Practices, Systems, and Context Working as Core Concepts in Modeling Socio-Technical Systems

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Abstract. This work draws on the cultural historical activity-theory and the theory of social systems to model socio-technical systems. The concepts of practice, system, and context work as core concepts to represent processes and activities such as learning and working. Current modeling approaches in the field of learning and work resemble the notion of workflows, relating input and output in a means-end-manner and prescribing the processes, and hence fall short in describing the situated and socially mediated nature of practices. Against this background the paper presents and describes an alternative modeling approach as well as its theoretical foundation and practical implications. It is characterized by (1) going beyond de-contextualized actions, objects, and resources and by (2) going beyond the decomposition of activities as it does not equate the sequence of actions with the respective activity.

Keywords: Knowledge representation, activity theory, social systems, socio-technical systems.

1 Introduction

The formal description of socio-technical systems as well as processes such as learning and work has attracted a lot of attention among researchers and developers in recent years and has resulted in a couple of specifications focusing on individual as well as collaborative processes of learning and working. The explicit and formal representation of such processes is relevant for quite diverse reasons. Besides their technical and economic relevance they also provide an important communicative tool for designers as they allow to share experiences and to coordinate activities among those involved in the design and development process. Furthermore, they are of interest for scientists as they provide a frame of reference for the analysis and comparison of different scenarios. While current modeling languages overcome the problem of de-contextualized objects by describing the use of these objects within a process, they resemble traditional workflow models and hence reproduce the problem of contextualization on a higher level, as the process is again de-contextualized. Even though these approaches acknowledge the complex nature of situated processes they are reductive in the sense that they equal the processes and activities with the sum of the actions entailed. Thereby the situated and socially mediated character of human

action is neglected. Against this background this paper outlines an alternative modeling approach which draws on activity-theoretical as well as systemic theories to depict practices. The formal concept of roles is used to represent the systemic nature of activity and its situatedness adequately.

The paper is structured as follows: An overview on conceptualizing practices and systems is given and key assumptions of the cultural-historical activity theory as well as the theory of social systems are introduced in section 2 to outline the underlying rationale of the modeling approach. In section 3 the consequences for modeling practices are shown. Referring to the theoretical foundation the modeling approach is developed step by step in section 4. Finally the practical implications of the modeling approach are shown.

2 Practices, Social Systems and Context

The concept of practice can be defined as "the ways of doing work, grounded in tradition and shared by a group of workers" [3]. In general it has to be distinguished between practices as implemented by a specific group of people (e.g. the way a particular lecture is given at a particular university) and practices as prototypical conceptualizations of a certain activity within a broader community (e.g. a pattern of an activity such as "the way lectures are given usually"). While the concept of practice can basically be defined as a customary *way of doing* things, it seems worthwhile to have a closer look at this concept and at the concept of systems and context from a theoretical point of view. Theories this work is founded in are the activity theory and a variant of the theory of social systems. First we give an understanding of the concept of practice. Then we provide a list of key-assumption on human-activity and social systems as well as the relation of systems to their context.

2.1 The Concept of Practice

This section provides a tentative introduction to the concept of practice and provides reference to respective work in the fields of Human-Computer Interaction and Information Systems. The aim of this section is to ground the modeling approach theoretically as we state that a modeling approach is never neutral with regard to its underlying assumptions.

At the core of the modeling approach is the idea of co-evolution which holds that tools, practices, artifacts, and agents do not exist in isolation, but are strongly interdependent and evolve in a process of reciprocal transformation (cp. the cultural-historical activity theory, e.g. Leont'ev, 1978, [6]. In contrast to a particular activity a practice represents a recurrent pattern which can be filled out by various activities actualizing the practice, or to put it differently, a practice denotes the prototypical characteristics of a set of activities including forms of bodily and mental activity, tools and their usage, as well as certain forms of knowledge, cp. [16]. In more detail practices can be characterized as follows:

- Practices are socially mediated, i.e. they are shaped by and evolve within social communities and can even become part of the communities' identity, cp. [5]. Being

bound to particular social entities also entails that a given practice broadly accepted by one community might be completely rejected by another. Furthermore, even though practices are social in nature they do not necessarily refer to collaborative activities. For example practices such as reading a book and Nordic walking are socially mediated but don't require social interaction.

