natural science(s)'.

If a process is scientific, this often means choosing a special discipline to further deal with this process. If we talk about a process in science, we often refer to a special discipline, for instance, 'this process is a physical process', or a natural process, i.e., a process investigated by the natural sciences. This leads to questions and the respective decisions about the comparison of a process studied in one discipline, and a process analyzed in another discipline. How would a sociologist compare a process from physics with a process from sociology? How would a jurist compare a legal process with an economic process? How would a mechanical engineer compare a technical process with a political one? This can run into fundamental opinions. In sociology, for instance, the term 'scientific process' often has a 'fundamentally' different meaning from that it enjoys in the natural sciences.

A real scientific process has several aspects or dimensions. Take as an example (Balzer and Manhart, 2011) a process in a science laboratory, where a file is printed. A real process of printing something out has, in view of the theory of physical rigid body mechanics, some properties (for instance 'some parts spin', 'other parts move in other ways', 'most of that parts are rigid'), which are not 'intended properties' in, for instance, the field of medicine. Instead, other things in this field, such as harmful fumes or irritating noises, are important. The process of printing can also be investigated by other disciplines. For instance, a part of the printing process takes place in the computer plus the printer used. This part of process can be described and studied from several points of view. A layperson would describe a computer process perhaps as an electrical current flowing through the processors. A physicist would view the same process through electrodynamics, a computer manufacturer as the use of software, a computer programmer as the execution of a program code, or a theoretical computer scientist as a sequence of bits.

If we try to decide by pure normal language analysis whether this printing is a scientific event or not, we will not really succeed. What is the fine-grained distinction in the English language between a scientific process and a process in science? The printing of text is not so much dependent on the formulation of the process in normal language; it is much more dependent on the content of the text which is printed out, and on the surrounding of the printing.

Most of the components of a real process can belong to two or more different dimensions. The atomic fact, for instance, which is used in the production of aspirin, that 'aspirin has always a special form', can be understood differently in different scientific disciplines. Chemically speaking, the substance can be in a solid or in a dissolved state; economically, the product looks stylish or cheaply packaged. Dimensions can be expressed at least in three ways. The formulation of a dimension of a process can be just a metaphoric phrase. In a second way, it can be defined by perceiving phenomena and measuring and storing data (Krantz et al., 1971), (Gärdenfors, 1990). In a third way, dimensions can be constructed from theoretical models and theories. We did not try to define the dimensions of the processes here; (Gärdenfors, 2000) would be a natural starting point.

In the social sciences one way to distinguish scientific processes from other processes is to use an account from science research, for instance (Krohn and Küppers, 1987). This account restricts processes to actions. This is the usual way to proceed in sociology. Other processes, for example, an astronomic sun implusion are not investigated. Krohn and Küppers distinguish *actions in science* from *research actions*. Research actions deal with the investigation and analysis of objects, facts and relations, which are of scientific interest. On the other hand, actions in science do not have the direct goal of investigating scientific objects or facts: they have the direct goal of executing auxiliary actions to promote science in the widest sense. In order to make research actions possible, actions in science are necessary. The example of printing a text makes this clear. The content of the printed text could say, that some experimental results were generated in this laboratory. The printing itself is an action in science, but not a research action. A research action could be, for example, that some chemical substances were put in an experimental apparatus, as is described in the printed text, and the resulting substances were taken from the apparatus.

In the social sciences, the objects of interest are social actions and social processes. Nevertheless, in social processes, as in research actions, we find parts, which stem from models of natural science. A lab worker investigating a genetic phenomenon has normally some knowledge of models of genetics, which are described in the way of natural sciences, e.g., at a molecular level. On the one hand, the lab worker is performing a research action, and on the other hand, is using natural processes. But how can we say, that a natural process can be a part of a social process? Again, this can run into fundamental differences, if we do not try to analyse the kinds of processes under discussion.

There are not many studies in which the same process is viewed from a position of different disciplines, for example, viewed from the discipline of science research, and from that of the philosophy of science, and also from that of the theory of science.[4] To open this domain, we want to study the many notions of a scientific process in such a way that, on the one hand, we clarify and formulate them precisely, and on the other hand, we compare processes from different disciplines and build their relations in a concise way. In other words, we indulge in the comparisons of notions of a process from different disciplines. It is clear, that these topics could be discussed in different ways, from physics to sociology and philosophy.

In our paper we analyse and clarify these issues in a meta-theoretical way. We distinguish social processes from non-social processes and scientific processes from non-scientific processes. Furthermore, we clarify some relations between processes and meta-theoretical entities. A process has to do with structures, models, data (intended applications), echelon constructions, generalized subset relations between structures ($\sqsubseteq$), neighbourhoods between structures, and links. For our analysis we introduce a general notion of state, which did not originate in special disciplines, such as physics, mathematics or computer science. In this way we can relate processes and subprocesses to theories and parts of theories

[4]The term 'theory of science' is only known in the German language ('Wissenschaftstheorie'). In German-speaking regions, this term is firmly established.

in a general way. In our paper we use a tool, namely the structuralist framework of theory of science, which was developed in the last forty years, see for instance (Diederich, Ibarra, Mormann, 1989, 1994). In the structuralist framework we can describe kinds of processes distinct from other kinds, and we can connect processes to other relations, which are parts of theories.

In Sect.2, we define states as parts of theoretical structures, such as models and submodels. Our account is more general than the state space approach, which originated in physics (Beth, 1948/49), and which is used now in many other disciplines, such as computer science, probability theory, and philosophy of science (van Fraassen, 1970), (Colodny, 1972).[5] In Sect.3, we relate processes to theories by using two notions: 'echelon construction' (τ) and 'generalized subset relation' ($\sqsubseteq$). In this way we connect processes to empirical theories in a clear way, but not really in a complete way.

In Sect.4, we use a global picture of a net of scientific theories in the way described in (Balzer, Moulines, Sneed, 1987, Chap. 8) in order to make a first step in embedding processes into scientific structures, and in Sect.5, we formulate our answers in an informal way. It is clear, that much more could be said about these answers by exploiting the notions discussed in Sect.2 and Sect.3.

2 States and Processes, structurally described

In this article we will not describe all the set-theoretic details, because most of the definitions are found in many different places in the scientific literature. The 'standard' notions, which we presuppose here are found, for instance, in (Balzer, Moulines, and Sneed, 1987), (Balzer, 1985) and (Balzer, Lauth, and Zoubek, 1994).

