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Informing Work Interaction Design by 3rd Generation Activity Theory

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Abstract. In this paper, we reflect on stakeholder interaction design supported by task behavior specifications and stakeholder benefits when framing design with (i) eliciting task knowledge and understanding work activities and activity systems, (ii) means of interactional representation for design, and (iii) capturing the dynamics of activity systems. Thereby, complimentary inputs to theory development and work interaction design techniques become evident. In particular, eliciting implicit knowledge on human task accomplishment and work processes helps understanding and representing activities as design-relevant behavior entities. Eliciting implicit knowledge influences the representation of work knowledge and the subsequent design process of socio-technical systems. We elaborate on some methodological interventions for creating stakeholder task behavior models, including patterns of information exchange for collaborative task accomplishment.

Keywords: Activity Theory, workplace design, stakeholder interaction

1 Introduction

Today's organizations are continuously changing. Resilience requirements have been followed by dynamic capability development, underpinned by digital transformation processes. All of them require organizational commitment, bringing upfront integrated or at least adjusted design of work and IT systems to support human workforce and organizational development. Thereby, an organization's knowledge acquisition capabilities in relation to work activities play a crucial role [1]. They affect stakeholders as knowledge holders and (re-)designers of socio-technical systems. Adopting the notion of 'knowledge as knowing' and activity theory (AT) as framework help eliciting knowledge of organizations and their people, and finally conducting business process improvements (ibid.). In particular, AT is of benefit when engineers design artifacts [2]. In this paper, we provide methodological input by addressing the interface between work knowledge acquisition and the design of task-based and stakeholder-oriented socio-technical systems.

While modeling-based designs of various kind should facilitate knowledge elicitation and transforming it to technological artifacts, we argue for tackling implicit work knowledge. Framing this social process by AT facilitates acquiring task- and stakeholder-relevant knowledge for further modeling and design processes. Clemmensen et al. [3] have shown in an in-depth analysis of AT contributions in the field of Human-Computer Interaction over the last 20 years that AT is used successfully in various ways ranging from developing new analytical tools, facilitating empirical analysis to informing the design of concrete interactive systems like learning environments, groupware systems or knowledge management support systems. In this paper we will investigate the contribution of AT concepts for developing a methodology to acquire knowledge within interaction design in digitally supported work processes, both in terms of relevant behavior, and task-based system development support. The relevant AT concepts range from object-directedness of activities and personal sense-making of knowledge to re-organize tasks according to their context.

We build upon seminal work in this context as provided by Bonnie Nardi and Victor Kaptelinin [4-8]. We follow the understanding that people act with technology, which is always designed and utilized in the context of people (cf. [9], [10]). We also follow the need of understanding people's desires and intentions (ibid.) that drive their behavior. This is why we argue for eliciting implicit knowledge, as, according to our experience [11,12], it contributes to deeper understand the needs and capabilities of users in interactive system design. This information needs to be captured in a structured while systemic way, e.g., by connecting task behavior models.

In section 2 we recapture organizations in terms of activity systems (in the sense of AT) and conclude for eliciting task-relevant stakeholder knowledge in a situated and context-based way, recognizing the flow of knowledge in terms of change (creativity) and mutual exchange of information and objects of work. In Section 3 we propose methodological interventions according to activity-oriented knowledge acquisition (as presented in section 2), in order to facilitate activity-(system) based interaction design. Its implementation enables dynamic changes and prototyping. Section 4 concludes the paper, wrapping up the presented findings and sketching future research activities.

For illustration purposes, we will use a scenario stemming from current healthcare developments throughout the paper. It is a domain heavily debated in socio-technical research and development communities (cf. [13]). We focus on home healthcare, as it requires cooperation among several stakeholders that needs to be rearranged due to remote operations and novel digital communication capabilities, such as edge computing (cf. [14]) or IoT [15]. Consider a patient at home coordinating several digital healthcare support systems ensuring individual wellbeing in a self-organized way while being connected on demand to medical experts and system vendors of his/her medical equipment. It is a scenario re-occurring in transformations to digitized environments. Such types of scenarios are driven by customization activities to individualize task activity chains, e.g., by means of apps, and include user control of devices and work processes novel for concerned users.