- Practices entail both a momentum of stability as well as change. While practices manifest and reproduce historically developed patterns of activity they are also open for change in that the concrete activities have continuously to be adapted to new situations and changing conditions. Consequently practices are both affirmed and modified whenever a respective activity is carried out, cp. [5].
- Practices change as a result of external and internal disturbances within and among the activities constituting the practice. While changes in practice are often attributed to external factors, such a changing resources or newly available tool, they can also be due to creative and innovative initiatives coming from within (e.g. initiatives by actors in the community), such as the introduction of a newly available tool, or the proposal for a new way of working, e.g. [2], [19].
- Even though practices are often characterized by the use of particular artifacts (e.g. giving a power-point presentation), practices are not determined by these artifacts in a strict sense. This difference is due to the fact that an artifact becomes a tool only when interpreted as such within in a social and historical context, cp. [7]. Hence, while an artifact might be more or less appropriate to carry out an activity, it is the practice that defines its actual usage. In this sense activity is not determined by computer artifacts, but "it unfolds in the space of opportunities open to technology users" [7].
- Furthermore practices do not exist in isolation but are part of a larger network of practices. Practices are interrelated as both individual and collective actors as well as artifacts are usually enrolled and used in several practices simultaneously. Therefore changes in one practice might also trigger or inhibit changes in other practices.

Given this notion of practices, in the next sections key assumptions of the underlying activity theory are presented and complemented by key assumptions of the theory of social systems. Beyond complementing key assumptions of activity theory regarding the concept of practice, the theory of social systems focuses on the concept of systems and their context (the difference system/context).

2.2 Key Assumptions of Activity Theory

Activity theory is a powerful philosophical framework and descriptive tool focusing on understanding human activity and work practices. It is based upon the anthropological and psychological theory of A. N. Leontjew (1978) and L. S. Vygotsky (1978). Here we summarize key assumptions the model presented later is based on, abstracting from what is said about the concept of practices before.

1. Human activity is object-oriented, i.e. it is directed towards a physical or conceptual object that is transformed or manipulated by the activity. It is the object and not the goal that allows distinguishing different activities from one another.

Objects can be such diverse things as the tree to be cut, the software code to be written, a common understanding between stakeholders regarding a certain issue, or a theoretical claim to be discussed within a community. What is important here is that from an activity theoretical perspective *artifacts* are not *objects of activities* by themselves, but that they can become an object of activity when they are targeted and transformed in the course of an activity. The difference between an artifact in the sense of a real entity and the object of an activity is crucial as one and the same artifact can be used for a multitude of different purposes in different activities, while the object of activity is unique for every activity. For example one and the same chest of drawers might be the object of the carpenters creation as well as the object of the restorers attempt to restore it a couple of years later. From a systemic perspective (see section 2.3) the artifact is not part of the activity system but belongs to its context, whereas the object is part of the system.

2. Activities are mediated by *tools* and *signs*, which are constitutive elements of the activity. Tools and signs are mediators which range from physical tools over less tangible artifacts like plans and spreadsheets to scientific theories and languages. Tools capture and preserve the socially shared knowledge developed in a given community and mediate the subjects' relation with the object of the activity as well as with other human beings, cp. [13], [20]. Again it is important to note that the artifacts used in an activity are not tools or signs in their own right, but that they become tools and signs when they are used as such. Even though certain types of artifacts are often associated with a particular function within an activity-system they are not a constitutive element of the activity-system itself, even though their properties shape the system. For example, while the use of electronic media such as CD-ROM instead of printed text has an impact on the respective activity system, e.g. the dissemination of lecture notes, the replacement of printed test by CD-ROM does not result in an entirely new activity-system but alters the existing system. Furthermore an activity can usually also be carried out in the absence of a particular artifact, as long as its function can also be fulfilled by other artifacts. Practices are the *way of doing* activities, viable within an activity system.
3. Activities are shaped by contextual conditions and circumstances. As a consequence human activity is guided but not predefined and determined by the plans of those engaged in the activity [1]. The variability of contextual conditions and circumstances inevitably results in a variation of the way the activity is carried out and can result in the evolution of the activity system if improper variations are selected and proper variations stabilized, cp. [17]. For example, a lecturer has not managed to prepare a scriptum for his/her lecture beforehand (contextual conditions). In order to compensate the lacking scriptum he decides to ask the students to create wiki-entries covering the main topics addressed in the lecture (variation). In case this variation is viable within the activity system, works out well, and is reproduced (selection) it might result in a transformation of the practice within the activity system (stabilization).
4. The relationship between subject, object, and tool is reciprocal. These elements are mutually interdependent, which means that a change in one of them will inevitably alter the other ones. In this sense the constituents of an activity form a system where each component is defined in relation to the other components. Again it is important to note that the dependency between subject, object, and tool refers to