From our structuralist point of view, the echelon construction scheme (abbreviated by ECS) defined in (Bourbaki, 2004, Chap. 6), is a central ingredient of structures. Informally, an ECS is a method of construction by which a complex set $\tau(X_1, ..., X_n)$ is formed by a list $\langle X_1, ..., X_n\rangle$ of simpler sets, using the Cartesian product and the power set operation.[6] An ECS can be seen just as a method to 'parse' relations of a special type. In this way it is possible to describe the structure of the models of a theory in a very general way. The idea is to find out how each relation used in a model can be 'reduced' to 'basic', atomic elements which are not further analysed by this model. This can be done by echelon construction schemes. Each relation in a model is constructed step by step, starting with basic sets. For such a construction only two procedures are needed, which can be iterated. If a set x is given we construct the *power set* $\wp(x)$ of x, and if two sets x and y are given we construct the *Cartesian product* $x \times y$ of x and y.

In the standard formulation, an *empirical theory* T contains the *core* K *of* T, the *approximation apparatus* A, and the *set* I *of intended applications* of K. The core K consists – among other things – of a class M of *models*, a class M_p

[5]We cannot discuss here the differences.
[6]See Balzer et al. (1987), Chap. 1.2.

of *potential models*, a class M_{pp} of *partial potential models*, and a set L of *links*. In the following, for simplicity, we abbreviate or omit some terms. In the term 'empirical theory' we omit 'empirical', in the term 'partial potential model' we omit 'potential'. From models, potential models and partial models we omit the auxiliary base sets. Also we omit here the *constraints*:

$$T = \langle K, A, I\rangle,\ K = \langle M_p, M, M_{pp}, L, ...\rangle \text{ and } I \subset M_{pp}.$$

Each theory T has a list $\langle \tau_1, ..., \tau_m, \tau_{m+1}, ..., \tau_{m+n}\rangle$ of *basic* ECSs *for* T.

Each potential model $x \in M_p$ has the form

$$x = \langle D_1, ..., D_m, R_1, ..., R_n\rangle$$

where the basic ECSs $\tau_1, ..., \tau_m, \tau_{m+1}, ..., \tau_{m+n}$ for the theory T are presupposed. For all i, $i \leq m$, and for all j, $j \leq n$, it is required that the following holds:

$$D_i \in \tau_i(D_1, ..., D_m) = \wp(D_i), \text{ and}$$

$$R_j \in \tau_{m+j}(D_1, ..., D_m),$$[7]

and we hypothesize that each model is a potential model:[8] $M \subseteq M_p$.

$D_1, ..., D_m$ are called the *base sets of* x, and $R_1, ..., R_n$ the *base relations of* x. The theory T has a fixed number p, $p \leq n$, by which we distinguish partial models from potential models. Each partial model $z \in M_{pp}$ has therefore the form $\langle D_1, ..., D_m, R_1, ..., R_p\rangle$. For our purposes we also introduce the set $E(T)$ of *all* ECSs *for* theory T.

If τ is a ECS for T, the expression $\tau(D_1^x, ..., D_m^x)$ denotes *the set typified by* τ *over* $D_1^x, ..., D_m^x$ *of* x. The *class* of these sets we define by $B(T, D_1^x, ..., D_m^x) = \{\tau(D_1^x, ..., D_m^x)/\tau \in E(T)\}$, and *the class of all typified sets of an empirical theory* T by: $B(T) = \bigcup_{x\in M_p} B(T, D_1^x, ..., D_m^x)$. These definitions can be relativized to models and partial models without difficulty. $B^M(T) = \bigcup_{x\in M} B(T, D_1^x, ..., D_m^x)$ contains typified sets in proper models x of T, and $B^{pp}(T) = \bigcup_{z\in M_{pp}} B(T, D_1^z, ..., D_m^z)$ contains the typified sets in the partial models z of T.

With these preliminaries settled, we can introduce classes of *states* in a potential model x and in a theory T. Normally, an empirical theory has several different possible classes of states. The notion of a state in T has therefore to be understood as being relative to a given list σ of ECSs, which we will call a *state signature* (in T). In quantum mechanics, for instants, we find position- and energy representations.

Using normal list notation, by which an element of a set X is a component of the *list* X^*, we introduce states of a state signature for a potential model of T. For this purpose we first introduce *structures of states in x typified by* a state signature, then *states in* x (relative to a state signature), and finally a *class* $S(x, \sigma)$ *of states for* x (relative to a state signature σ) and a *class* $S(T)$ *of all states of theory* T. Informally, we could just define a state for a (potential) model in the normal way. In physics, it is said that a state is a list of values of functions which can be determined in one system by observables. But our

[7] In (Balzer, 1985) a variant, heretical to ZF, was used.

[8] As an example we describe the potential models and the ECSs of the theory of classical collision mechanics **CCM** (Balzer et al., 1987, Chap. III.1) in a semi-formal and very brief way in the appendix.

approach is more general. It originated from the work of Bourbaki, especially from the notion of 'deduction of structures' (Bourbaki, 2004, Chap. IV.1.6). In our terminology, one term from one (potential) model of one theory can be constructed from another term from a (potential) model of another theory. For such a construction it is essential to use the notion of echelon. In an echelon construction it is possible to come from one term of level A to another term of level B. For instance, we take several objects from one model, transfer them to a set, and then use this set in a model of another theory as a new object. In first-order logic this cannot be done directly. If we use terms of different levels in first-order logic it is necessary to introduce a set-theoretic model of the kind of Zermelo-Fraenkel (ZF), and plug in this ZF-model into the model of an empirical theory. In Bourbaki's approach this is not necessary. As the original formulation of Bourbaki is rather difficult to read, and as we did not find formulations of the notion of state and it's cognates in a structuralistic setting, we describe several definitions in a more readable, semi-formal way in the appendix.