Setting up such systems does not only require architectures that allow networking or composing systems in a modular while in an effective and efficient way [16] but rather conceptual understanding of adjusting features according to specific stakeholder roles and their task-related behavior [14]. For instance, home healthcare users or patients have become users in different roles. Once a medical device, such as an instrument for measuring the blood pressure, is delivered from a provider or vendor, users start in the role 'configurator', continue as 'operator' when measuring their blood pressure, and act in a third role when maintaining the device. In addition to configuration, operation, and maintenance, users are confronted with networking capabilities of digital devices, enabling coordination with other digital systems in their (home) environment, communication with peers and medical care takers, and adaptation to fine-tune a device's use. This complexity requires not only several technical skills, but also awareness and transparency, that using medical devices in home healthcare does not only affect the patients themselves, but also other stakeholder behaviors, such as medical caretakers and infrastructure providers. Designing such socio-technical systems can be structured by task-based stakeholder orientation including corresponding service abstractions [17,18].

We consider a home healthcare scenario with several support tasks (for an overview see also the grey boxes in Figure 4). For the patient, a Personal Scheduler coordinates all home healthcare tasks. Personal Scheduler denotes a behavior abstraction of a task in the sense that it is not specified, whether it is performed by humans or digital devices or services. Since design abstracts from actual implementation, such an abstraction facilitates task-specific specifications. Due to the use of these task specifications throughout the paper we label them with capital letters.

The Personal Scheduler handles all patient tasks to be set in a certain period of time, and can be set public to other concerned stakeholders, such as relatives, medical experts, and social services. A Medication Handler takes care of providing the correct medication at any time and location and is collaboratively controlled by medical care takers and the patient. Healthcare instruments support specific services, e.g., Blood Pressure Measurement sensing the medical condition of the patient. They are linked to their provider companies or producers, ensuring proper operation. In addition, a Shopping Collector serves as container for all items to be provided for medication and wellbeing. These sets of home healthcare tasks include the mutual interaction of various stakeholders and their interactions with digital systems, such as apps on smartphones. Since they need to follow a certain domain logic, e.g., identifying the demands from existing medications when making a shopping list, workflows can be defined when digitizing home healthcare settings.

2 Activity-theory-based Acquisition of Work Knowledge

Acquiring work knowledge is a complex endeavor because of the multiple facets of and different perspectives on one and the same work process, the interrelatedness of subjective, objective as well as organizational factors, plus the – often tacit – knowledge that is needed to engage in certain processes and achieve certain outcomes. Therefore, the acquisition and representation of work knowledge has to take into account the heterogeneous elements, relations and processes of that knowledge as well as to understand that the acquisition process itself becomes part of the whole endeavor. Thereby, the context-sensitive elicitation of stakeholder-specific knowledge is of immanent importance, as various mental models, either consciously or unconsciously, shape design and thus, user acceptance (cf. [19]). Referring to our home healthcare scenario, the mental models of how a patient envisions medical care at home might significantly differ from how a home health nurse conceives it. Both will probably be different from the understanding of medical experts working in hospitals.

What makes up the multiple facets of human work knowledge elicitation? Individual stakeholders handle work tasks in their own specific way, they do not only pursue organizational goals, but individual ones as well. They act according to their individual mental models, knowledge, skills, self-restraints, personal needs and intentions, etc. In today's knowledge society, in many cases, teams instead of single individuals work on a task together in order to bundle their competences. By that, the complexity of acquiring work knowledge is increasing. It is not only the knowledge of single actors that must be elicited but group processes, interpersonal relationships, patterns of communication, collective mental models etc. have to be taken into account. In the addressed home healthcare scenarios at least the following groups are involved: healthcare specialists, patients, service and product providers from various fields, including home, delivery, medical equipment service.

Certainly, acting on a work task is not only influenced by its actors (individual or team), but by the requirements, drawbacks and potential of other stakeholders like those working on subsequent or precedent tasks. Moreover, each work task is essentially formed by the organization or the organizational setting itself with its culture, structures, processes, technical tools and physical surroundings. Work tasks are embedded in a broader organizational context, they (should) contribute to the organizational goal. Last but not least, the content/object of the task itself is contributing essentially to what a work task is made up of.

A task produces a certain outcome that is the starting point of or a means in some other tasks in the work process. Moreover, the task is transforming some sort of objects (material or immaterial) and, by that, it is dependent on the characteristics of the object itself as well as of the domain the task belongs to. Such a situation is given in the scenario of home healthcare, when some health indicators, such as the blood pressure, require further consultations of further stakeholders, for instance when the patient’s measurement of blood pressure indicates a value above average. For deeper analysis, the patient contacts medical experts. From the point of view of medical experts like nurses or physicians the object is the physical condition of a patient measured through indicators like blood pressure, body temperature or blood sugar level aiming at a healthy functioning of the body. From the point of view of the patient the outcome of a healthy body might be much more dependent on the feeling of personal wellbeing, subjective performance capability, and absence of pain. However, patient and healthcare workers cooperate on the shared object of the patient’s physical condition, apparently having different perspectives on the same object, but sharing the same data (e.g., the measured blood pressure value).