their role within the activity system and not to the artifacts and actors that fill these roles. For example, while the role of the teacher can only be defined in relation to the tools he/she uses and the objects of the educational activity, the person who teaches and the artifacts can be defined without reference to the activity (Here it is important to note, that the teacher only causes the variation and not the transformation of the practice per se).

5. Activities are hierarchically structured. According to [13] three levels of an activity can be distinguished, namely collective activities which are carried out on a communal level often involving multiple actors, actions that are performed by a single subject to achieve a certain goal relevant to the collective activity, and operations in the form of fine grained automated routines. But even though activities are structured hierarchically [13] notes that the relation between operations and actions as well as actions and activities is not an additive one. Therefore it is not possible to simply decompose an activity into a set of actions. The difference between a set of actions and an activity is not a quantitative but a qualitative one. For example, the activity of driving to a rented summer cottage for vacation is something qualitatively different from the sum of the actions necessary to do so such as to refuel the tank, driving on the motorway, and navigating in an unfamiliar environment. The relation between operations, actions, and activities, as proposed by [13], can also be understood as the relation between different levels of emergence (see section 2.3), whereby the specific properties of the higher level systems are emergent and cannot be reduced to system properties on lower levels.
6. Practices are never static but evolve when contradictions or tensions emerge between the elements in an activity system. Due to the systemic nature of activities changes in one element or the relation between elements usually affect the entire system. Again, evolution requires variation, selection, and stabilization. Due to their dynamic nature practices are historical entities in the sense that they change and develop in time. As a consequence the analysis of practices also requires at least an assumption about their history.

2.3 Key Assumptions of the Theory of Social Systems

The Theory of Social Systems is a descriptive framework presenting a system-centered (systemic) view and is a non-deterministic and non-prescriptive meta-theory. It is a variant of General System Theory (e.g. Parsons, 1951, a functionalist in sociology). “In ’The Social System’ 1951, Parsons argued that the crucial feature of societies, as of biological organisms, is homeostasis (maintaining a stable state), and that their parts can be understood only in terms of the whole”. [24] characterizes this theory as universal regarding domains and disciplines. Many disciplines are confronted with similar problems, e.g. the problem of increasing complexity, which can not be reduced to simple categories and principles. A comprehensive introduction into the Theory of Social Systems is given by [24] and [11], the foundational work is Social Systems by [12]. Here only few key assumptions are presented.

1. Personal systems as well as social systems are meaning processing systems. Systems process information by constructing meaning. A social system is not equivalent with the group of people in the system, but it is of different quality.

Personal systems and social systems process environmental complexity by reducing complexity. Systems reduce environmental complexity as the environment is processed selectively. Systems organize their inner complexity and reduce contextual (environmental) complexity. Thus, inner and outer complexity is different. Systems are closed and self-regulated. Meaning is processed according to the actual state and current structure of the system and is defined by the system itself. Processes are inherently in-determined from an observer's point of view, cp. 24. Within a system, elements generate each other, e.g. in listening, the audience creates the speaker and vice versa.