The construction of a state s for a potential model x can be described as follows. For a given potential model x of the form $\langle D_1, ..., D_m, R_1, ..., R_n\rangle$ with it's state signature $\sigma = \langle \tau_1, ..., \tau_m, \tau_{m+1}, ..., \tau_{m+n}\rangle$ we choose other ECSs which start from the ECSs of σ such that these new ECSs altogether form a new state signature $\sigma' = \langle \tau'_1, ..., \tau'_t, \tau'_{t+1}, ..., \tau'_{t+u}\rangle$ for a new structure. Then we pick for each index i $(i = 1, ..., t)$ an object a_i from D_i and for each index j $(j = 1, ..., u)$ we pick an element r_j from R_j and build a potential model $\langle D'_1, ..., D'_t, R'_1, ..., R'_u\rangle$ of the form $\langle\{a_1\}, ..., \{a_t\}, \{r_1\}, ..., \{r_u\}\rangle$. The set-brackets $\{\ \}$ are then omitted. If the elements r_j are values of functions the objects are shifted to the right; they become arguments of functions. For instance, instead of $\langle a_1, a_2, a_3, r_1, r_2\rangle$, it is written $\langle r_1(a_2, a_1), r_2(a_1, a_3)\rangle$. In examples, states often can be described in this simple way. In collision mechanics, for instance, a state is written as $\langle v(p,t), m(p)\rangle$, or even more briefly as $\langle v, m\rangle$.

The result of such a construction (including set-brackets) again is a potential model. It has a very special form. Omitting the set-brackets and the objects from the base sets we get a *state* (of state signature σ'). The way of picking out objects and elements of relations for a state depends on the order and on the assignment of indices i and j. Formally, we introduce injective functions $\xi : \{1, ..., t\} \to \{1, ..., m\}$ and $\zeta : \{1, ..., u\} \to \{1, ..., n\}$ to control the process of building such states.

By this construction we must specify the ECSs for special states $y = \langle D'_1, ..., D'_t, R'_1, ..., R'_u\rangle$ and the corresponding structure. Base sets and base relations of y are typified in the same way as 'normal' structures. But how can we relate the sets and relations of y to those of x? In general, we cannot define the ECSs of y explicitly by the ECSs of x. This can be done only in special applications. In general, each ECS τ'_j, $j = t+1, ..., t+u$, relates the jth relation R'_j of y to components of x in the following way:

$$\tau'_j(D'_1, ..., D'_t) \subseteq \tau_{\xi(j)}(D_1, ..., D_m),$$
$$\{r_j\} = R'_j \subseteq R_{\zeta(j)} \in \tau_{\zeta(j)}(D_1, ..., D_m).$$

All this can be applied also to models and partial models.

One's first reaction normally would be to say that these formulations are rather idiosyncratic. But there are two points, which can be clarified only in this way. First, a computer has no other way to 'calculate' the ECSs, and the elements found in the computer's data base. Second, in theory of science, when we speak of relations between two theories from different disciplines, it is sometimes tedious, but necessary, to formulate a fact about a complex relationship in this way or in a longer, natural language formulation. Furthermore, we think that, at the moment, our set-theoretic approach is best suited to represent the global structure of science. Especially, we do not see a better approach to investigate the relations between links and neighbourhoods, when links are connected to theories of different disciplines (see below).

Using states, we can now introduce a very general notion of *process*: informally, a process p is just a pair of states, such that both states are causally related to each other. There are (at least) three different meanings of 'cause'. Causation can be investigated as a psychological phenomenon: cause and effect are found in actors. In this sense, cause is studied in belief revision and in the *belief - desire - intention* approach (BDI). In a second sense, the notion of cause is discussed as a metaphysical entity, which largely escapes human comprehension. A third sense of 'causation' is used in different scientific disciplines. Here we are only interested in the third sense. Each discipline has its particular approach to representing causation.[9]

Formally, we describe a process as an element of a given causal relation, where cause is neither a metaphysical entity nor a system of believe statements. So we must begin with the notion of a *kind* of process which can be investigated in several disiplines. We use the index b to indicate the *beginning*, and e to indicate the *end* of a process, and we use s, s', s_o for variables for states.

A process p consists of two states, the beginning-state and the end-state, such that both states are causally related, i.e. the states are bound together by a relation of causation studied scientifically. We differentiate causes and direct causes. A *direct* cause is a cause by which two states s, s' are causally related only if there are no further states s_o, which lie causally 'between' the related states s and s' (see appendix, D2). By this account we get a general framework, which would be filled in ways investigated by several authors.[10] Even though this account is coarse, we think it is in accordance with empirical science, for instance with quantum mechanics. We see no problems to spezializing this account to the idealized, continuous level, and to the level of probability. The requirements stated above can also be generalized in such a way, that the causal relation gets even weaker. For instance, we can use the structuralist apparatus of approximation.

[9] Ulises Moulines (personal communication) argued that the notion of cause just can be omitted structuralistically without loss. At the moment, we, the authors, are undecided.

[10] For instance (Rott, 2006), (Salmon, 1984), (Suppes,1970).

3 Processes in Science

We embed the processes and their kinds into a given empirical theory and into a given model. This idea is not new. In (Lauth, 2002) the notions of state and process were treated as *transtheoretical*.

To this end, we assume that a theory T, the class of models M belonging to T, and a state signature σ are given. We say, that p is a *theoretical process* (*in x typified by σ*) if and only if the state space $S(x,\sigma)$ for x typified by σ is given, s_b and s_e are the beginning- and the end-states of this process, and there exists a causal relation *caus* so that p is an event of this relation ($p \in caus$). Such an event therefore is described by a pair of beginning- and end-states. We collect all theoretical processes for all models and all state signatures for T, and introduce the *class $PC(T)$ of all theoretical processes in T.*

Here it is important to bind processes to the proper models. In a potential model, there can be pairs of states from a given theory, which look a bit odd. For instance, why would two 'arbitrarily chosen' states in particle mechanics, which contain the same point of time be a process? In other words, a causal relation *in* a theory is essentially determined by the hypotheses of this theory. Of course, we can also investigate just possible processes, which exist in a theory. But we wish to distinguish them from the 'proper' processes. To highlight this point we use the term *theoretical process*.

The notion of state and of process is easily restricted to the level of partial models. For this end, we use a generalized subset relation $\sqsubseteq$, studied, for instance, in (Balzer et al., 1994).

If $x = \langle D_1, ..., D_m, R_1, ..., R_n \rangle$ is a potential model of a theory T, and $\tau_1, ..., \tau_{m+n}$ are the basic ECSs for T, we say that x' is a *generalized substructure of x* if and only if x' has the form $\langle D'_1, ..., D'_m, R'_1, ..., R'_n \rangle$ and the following conditions hold. For all $i \leq m$ is D'_i a subset of D_i ($D'_i \subseteq D_i$), for all $j \leq n$ is R'_j a subset of R_j ($R'_j \subseteq R_j$) and R'_j is typified by τ_{m+j} ($R'_j \in \tau_{m+j}(D'_1, ..., D'_m)$). If x' is a generalized substructure of x we write: $x' \sqsubseteq x$, and the *class* of generalized partial models for T we denote by M_{pp}^{gen}.