The more expertise is needed in order to perform a work task, which is typically the case in complex and unforeseeable situations, the more the tacit knowledge plays a crucial role [20]; for an empirical investigation [cf. 21]. Consider the behavior of a patient not being used to digital system support. He/she is likely to have developed a certain behavior pattern of acquiring medical advice, e.g., visiting the local doctor. It is also very likely, the activity of visiting a local doctor is triggered by a set of tacit knowledge, e.g., feeling poorly, strange differences in blood measurement results (the patient might already use medical technological tools but to the point not digitally connected). This existing knowledge including the patterns of behavior needs to be elicited in case of transforming to digital healthcare support. The same is true for the tacit knowledge of the local doctor: The doctors knows the patient in context: his/her medical history, his/her needs of re-assuring, his/her worries concerning side-effects of pharmaceuticals, the family situation etc. All this work expertise and tacit knowledge are a challenge to elicit (ibid.).

Recognizing shifts of organizational settings, as it happens in healthcare from medical environments to home settings, makes it even more reasonable to elicit implicit knowledge. At least the following issues need to be tackled in that context. First, it needs to be acquired, whether a home infrastructure allows locating and operating medical equipment in a way that a hospital or clinic does. Secondly, the delegation of roles is evident: the patient as a user of medical devices at home becomes an essential part of medical workflows, namely collecting fundamental data for further processing. In order to design work tasks given such a change of settings requires activating of tacit knowledge, as this shift can be considered as an organizational learning step (cf. [22-24]) embodying the patient in novel roles (cf.[13]).

Recognizing such multi-faceted complexity we suggest framing task knowledge acquisition by AT. AT enables us to make graspable the complex interrelations in which work knowledge is embedded. The interrelations range from those between different actors, teams and the organization as an institution with its structures, functional roles and processes to objects, mediating tools, and the socio-cultural context. AT meets the challenge of comprising the complexity of organizational work as well as to regard the dynamic nature of knowledge oscillating from the conscious to the unconscious level according to its respective context. Moreover, AT allows us to consider the elicitation process as part of the context and the future technology as changing (mediating) the activity itself [25]. Beyond that, we back Karanasios' [25] argument that the design of information systems informed by AT should contribute to subjects' emancipation instead of control, restriction or prediction.

2.1 Organizations as Activity Systems

Organizations can be viewed under the "lens" of AT [25-27]. AT itself was originally formulated as an encompassing theory of psychology [28], with roots in Vygotsky's cultural-historical psychology [29] and emphasis on the crucial role of language and signs in mediation, and with underpinnings in the German philosophy of the 18th and 19th century, above all deriving Marx' concept of activity as crucial entity that mediates between subject (human) and object (the German "Gegenstand"). Today's AT has grown into a meta-theory that has applications in many different fields, above all in Human-Computer Interaction e.g., [3,5,9,30-33], knowledge management [24,34-39], organizational learning and research [26 40-44].

A special characteristic of AT that makes it so powerful for the purpose of knowledge elicitation is that it takes into account the dynamics of knowledge [6] as well as its immanent connectedness to its personal, social, cultural as well as physical context [34] or like Nardi ([6], p.76) puts it: "the activity itself is the context." Within the frame of AT, the unit of analysis for (work) knowledge is neither a person nor a small snippet of behavior like in other psychological theories, but the activity (in the sense of an activity system) itself. Activity can be seen as an integral unit of consciousness and behavior [28] enabling to grasp the complex interrelations of actions, actors, institutions, tools in use, social rules, products and the society within a certain context, in a systematic way.

The concept of activity enables us to dissolve the artificial separation of body and mind because activity is the joining element between subjective and objective processes (cf. Figure 1). “In activity there does take place a transfer of an object into its subjective form, into an image; also in activity a transfer of activity into its objective results, into its products, is brought about.” ([28], p. 50). Thus, the process of knowledge elicitation has to consider subjective views, meaning and motives as well as objective conditions, means and products – in its reciprocity. Moreover, AT helps to understand that each knowledge elicitation process becomes part of the context wherein it is applied and thereby might change the activity itself. Hence, for home health care system design we not only need to incorporate the medical expert’s cause-and-effects-knowledge in the context of the respective illness and additional parameters (age, sex, other health indicators etc.), but also the patient’s values about what is important to him/her (simply feeling well or being able to practice a serious sport). Moreover, context data is needed to interpret every single measurement result (e.g., room temperature, medication, activity level during measurement process, day time, former results etc.).