2. An entity, such as a person (personal system) does not belong to a social system but to its environment [12]. This means, a person (and any other entity/type) does not belong to a system for all intents and purposes but in some respect, filling a specific role. "In systemtheoretischer Perspektive gehören die Mitglieder eines sozialen Systems als Personen zur Umwelt dieses Systems (...); denn sie gehören nie 'mit Haut und Haaren', sondern nur in bestimmten Hinsichten, mit bestimmten Rollen, Motiven und Aufmerksamkeiten dem System zu" [24], p. 39. For example: The person Peter and the person John belong to the environment of the system family. Only Peter filling the role son and John filling the role father, belong to the system. The legal system also belongs to the environment of the system family. The person John belongs to the environment of the legal system. Only for some intents and purposes John e.g. filling the role of the accused, belongs to the legal system. This issue is crucial, as one system can not determine another, e.g. a personal system can not determine a social system.
3. The difference system/environment (not the object or type) is the central paradigm. The Theory of Social Systems is a descriptive framework which describes the world in terms of systems, drawing a difference between a system and its environment. Whereas in object-oriented modeling objects and categories are defined ("there are objects"), the Theory of Social Systems states that the difference system/environment is constructed ("there is the difference system/environment"). "The central paradigm of recent system theory is 'system and environment'. The concepts of function and functional analysis no longer refer to 'the system' (...) but to the relationship between system and environment." [12], p.176. Luhmann stresses that the concept of the environment is not just a residual category, but that the relationship to the environment is constitutive in system formation. A system constitutes itself by defining the difference system/environment and by forming its boundary. Its identity is possible only by difference. The consequence of this theoretical foundation is the point of reference, which is difference rather than identity, "This leads to a radical de-ontologizing of objects as such (...). This interpretation contains no unambiguous localization of any sort of 'items' within the world and of any classifying relations between them. Everything that happens belongs to a system (or to many systems) and always at the same time to the environment of other systems." [12], p. 177. The difference system/environment is not ontological but an epistemological – it is continuously constructed by the observer, based on his actual motive.
4. Human activity whether carried out by an individual or collectively cannot be detached from its social context as its meaning is bound to its interpretation within a collective. From a systemic point of view the activity system does not exist in

isolation but always in relation to other systems. Following [24] a social system can be demarcated against (a) other (sub-)systems of an overarching system (horizontal relations), (b) the overarching system (vertical relations), and (c) (sub-)systems outside the respective overarching system (lateral relations). For example the practice of teaching is related to the practice of assessment (horizontal relation), both being part of a more comprehensive activity system formed by the organization in which both teaching and assessment take place (vertical relation). Beyond this, the practice of teaching is also related to practices outside the organization (lateral relation), such as the practices of teaching and learning the students encounters before or in parallel to their enrolment in organization at hand.

Thoroughly contrasting and complementing the key assumptions of both theories is done in some further work. Here we state, that the concept of practice and the concept of social systems hold common and complementing assumptions which the modeling approach is based on.

3 Consequences for Modeling Practices

This section relates the above mentioned to the field of learning and working in order to point out specific consequences and discusses several concrete problems when modeling processes.

3.1 Decomposition of activities

The problem of decomposition of activities directly relates to the relationship between activities and actions. The question is whether an activity can be broken down into a set of interrelated actions without a loss of information. Common modeling languages such as the Unified Modeling Language [15], the Business Process Modeling Notation [14] and IMS Learning Design [10] are build on the assumption that such a decomposition is possible and hence equate the sequence of actions with the respective activity. Nevertheless this is problematic not only from a theoretical but also form a practical point of view. Given that the assumption would be true it would follow that the sequence of actions including the actors, artifacts and tools would suffice to describe an activity. Consequently it would be possible to compare two activities by comparing the actions entailed. For example the IMS-LD Best Practice Guide [10] describes a problem based learning scenario as an arrangement of 17 actions, implying that differences between pedagogical scenarios are due to the organization of actions entailed. From this point of view it would not make a difference whether the students solve a well- or ill-structured problem, whether it is a theoretical or practical problem, etc. Crucial differences cannot be modeled adequately and therefore result in misleading or even wrong comparisons across pedagogical scenarios in particular and practices in general. The meta-model introduced here can handle these differences as it models activities as entities which cannot be decomposed.