In the same way, we can introduce the class $S_{pp}(T)$ of partial states in T, the class $S_{pp}^{gen}(T)$ of generalized partial states in T, and the class $PR_{pp}^{gen}(T)$ of generalized partial processes in T defined by $S_{pp}^{gen}(T)$.

Finally, we restrict the processes to the level of *intended*, and therefore in a sense 'real', processes in the way used in the structuralist approach. Coming from the empirical claim of T which implies that $I \subseteq M_{pp}$, we get to the generalized partial models and from there to the generalized partial processes $PR_{pp}^{gen}(T)$. We restrict the latter class to a set of *intended* generalized partial processes for T, and omit the terms 'generalized' and 'partial'. The latter set cannot be defined, it must be used as a basic notion in the theory of science. We denote the set of intended processes of a theory T by $IP(T)$: $IP(T) \subseteq PR_{pp}^{gen}(T)$.

4 A Look at the Architecture of Science

Using an example, we described in Sect.1 various dimensions of a process. We think it is possible to integrate the dimensions of processes in the state space approach (van Fraassen, 1970) and in the conceptual space account (Gärdenfors, 2000). But we did not try to formulate a detailed account, which would define the dimensions of a (potential, partial) model. The notion of the generalized subset relation $\sqsubseteq$ as introduced above could also be used in this case. In this paper, we just assume that a (potential, partial) model can be separated into several submodels in such a way that each submodel lies in just one dimension of the model, see Figure 1.

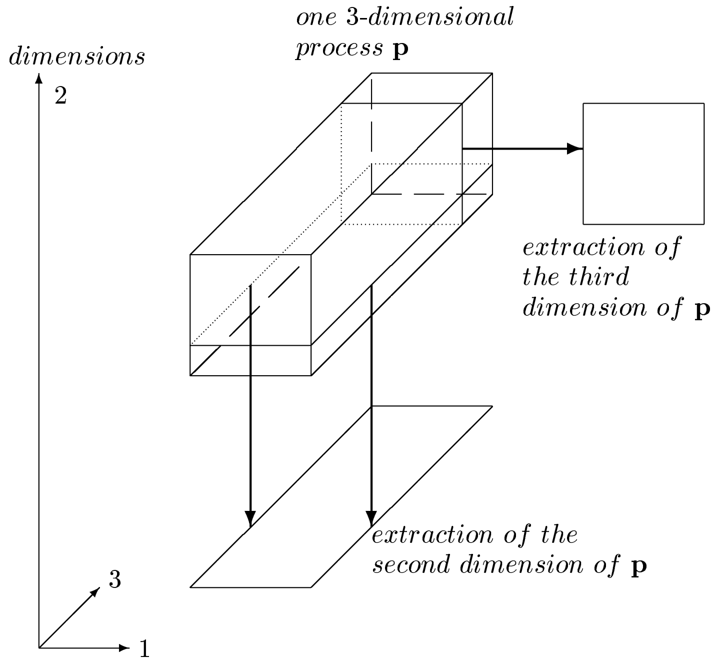

Fig.1. Extraction of single dimensions.

Figure 2 (below) depicts some disciplines, theories, classes of theoretical processes, und sets of intended processes. For a theory T_i^r, we see the respective class TP_i^r of theoretical processes. This is depicted by arrows. For example, T_k^{phy} could be the theory of classical partical mechanics, and TP_k^{phy} could be the respective class of theoretical processes, in which are found the position-, velocity-, mass- and force functions. Also the derived processes belong to this class. In Figure 2, the lefthand, big oval represents the class of all processes, which take place in the different sciences, and therefore *in science*. On the outside of this oval, we find other processes, which have nothing to do with science.

The transition from a theoretical process to an intended process corresponds to the transition from a (potential) model to an intended application. These transitions are precisely formulated by the generalized subset relation $\sqsubseteq$.

We depict three theories and the appertaining sets of generalized, intended processes. For one special, psychological theory T_j^{psy} we depict, at the left, the set IP_j^{psy} of generalized, intended processes and we depict several neighbourhoods of this set of processes. T_j^{psy} could be, for instance, the theory of Festinger, in a reconstruction of Westermann.[11] A *neighbourhood* is a set of (partial) processes, which are similar to intended processes in a certain degree. These neighbourhoods can be described structuralistically in a precise way.

For a theory T_j^{psy}, we depict just one single, intended process by a big black point p, at the left. Such an intended process p can be represented by a substructure, in which, as discussed above, some theoretical parts are left out. In the theory of Festinger, for instance, p could be one of the processes, by which a person partially reduces his or her dissonance.

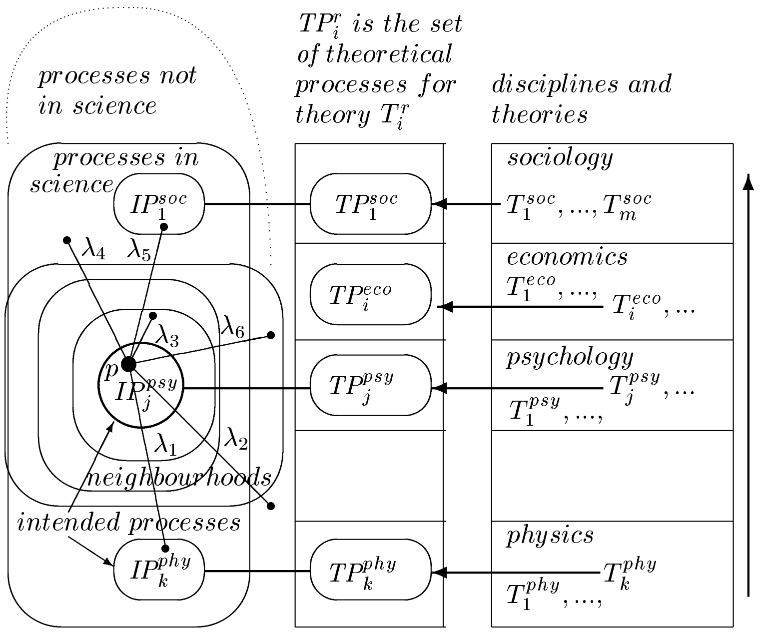

Fig. 2. Real processes, links and theoretical processes are ordered by scientific theories.