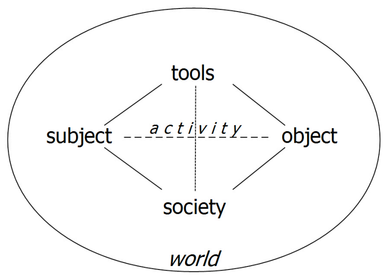

Fig 1. Activity as mediating unit between subject and object

In line with the above mentioned shift of organizational context, a patient having to identify the next step in home healthcare, e.g., after measuring his/her blood pressure, has different background and knowledge than a medical expert. For instance, guiding a patient to find out whether to consult medical experts due to the result of current measurements, requires understanding of the individual situation. It becomes even more essential when scheduling medication and ordering further drugs by putting them on the shopping list. Thereby, the course of previous activities and the current wellbeing of the patient are likely to be additional context parameters.

For the analysis of an activity, the general internal structure of activity helps to understand the dynamics within an activity system when the context changes (cf. Figure 2): Each activity, motivated by an object that meets an actor's need, consists of actions directed toward concrete goals and of operations, i.e., by what means the goal is reached under specific circumstances. The activity holds the actions and operations together in the sense that it gives them its meaning in the respective context [28]. For instance, the further shopping of the prescribed drugs depends on whether the state of wellbeing and health could be reached in the past by taking those drugs. Therefore current subjective and objective data on the state of wellbeing and health of the patient need to be incorporated and decided upon when scheduling the next medication and shopping trip.

The dynamics within an activity can be described as follows: An activity might convert into an action by losing its original motive (the motive turns into a goal). In return, an action might become an activity through transformation of a goal into a motive. Furthermore, an action can become an operation through regular practice, or, if conditions change, an operation might (re)turn into an action. Operations can be crystallized in form of external means like software programs. However, if the conditions change, the operational content of the action changes too [28]. Means should always be considered in relation to their goal, operations in relation to their action. In our home healthcare scenarios, a typical goal is to identify the daily status of wellbeing based on the current blood pressure. It is motivated by keeping a certain level of wellbeing which leads to activating a certain app and the corresponding device. Measuring the blood pressure is one of the required actions that leads to operating a corresponding instrument at a certain point in time, e.g., the morning after getting up.

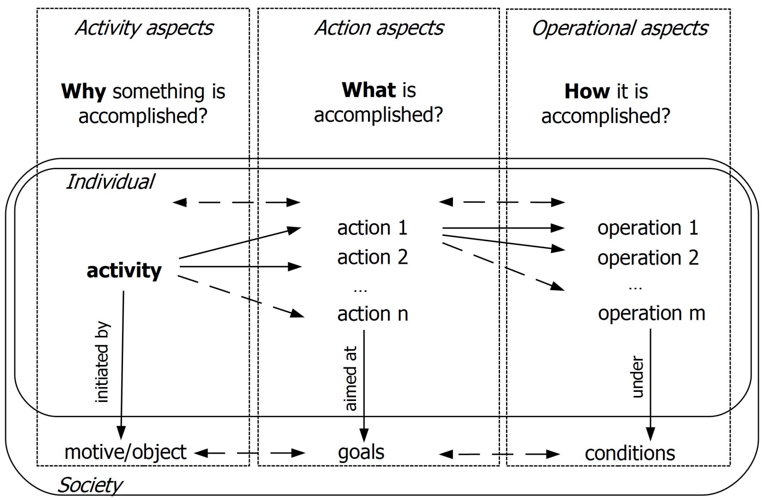

Fig 2. General internal structure of an activity with its three main components activity, actions and operations

Although "[h]uman activity does not exist except in the form of action or a chain of actions" ([28], p. 64), it is the activity and its initiating motive that is responsible for personal sense making. This implies that all observed or recorded behavior can only be understood within the context of the respective activity of which it is part. The same behavior can contribute to different activities and, by that, can have a completely different meaning. How an activity is accomplished depends upon the why it is accomplished. As a person facilitating knowledge elicitation, one has to ask *why* a person (or a team) is engaged in what s/he does (they do) in order to be aware of the context in which a certain task is accomplished in this or that way.