3.2 Equivalence of actions and its components

Another problem relates to the comparability of actions and its components, i.e. the question whether two actions are equivalent or not. From the practical point of view this question is of interest with regard to the modification of a pedagogical design or the implementation of a given design in another context. Both modification and re-implementation require knowing the constituting elements of the original solution in order to modify or transfer them intentionally. Modeling languages that do not distinguish between role- and type-based attributes of the objects involved run into trouble when it comes to the equivalence of actions and its components. The problem is that they either generalize to natural-classes or that they mix up role- and type-based attributes. In both cases the misleading conclusions might be implied. For example in a given pedagogical design the students are administered a multiple-choice test in order to assess their understanding of the topics addressed in the course. The aim of the multiple-choice test in this case is to provide a formative feedback whether the students understood the core concepts or if remedial activities are required. When modifying or adapting the pedagogical design it might become relevant to replace the multiple-choice test by another instrument and hence to know what is equivalent to this test regarding its purpose and role within the scenario. In case one generalizes to the natural-class the static attributes of the test, namely that it is a multiple-choice test focused on domain specific topics comes to the fore while its particular purpose is dropped. Consequently the test might be replaced by another test which is not designed to provide formative (not having the quality of providing formative feedback) but summative information on students' performance. It remains unclear which attributes of the test are relevant and which not and hence might lead to the false conclusion that it is important to use a multiple-choice test while in fact any other instrument filling the role (purpose) of providing formative feedback on students understanding would be suitable.

3.3 Coupling of actions

The last problem to be discussed here relates to the modeling of interrelations between actions. Following the idea of hierarchical decomposition most of the current modeling languages treat activities and actions as self-contained entities related to other activities and actions via respective pre- and post-conditions. Consequently activities and actions are either organized sequentially or in parallel, while in the later case no direct dependency exists between the actions while being carried out. While this approach allows to depict the overall flow of actions and activities it ignores the fact that actions or activities are often coupled via the persons involved and the artifacts used. For example a brainstorming session might be decomposed into the following set of actions: the problem owner specifying the problem, the moderator chairing the session, and the team brainstorming ideas. While the resulting model might be sound in general a concrete instantiation might fail when the roles of the problem owner and the moderator are filled by the same person. In other cases two actions might have to be coupled in order to work correctly. Even though giving a lecture and listening to the lecturer can be decomposed into two distinct actions the

coupling of these actions is essential for the overall outcome, as they generate each other. Hence, the mutual dependency of synchronous actions or activities is of vital importance for understanding the mode of operation. While these dependencies cannot be described adequately when action and activities are treated as self-contained entities, the meta-model introduced here overcomes this problem by allowing a person or artifact to fill different roles in the context of different actions and hence to couple them explicitly.

4 The Modeling Approach

This section outlines a modeling approach for modeling socio-technical systems. The approach draws on the concept of practice and refers to activity systems as coherent social systems. The approach proposed here is based on some principles and design decisions which are briefly explained below.

4.1 Principles

The systemic character of activity systems: In contrast to workflow models, which work as means-end-models and emphasize the sequential organization of actions and activities towards a given outcome, activity theory stresses the systemic nature of activity systems. As a consequence the framework introduces a system-centered (systemic) perspective to model a system of elements which generate each other mutually. Changing one element within the system also effects all the others. **Role-based modeling**: In addition, a role-based approach for modeling activities is chosen, in order to account for the context-dependency of the roles filled by persons and objects within a particular activity. In contrast to other approaches the formal concept of roles is not only applied to persons but also to objects both physical as well as conceptual. Distinguishing the formal concepts `natural type` from `role type` allows to distinguish between an object and its role within a specific context, cp. [21], [9]. **Modeling an action by relating object, subject, and tool**. To overcome shortcomings of prescriptive workflow models which work as means-end-models, this work models `action` as an n-ary relation. Furthermore, `action` and `activity` are modeled on different levels of emergence. Thus the modeling approach addresses several key assumptions of activity-theory and the theory of social systems: (1) processes are contextualized, (2) activities can not be de-composed to several actions without loss of information - the relation between operations and actions as well as actions and activities is not an additive one, (3) the elements of a system generate each other, (4) activity systems can not be reduced to a chain of actions - it is not possible to simply decompose activities into a set of actions, (5) social systems are meaning processing systems - the difference between a social system and a group of persons is not a quantitative but a qualitative one. A final example might illustrate this: Taking into account Leontjew's [13] concept of activities, actions and operations, one and the same action is capable to be a component of different activities. An activity can not be decomposed to the actions it contains without

loosing information. The action of reading is different depending on the activity the subject carries out (reading a problem statement in a setting of knowledge creating, or reading out loud in a setting of instructional design, e.g.).