The process p has many links to other processes. Some few processes, which are classificatorically important, are depicted with the respective links $\lambda_1, ..., \lambda_6$. Besides the points and links depicted, there are other links to other processes, which are not depicted. p has a link λ_1 to a physical, and through λ_5 to a sociological process. The link λ_3 leads from p to a process which is similar to p

[11](Westermann, 2000), see in (Balzer et al. 2000).

and takes place *in* science. On the other hand, the link λ_6 leads to a process, which is situated out of science. It could be, for instance, a 'natural' process (such as 'it is raining'), but it could be relevant for the reduction of dissonance. The link λ_2 leads to a non-scientific process, which is *not* similar to p. The link λ_4, finally, leads to a process taking place in science which is not similar to p and is not a member of the set of intended processes of another theory – if this is possible. TP_k^{phy} could be the class of *theoretical processes* of the theory of classical particle mechanics T_k^{phy}, and IP_k^{phy} the set of *generalized intended processes for* T_k^{phy}. TP_k^{phy} contains, in a sense, parts of paths, parts of velocity functions, and other things. In this theory there are also derived processes, which can be calculated from positions, velocities, masses and forces at times t and t'.

The thick horizontal lines connecting two ovals represent the relations between the intended processes (which are observed and investigated in reality) and the theoretical, possible processes (which can be defined in the respective theory). The set IP_i^r of generalized, intended processes in T_i^r is always a subset of the class of theoretical processes.

We claim, that the generalized subset relation $\sqsubseteq$, which is a set-theoretic relation, covers in principle all parts and aspects of processes. We also claim that the description through links and through $\sqsubseteq$ is often more adequate than a simple multi-dimensional representation.

5 Our Answers

We can now formulate three precise questions, in which we are interested. The first question is, whether there are processes in science, which are *not* scientific. We came to this questions by looking at Figure 2. There we find a link λ_4, leading from an intended process to a process, that takes place in science, but which is not a scientific process, i.e. it is not a process, who 'belongs' to a scientific theory. By analysing such a process we should first invent a new scientific theory.

A first, partial answer of this question we discussed already in Sect. 1 refers to processes, which take place in actions in science and in research actions (Krohn and Küppers, 1987). We are not satisfied with this answer for two reasons. First, this account does not say anything about processes in science, which are not actions. Second, it cannot clarify why an action in science could not be also at the same time a research action. These insights can be further clarified by the example of printing a text. We can limit the printing of a text in such a way, that the person who 'starts' and 'ends' the printing is not a part of the process. The process of printing in this narrow sense is not an action. But such a concrete printing surely can be a part of an investigation, a part of a research action, in which for instance a new kind of printer is developed and tested.

In our structuralist frame we can say more about the question of the bounderies of the set of intended processes. *If* we assume, that the set of all intended processes of all theories 'somehow' could be uniquely delimited, we could formulate precisely, that some processes do not belong to any empirical theory. Is the daily process of greeting, for instance, an intended process for a special empirical theory? We think so. A psychological or socio-psychological theory should be around, which investigates greetings, even if we do not know the theory. (That would be our fault.) With this idealized assumption, the question would be: Is each process in science an intended process for a special theory? We are inclined to a positive answer.

But we think this assumption is not adequate. We must use the notion of neighbourhood to get rid of the idealization. In this way, we can say, that we are interested in processes, which are only *similar to* an intended process. I.e., the non-idealized process itself is not an intended process *for the theory* under discussion. In this case, it becomes even more difficult to find scientific processes, which are not similar to any intended process in any theory in any degree. In this case we are inclined to say, that each process in science also is investigated in some discipline. Of course, we are talking about types of processes, not of concrete processes. We are open for further discussion. In the following, we use the term 'scientific process' for both variants of meaning (types and tokens).

A second question, which has often discussed concerns the distinction of *social* and *non-social* processes in science. What is, in another formulation, a non-social process in science?

In Figure 3 we distinguish processes in scientific processes from other processes, and we distinguish social and non-social processes.

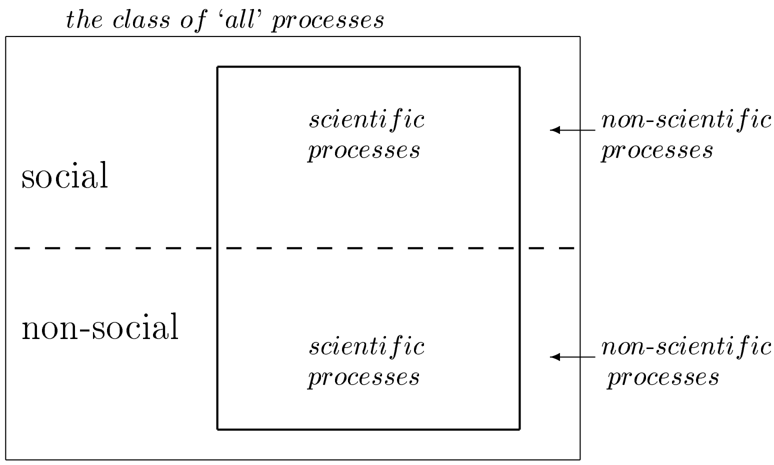

Fig.3. Distinctions of processes in two ways.

What is a social process? This notion and that of the respective actor (or agent) was investigated in different disciplines, such as, for instance, psychology, sociology, cognitive science, computer science, and philosophy. One of the simplest accounts of the term 'actor' is found in computer science (Genesereth and Ketchpel, 1994). A is an *actor*, iff A interacts with other actors and uses a required language. An actor is only able to act socially, if the actor has these two properties, and therefore takes part in social processes. Of course, there are many other properties, which are important for social processes, such as recognition, team formation, plan formation, team action.[12] But for a social, scientific process, it is central, that in such a process several actors are involved in that process and talk with each other.

A first answer to the question of the existence of non-social, scientific processes is, that there are no processes, that are at the same time scientific and non-social. In normal speech, this answer is not often found. In some disciplines, in sociology and in the humanities, there are groups, such as hermeneuticists, social-constructivists, and radical subjectivists holding, that all processes, which can be discussed and investigated, are social processes. In this 'usual' strategy of argumentation, processes are social, because persons talk about these processes, and because these persons communicate about these processes in a language (or in several languages). But language is a social affair. In this way, each process, which we can perceive is 'infected' by more basic, human and social actions.

The adverse party says, that there are real, non-social processes, which scientists can discuss. This implies, among other things, that there can be actors who have no language, and can nevertheless signify entities, that are natural and non-social. Or that there can be actors which 'live on an island'. We think, that the two parties might go on this way for a long time. We mention some, today recognized, protagonists: from the sociological side (Bloor, 1996), (Woolgar, 1981), and from the realist side (Giere, 1998) and (Searle, 1995).

We think it makes more sense to investigate the connection between social action and social process in the way employed by the theory of science. Take again the process, in which a file is printed. Whether this process has both scientific and social aspects depends strongly on the digitized content found in the file. If the printed item contains data recently generated by a lab, then it clearly relates to theories for which the lab is suited. If the data imply, that a new virus was generated, which is deadly to humans, the printing seems to have a social component. If the file is about a paper, which the author has just printed for the first time, than also theory is involved. If the printing is that of a fake, it has also social content. The printing of a thirty-year old document, found on the Internet by a lab worker for a researcher, is a process, which has links to sociological and psychological areas. If the facts in this text are found to be false, the document leeds to science research. This, too, can generate social processes. When a lab worker prints out a family picture, because the worker's home printer broke down, the process itself does not belong to science. But the printing has social components. The question, therefore, as to whether there are scientific processes without actors in which nevertheless something socially important happens, must be posed more clearly.

To clarify this point, we start from a real process p, and ask which theory or discipline would be the best theory (or discipline), to investigate this process in a scientific way. This question would be best answered by using the theory of science, even if this theme has not been investigated in much detail.

From our point of view, see Figure 4, several cases arise. If in this picture a black dot (apart from p_1 and p) is not an intended process for a theory,

[12] See, for instance, (Wooldridge and Jennings, 1999), (Wooldridge, 2009).

we must consider subcases. If, for instance, p_5 (left, above) is not found in a neighbourhood of an intended process, it is not scientific. If, for instance, p_7 lies in just one neighbourhood of an intended process, there is a unique theory which can describe and study this process (here: T_{i3}). If the process belongs to two neighbourhoods from two different theories, a decision is difficult, see for instance point p_4. On the one hand, not all neighbourhoods have grades, which can be expressed by numbers. If two neighbourhoods have grades, we can compare the grades, and we can say that the process is nearer to an intended process. In such cases, *that* theory is taken, which has an intended process which is the nearest one to the process under investigation. But in other cases, the question remains open.

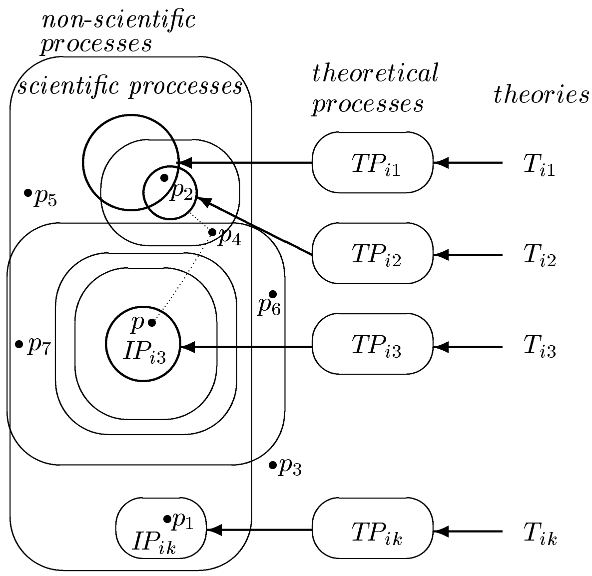

Fig.4. Processes, subsumed nearest to a theory.

In a second main case, there exists exactly one theory, such that the process is an intended process. In Figure 4 we see for instance a point p_1 of IP_{ik}. In this case the answer is clear. The process is best described by T_{ik}. We will not go into the normal theme of ambiguous descriptions. In a third main case, there are at least two theories for which the process is an intended process. Also in this case, there is no formal way to decide which theory is best. In the worst case, a process could be intended for two incommensurable theories. Even if we have no examples at the moment, one can appreciate the problems, see point p_2.

In the structuralist framework, each theory has an approximation apparatus. In general, this apparatus contains a system U of *blurs* (or neighbourhoods) and a set E of *admissible blurs.* A blur is a set of potential models, and the same holds for the admissible blurs.[13] In Figure 4, we see the blurs of the set IP_{i3} of intended processes of theory T_{i3}. One blur of the set IP_{i3} is one oval, which contains the 'base' IP_{i3}. In most theories, this apparatus is used in a more special form. One point (for example p_4) from a blur of the base IP_{i3} has also a well determined distance to a given point (for instance) p from IP_{i3}. There are many different ways of defining distances. This depends on the special theory we are looking at (Balzer and Zoubek, 1994). This apparatus can be transferred to generalized partial models, partial states, and generalized partial states, as introduced in Sect.3.

As an example, we can take a process from a sociological network theory from (Burt, 1982), reconstructed in (González-Ruiz, 1998). A network is given by several functions. One of these functions describes the *prestige* at time T of an action typ AT, and of the respective actor A, i.e. the $prestige(T, AT, A)$ is expressed by a real number: $prestige(T, AT, A) = \alpha, \alpha \in \mathbf{IR}$, $0 \leq \alpha \leq 1$. For two points of time we can describe a pair $process1 = \langle (T_b, AT, A, prestige(T_b, AT, A)), (T_e, AT, A, prestige(T_e, AT, A)) \rangle$ of prestige values, which forms a process of a change of prestige. We can then formulate distances between processes, such as $process1$ and $process2$ just by comparing the respective vectors: $\mid process1 - process2 \mid$ in the normal way.[14] Another function g, the *graph function*, assigns each point of time T, and each action type AT a matrix $\mathbf{M} = (r_{ij})_{i,j}$, whose elements r_{ij} express that actor A_i and actor A_j are related by the action type AT, or are not related. An element r_{ij} is just a number 0 or 1. If r_{ij} is 0, the actors A_i and A_j do not maintain a relation of the action type AT, otherwise, they are related ($r_{ij} = 1$). g describes empirical data. It is often not possible to determine all relations for all actors. In these cases, some matrix elements are just absent. Nevertheless, it is possible to compare matrices, which are only partially determined. A consistent set of data can be formed into a generalized partial model of the theory, and using a special state signature we can compare and calculate distances between processes (in this case: matrices).