4.2 Meta-Level Categories Natural Type and Role Type

In the context of knowledge representation, meta-level categories are categories used to model the world, such as `concept`, `property`, `state`, `role`, `attribute`, and `relation`. Within this work, distinguishing the meta-level category `natural type` from `role type` [9] is crucial.

Types, classes and relations are fundamental concepts in object-oriented modeling. "A type is a specification for a set or collection of entities that exist or may exist in some domain of discourse." [18], p. 98. The question of *What are the types in a domain*? is the question of *What exists in the domain?* A type is an abstract specification, not a set of concrete things. Categories and types are fundamental in designing databases, knowledge bases, and object-oriented systems. "A choice of ontological categories is the first step in designing a database, a knowledge base, or an object-oriented system. In database theory the categories are usually called domains, in AI they are called types, in object-oriented systems they are called classes, and in logic they are called types or sorts." [18], p. 51. Classes can be thought of as a set of elements. Individual objects that belong to a class are referred to as an instance of that class (Antoniou & van Harmelen, 2004). Up to this, the category `type` has been defined. What is a `natural type`, then? [8] provides an ontological distinction, separating role types from natural types. This distinction is based on the meta-properties `identity` and `rigidity`. [22] states that the definition of natural types matches the class construct of object-oriented modeling, as the definition of classes is outside the context of any relationships, and the instances keep their types for their lifetimes (identity). A type is a natural type if "belonging to the type is independent of being engaged in a relationship (except for, perhaps, a whole-part relation) and if an object cannot leave the extension of the type without loosing its identity." [22].

[8], [9] distinguish the meta-level category natural type from the meta-level category roles type. [21] integrates the category role type into object-oriented modeling and states this category is as fundamental in object-oriented modeling as the category of natural types and relations. He states that due to the fact that usually no difference is made between the concepts of natural types and role types, the concept of role types is relatively unknown. The concept of types normally represents both: natural types and role types. Due to a synopsis prepared by [21] the concept of role types does not play a role in most formal languages, including the logics, while it plays a major role in linguistics, cp. [4]. In linguistics there is a common theory of formal languages, integrating the role type as fundamental concept complementing the concepts of predicates and objects. Actually, the difference between role types and natural types is in its contents. Syntax allows to work without distinguishing the concepts, but semantically many problems arise from not drawing the difference between the concepts [21]. The concept of role types is founded in semantics, linguistics, ontology, and formal languages. Husserl introduces the quality of

Fundierung (en: foundation), [8] (in the context of knowledge representation) specifies semantical and ontological rigidity [21]. A concept is founded if none of its instances can exist alone: Each instance is related to another instance. A concept is semantically or ontologically rigid if an instance can not join and leave the extension of the concept without loosing its identity. “If x has the property of being an apple, it cannot lose this property without losing its identity (…).” [9]. [8] founds the concept of `role type` as an ontological concept and gives a formal definition assigning two conditions *(founded* and *not semantically rigid)*. `Natural types` are those concepts which are *semantically rigid* and *not founded*. According to [9] the meta-property rigidity means: “A property P is rigid if, for each x, if P(x) is true in one possible world, then it is also true in all possible worlds. Person and location are rigid, while student and tall are not.” Summarizing [21] a role type specifies the behavior within a context - a behavior is a contract or relationship between two entities. A role type implies a specific relationship between instances filling the role (but a role type is not to be used in a part-whole-relation). Role types require the instance to have an identity apart from its role type. Natural types grant an instance its identity. A natural type cannot leave its type without losing its identity. The concept of role types allows describing the function an object fills within a specific context. [21] states that the standardization of the term role (role type) in modeling complements the meta-level categories type and relation. Instances of types can play roles, correctly speaking: *Types fill roles*. The classical dichotomy type/relation is extended to the trilogy type/role/relation. [21] works out practical implications for its integration in object-oriented modeling and its representation in the modeling language UML (Unified Modeling Language). In contrast to the static character of natural types, the character of role types is dynamic. Role types are dependent from relations and context. [22] describes the distinction, paraphrased in object-oriented terms as follows: “a type is a role type if for an object to belong to the extension of the type it must engage in a relationship associated with the type and if entering or leaving the extension of the type does not alter the object’s identity.” Role types specify the interaction of individuals. An instance is statically classified by its natural type and dynamically classified by the role type(s) it fills. Each instance of a certain natural type can fill different role types, called polymorphism [22]. According to [21] role types and natural types are interconnected by the `supports` relationship, specifying which natural types support which role types. The role type specifies the behavior, instances of a natural type must provide in order to be able to fill the role. How the behavior is achieved is left up to the natural type that support it. It depends on the natural types’ properties and qualities whether its instances can fill a role or not. Instances of natural types can fill, adopt and leave a role without loosing their identity. Role types are defined by context and relation.

Integrating the concept of role types in UML, the notation for role types must be specified. [21] recommends using the lollipop-notation, which in UML represents interfaces. In the UML diagram (figure 3) a rectangle indicates a natural type, a circle indicates a role type. The UML diagram specifies role types the instance of a natural type can fill. In specifying metadata, it is necessary to distinguish between static attributes (such as Dublin Core and vCard attributes), which are based on the natural type of a resource, and context- or role-dependent attributes which are based on the

role type a resource fills. Natural types such as information assets and actors have context-independent static attributes. These static attributes are independent from the role a resource fills. Besides static attributes, context-specific role-based attributes are attached to resources. Role-based attributes are specified according to a specific context.

4.3 Modeling Practices as Coherent Social Systems (System Centered)

Roles within a system are related as elements within an activity system generate each other reciprocally. For person related roles this means for example: there is no accused without a complainant, no father without a son or daughter. A person (natural type) filling a role within a system has expectations towards the other persons filling roles. The accused has specific expectations towards the judge. An instance of a natural type fills a role as soon as it moves into the system. In case of the natural type person, the concept of role types is intuitively understood (figure 1). But also further natural types such as information asset (e.g. a picture), behavior, technology, service, etc. fill roles within systems (figure 2). Within the legal system (which serves as an example here) the type picture does not exist on its own. But a picture which fills the role indication does exist in the legal system. This means: The judge introduces a picture into the system as indication (the picture filling the role indication). Only filling the role indication (or another role) the picture is part of the system. The same with the role evidence: only as the judge accepts an asset as evidence it becomes part of the system. It is not part of the system per se, but filling the role evidence.

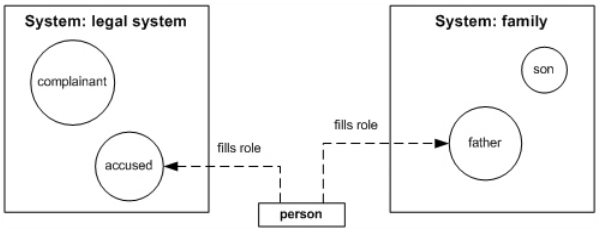

Fig. 1. A person (natural type) filling roles within different systems/context

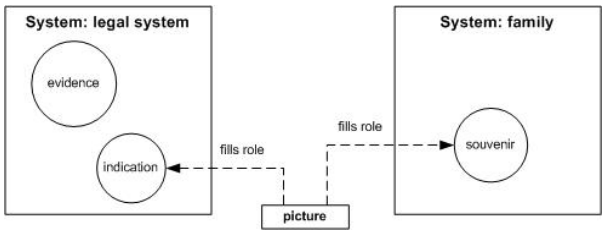

Fig. 2. A picture (natural type) filling roles within different systems/context

Natural types do not belong to a system but to its environment [12]. An instance of the natural type person which fills the role accused in the legal system fills the role father in the system family, each with specific intents, aspects, and purposes. The

relation `father-son` is insufficiently described by a binary relation as in a system the relation father-son is entirely affected by any other role represented in the system e.g. the role mother. The absence of an instance filling the role mother entirely affects the relation father–son.