The presence of the different cases described in Figure 4 leads to the question of whether we can order theories in a partial way. Such an ordering can be seen in two complementary ways. A discipline D is, metaphorically speaking, *deeper* than another discipline D' iff D is located below D', and in the same way D' is located above D. Physics, for instance, goes deeper than economics. Classical mechanics is deeper than the pure exchange economy. These formulations can be understood either metaphorically or as ontological statements. But we can formulate these relations also in the way of the theory of science, if we use the following notions.

We suppose, that two empirical theories and an embedding relation are given. We say, that a theory T is embedded in another theory T'. This notion was introduced by (Ludwig, 1991). Informally, a chemical theory is embedded in a physical theory; a biological theory in a chemical theory, and so forth. It is deplorable that this relation is not discussed in depth. But it is also clear

[13](Balzer et al., 1987), Chap. VII.
[14](Balzer and Zoubek, 1994).

that this relation makes, ontologically seen, good sense. In the structuralistic literature we find examples, in which one theory simply is a basic part of 'the next'. This theme goes from geometry via physical theories to chemical, then to biological and in the end also to sociological theories. What is missing are studies of comparisons of theories, which 'live' in different disiplinces. But even a layperson can see, that chemical relations have something to do with aspects of space, and so forth.

It is clear, that we live here in the 'thin air' of hypotheses. But it is also clear, that there are studies, in which theories from the same discipline are compared. For instance, particle mechanics and collision mechanics and their intended applications were studied intensively. The interesting point for us is, that there are implicit or explicit aspects or dimensions of the intended processes and applications of theories, which lead to other empirical theories. In a first step, we depict in Figure 5 two theories and their intended processes, where some intended processes are for both theories the same. One common process is depicted by a diamond: $\diamond$.

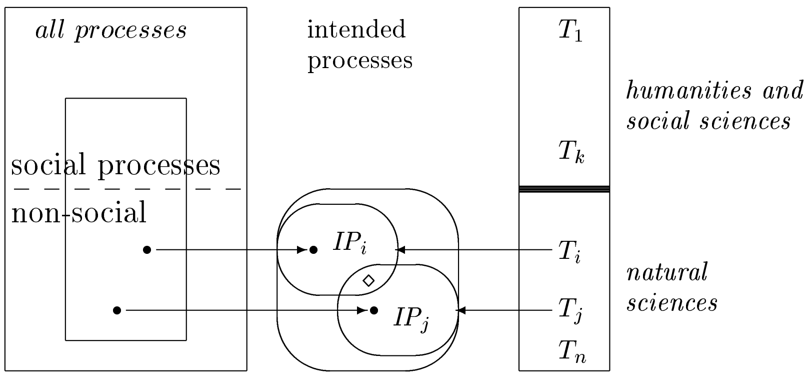

Fig.5. A non-social process, intended from two theories.

At the right side, we see the 'great divide' between the natural sciences and the others. The 'fight of cultures' between these disciplines seems to decrease at the moment. One aspect seems to be, that computer science has entered into the social sciences (see, for instance, the *Journal of Artificial Societies and Social Simulation*) and even into the humanities. Robots and the simulated groups of actors are becoming more similar with each step to humans and groups of humans.

We can now come to our last question, namely, whether it is possible, that a non-social, scientific process can be a part of a scientific process in a social science. This formulation sounds strange. How can a non-social process also be social? In this coarse formulation, there are two assumptions, which are of course false. First, we do not claim, that the process itself is social. We only say, that the process is investigated by a social theory. Second, a non-social process 'is' not identical with an intended process, which is studied by a social theory. The non-social process is 'only' a part of a more complex process, which is studied in the social sciences. We represent our answers in a more realistic way in Figure 6 (below).

On the left, a special, non-social, scientific process is drawn as a point, and in the middle of the figure, the same process is represented in a more detailed way. The process was 'opened', in the same way in which we open a file. The process depicted by the point is opened by the relation $\ll$. From this point, a complex system x_k is opened. x_k could contain, for instance, an intended process of IP_k of a physical theory T_k. We depict a quadrangle ('a plane') and a circular movement, which takes place in this plane. One process would be the change of the position of a particle, depicted by the symbol for 'arrow'. By the complementary relation $\gg$, the system x_k is closed again and becomes a point, an element of the set IP_k. In another possibility, the process is depicted by a set-theoretical substructure of a bigger, and more complex, process, which is an element of a set of intended processes of another social theory T_i. The embedding is represented by the generalized subset relation: $x_k \sqsubseteq x_i$.

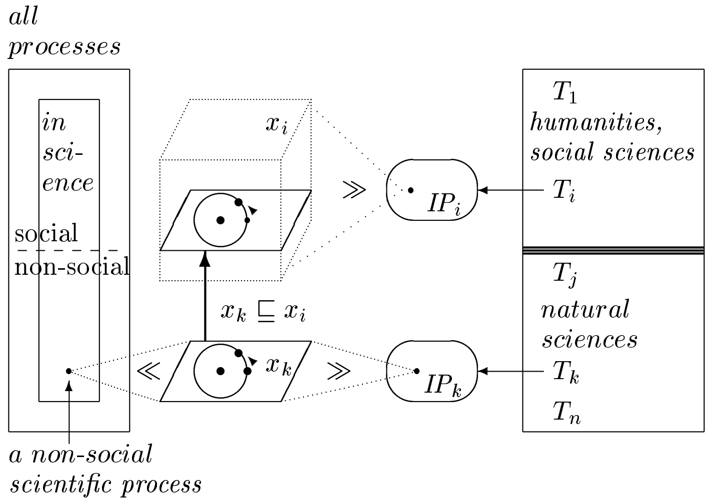

Fig.6. A non-social process investigated in natural science and embedded in a social, scientific process.

We depict this situation here in a way, which is also used in dimensional analysis. But, as discussed, this picture is only a vehicle for human understanding. A multi-dimensional representation can sometimes go astray.

Conlusion

We analysed and clarified the notions of a scientific process and of a social process with the help of the structuralistic framework. We were able to embed these notions in this general model of science. We could describe relations between scientific and social processes in a rather precise way. We were able to express clearly the way in which a scientific process which has no social component can be nevertheless used in a social theory, and therefore can be a part of a social model.

In the beginning, we posed three questions, which we then answered in a (notational somewhat cumbersome) structuralist way. After translation, we can answer our questions in simpler formulations as follows. A scientific process is a process, which is investigated in some theory, which has some standing in science. A social process contains human actors, which interact and talk with each other, and it must be investigated by a theory of social science. A non-social process is a process, in which there are no humans acting or else it is a process, which is not analysed by a theory of social science.