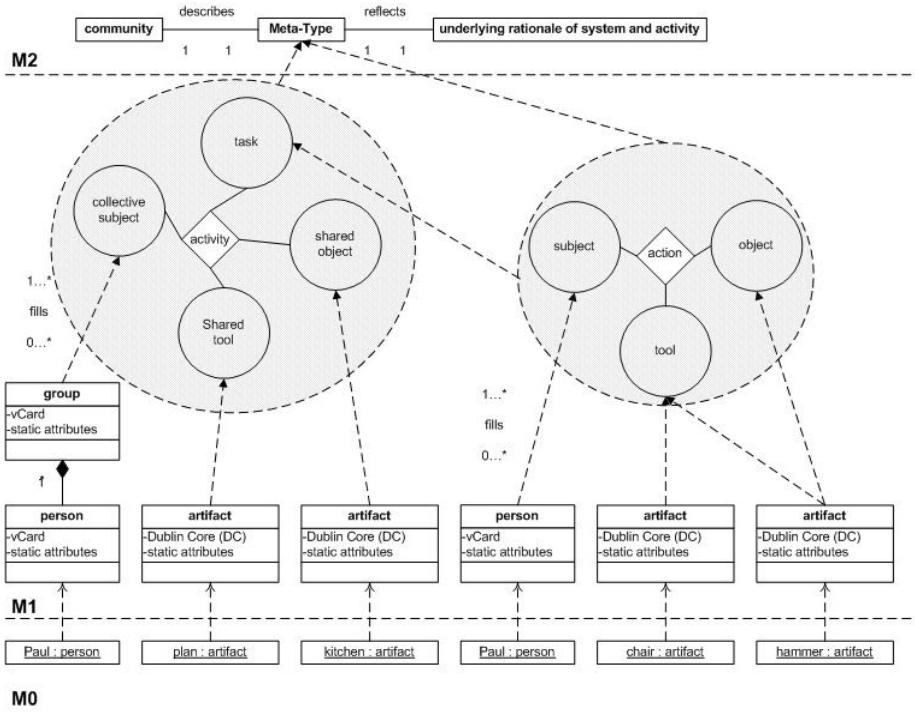

Fig. 3. The meta-model of a system-centered role-based modeling approach.

Modeling an activity system requires a further level of abstraction as any system has a (theoretical) foundation and underlying rationale. The legal system, which is a highly formalized system, serves as an example to illustrate issues relevant for modeling social systems. Legal systems are either based on codified law (e.g. the German legal system) or on case law (as in Anglo-Saxon countries). This foundation conceptualizes the system. The underlying rationale of the system, which can not be formalized, is reflected by the Meta-Type in M2 (meta-level 2, figure 3). The meta-meta-level category meta-type is crucial in modeling socio technical systems, as there always is an underlying rationale which can not be formalized. The meta-type reflects central issues/culture/identity of the activity system. The role-based modeling approach allows modeling a natural type filling different roles within different activity systems. Interoperability between the activity systems and different contexts is given via the natural type.

Modeling activities and processes, entities are usually related in a cause-and-effect chain, forming a process-oriented workflow model. This means to model a `subject` which performs an `activity` using some `resources` to reach a predefined goal, cp. [10]. Thus, learning is assumed to result from a chain of actions. Such a model

would oversimplify learning for several reasons, cp. [17] and see next section). To avoid this, this work models `action` as an n-ary relation and `action` and `activity` are modeled on different levels of emergence (figure 3).

5 Further Work

Further work is to be done in specifying a descriptive framework which is based on the approach presented in this paper. We already started to do so. For practical reasons we model roles as relations. Modeling languages are needed to describe practices and socio technical systems e.g. in the field of computer-supported collaborative learning and computer-supported cooperative work. In our work within an EU project we guide the co-design of tools and will need to outline a descriptive framework for knowledge practices in order to depict important aspects of collaborative learning and working processes. The descriptive framework is meant to become a boundary object for technical, pedagogical and theoretical partners. In particular the framework is intended to support the following tasks: (1) Description and communication of knowledge practices (boundary object); (2) Systematic comparison of different knowledge practices for design and research purposes; (3) Specification of high-level end-user requirements, based on the analysis of knowledge practice. The framework is meant to be descriptive in the sense that its basic aim is to depict and model existing or envisioned knowledge practices in a systematic manner. The descriptive framework itself makes no claims regarding the appropriateness or suitability of a given practice. In this sense it is not meant to be a prescriptive framework.

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