We hope, that our main questions and their answers can help to make the cleavage between social sciences, the humanities, and the natural sciences a bit smaller.

Appendix

x is a *potential model of collision mechanics* ($x \in M_p(\mathbf{CCM})$) iff x has the form $\langle P, T, \mathbb{R}, v, m\rangle$, and 1) P is a set (of particles), 2) T is a set (of points of time), 3) $\mathbb{R}$ is the set of real numbers, 4) $v : P \times T \to \mathbb{R}^3$ is a function (the velocity function) and 5) $m : P \to \mathbb{R}$ is a function (the mass function).

Omitting formal details, we define three ECSs τ_1, τ_2, τ_3 for the base sets and auxiliary sets for **CCM** as follows. $\tau_1(P, T, \mathbb{R}) = P$, $\tau_2(P, T, \mathbb{R}) = T$, and $\tau_3(P, T, \mathbb{R}) = \mathbb{R}$. We define two ECSs for the base relations for **CCM** as follows. $v \in \tau_4(P, T, \mathbb{R}) = \wp(P \times T \times \mathbb{R}^3)$ and $m \in \tau_5(P, T, \mathbb{R}) = \wp(P \times T \times \mathbb{R})$.

The formal expression $\langle p, t, \alpha_1, \alpha_2, \alpha_3\rangle \in v$ says that $\langle \alpha_1, \alpha_2, \alpha_3\rangle$ is the function value of v: $v(p, t) = \langle \alpha_1, \alpha_2, \alpha_3\rangle$, and $\langle p, \alpha\rangle \in m$ says: $m(p) = \alpha$.

D1 Let $x = \langle D_1, ..., D_m, R_1, ..., R_n\rangle \in M_p$ be a potential model of T typified by the list $\langle \tau_1, ..., \tau_m, \tau_{m+1}, ..., \tau_{m+n}\rangle$ of basic ECSs.

a) y is a *structure of states in x typified by* a state signature $\langle \tau'_1, ..., \tau'_t, \tau'_{t+1}, ..., \tau'_{t+u}\rangle$ iff there exist $D'_1, ..., D'_t, R'_1, ..., R'_u$, there exist an injective function $\xi : \{1, ..., t\} \to \{1, ..., m\}$ and there exist an injective function $\zeta : \{1, ..., u\} \to \{1, ..., n\}$ such that the following holds:
1) $\forall i \leq t \exists a_i (a_i \in D_{\xi(i)} \wedge D'_i = \{a_i\})$
2) $\forall j \leq u \exists r_j (r_j \in R_{\zeta(j)} \wedge R'_j = \{r_j\})$
3) $\forall j \leq u (r_j \in \tau'_j(D'_1, ..., D'_t))$
4) $y = \langle D'_1, ..., D'_t, R'_1, ..., R'_u\rangle$.

b) s is a *state in x typified by* state signature $\sigma = \langle \tau'_1, ..., \tau'_t, \tau'_{t+1}, ..., \tau'_{t+u}\rangle$ iff there exists a structure y of states in x typified by σ such that y has the form $\langle U_1, ..., U_{t+u}\rangle$, and for all $j \leq u$ exists r_j such that
1) $U_{t+j} = \{r_j\}$, and
2) $s = \langle r_1, ..., r_u\rangle$.

c) $S(x,\sigma)$ is the *class* of states (or the *state space*) in x typified by σ.
d) $S(T)$ is the *class of all possible* states in T.

D2-a) *KP* is a *kind of process* iff there exist S, S_b, S_e and *caus* such that the following conditions hold:
1) $KP = \langle S, S_b, S_e, caus \rangle$
2) S is a non-empty set, (a set of states)
3) $\emptyset \neq S_b \subseteq S$ and $\emptyset \neq S_e \subseteq S$,
(sets of 'beginning-' and 'end-states' of processes)
4) $caus \subseteq S \times S$, ($caus(s,s')$ means: s is a direct cause of s')
5) $\forall s, s'(\ caus(s,s') \rightarrow s \in S_b \wedge s' \in S_e)$
6) for all s, s', s_o, if s, s', s_o are pairwise different, then
$caus(s,s') \rightarrow \neg(caus(s,s_o) \wedge caus(s_o,s'))$
7) $\forall s, s'(\ (s \neq s' \wedge caus(s,s')) \rightarrow \neg caus(s',s))$.

b) p is a *process of kind* $\langle S, S_b, S_e, caus \rangle$ iff
1) $\langle S, S_b, S_e, caus \rangle$ is a kind of process
2) there exist s_b, s_e such that
2.1) $s_b \in S_b$ and $s_e \in S_e$
2.2) $\langle s_b, s_e \rangle \in caus$
2.3) $p = \langle s_b, s_e \rangle$.

D3 Let $T = \langle \langle M_p, M, M_{pp}, L, ... \rangle, A, I \rangle$ be a theory, x a model of M and $\sigma = \langle \tau^1, ..., \tau^r \rangle$ a state signature in T.

a) p is a *theoretical process in x typified by σ* iff there are sets S_b, S_e, *caus* and $S(x,\sigma)$ and the following holds
1) $S(x,\sigma)$ is a state space for x typified by σ
2) $\langle S(x,\sigma), S_b, S_e, caus \rangle$ is a kind of process
3) p is a process of kind $\langle S(x,\sigma), S_b, S_e, caus \rangle$.

b) $PC(T)$ is the *class of theoretical processes in T* iff
$PC(T) = \{p / \exists x \in M \exists \sigma \in E(T)^*(p \text{ is a theoretical process in } x$ typified by $\sigma)\}$.

D4 Let T be a theory, $x = \langle D_1, ..., D_m, R_1, ..., R_n \rangle \in M_p$ and let $\langle \tau_1, ..., \tau_{m+n} \rangle$ be the list of basic ECSs for T.

a) x' is a *generalized substructure of* x, $x' \sqsubseteq x$, iff there are $D'_1, ..., D'_m$, $R'_1, ..., R'_n$ such that
1) $x' = \langle D'_1, ..., D'_m, R'_1, ..., R'_n \rangle$
2) $\forall i \leq m(D'_i \subseteq D_i)$
3) $\forall j \leq n(R'_j \subseteq R_j \wedge R'_j \in \tau_j(D'_1, ..., D'_m))$.

b) z is a *generalized partial model* iff there exist $y \in M_{pp}$ such that $z \sqsubseteq y$. The class of generalized partial models is denoted by M_{pp}^{gen}.

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