However, AT does not formulate hierarchies of needs or motives but takes into account that (new) needs and motives can come into existence through (new) activities [28]. In that context, Leont'ev [28] emphasizes the difference between objective and subjective significance: Whereas objective significance is the objective meaning of certain objects, like examination marks developing in a society over time, subjective significance is the personal sense, it is the role that an object plays in an individual's life. The objective meaning can only be understood through analyzing it as a product of society and historical development. In contrast, the personal sense reveals only by figuring out the role that an object plays in a person's life, by regarding this person's needs and motives. Personal sense is therefore bound to emotions, personal history, values and aspirations, i.e. a system of individual constructs [45]. Still, the personal sense is not independent from the objective meaning and by that not independent from societal history. In that sense, knowledge can be seen as "… representations exist inseparable from the subject's activity, and they fill it with the riches accumulated in them and make it alive and creative..." ([28], p. 76). Though, a holistic knowledge elicitation process can be done through an analysis of activity and its internal structure and dynamics.

Looking from a task perspective, e.g., scheduling medication, supports focused elicitation of task-specific behavior on all levels of activities. An activity represents a unit of work with a certain objective, e.g., ensuring wellbeing every day. It requires a set of actions, such as the patient configuring a digital blood pressure measurement system and operating it for measuring blood pressure every day. For elicitation, all required actions, including those not having been explicit so far need to be part of contextual inquiry. In the addressed case, the shift of context corresponds to assigning new technical roles to users related to crucial tasks, namely collecting reliable data for further processing. Eliciting this information could lead to some design effort, e.g., configuration support for a blood pressure device through a wizard app linked to second level customer support of the device vendor.

When we started to apply ideas from AT to knowledge elicitation it soon became evident that AT is not one uniform theory, but a slightly diverse pool of concepts and models which are more or less related to Vygotsky's cultural-historical school [29] and/or Leont'ev's [28] theory of activity. Central notions are not always used with the same meaning (e.g., the terms "motive", "need", and "object"), but are interpreted in different ways. This is especially true when different concepts are mingled without clearly stating their definition. Already Leont'ev himself observed this:

> "I have had occasion to encounter, distressingly often, the expression activity approach and other terms about activity, not always in a sufficiently distinct and defined meaning, and situated somewhere in a broad space of meaning and concepts. [...] Now when I see the phrase 'from the point of view of the activity approach', I must state, sincerely, it disturbs me" ([46], p. 31).

We therefore went back to the historical roots of AT, above all to Leont'ev's "Activity, consciousness, and personality" ([28]; comparing it with the Russian original "Deyatelnost, soznanie, lichnost", 1975, as well as its German translation "Tätigkeit, Bewußtsein und Persönlichkeit", 1982 [47]), to Vygotsky's concept of mediation [29] and the philosophical influences from the German dialectical materialism according to Marx and Engels.

Then, we searched for AT approaches of the second and third generation[2] choosing only those for analysis that described their reception in sufficient detail and were related to the field of knowledge theory or knowledge generation in organizations. Therefore, in addition to 1) Leont'ev's theory of activity [28], the following approaches were included in our analysis: 2) Engeström's theory of expansive learning [42,43], 3) Raeithel's activity theoretical design theory [32,48], 4) the occupational psychological cooperation model of Wehner et al. [49], 5) Clases' model of cooperative knowledge production [35,36], 6) the model of situatedness of knowledge sharing of Boer, van Baalen and Kumar [34], 7) Hasan and Gould's cultural-historical activity theory (CHAT [37,50], and 8) Blackler's theory of organizations as activity systems [26]. We compared them systematically to find the differences as well as the common ground. These steps enabled us to finally develop an activity-theoretical understanding of knowledge and knowledge elicitation (cf. [51]).

It has become evident, that Engeström's [42,43] and Raeithel's [32] work can be seen as second generation approaches of AT that ground deeply in the original work of Leont'ev [28] and in Vygotsky's concept of mediation [29]. However, they go beyond by incorporating other theories (above all systemic and constructivist concepts of Maturana, Varela, Luhmann, Mead, and others) and broaden the horizon of AT from focusing on single subject activity systems to collective subject activity systems. Whereas Leont'ev himself was interested in individuals' activities in order to understand their development in the context of their biographies and the socio-historical circumstances, especially Engeström calls for teams as *collective* subjects of activities in order to understand the development of new forms of activity.

Apparently, also Leont'ev himself emphasized that (work) activity is always a social process because of the historically grown division of labor, the mediating means (language above all) and the influence of the society on each activity [52]. Both Raeithel and Engeström put a stronger focus than Leont'ev on the *interaction* between activity systems in order to understand each activity system in interrelation with other activity systems and to draw conclusions for design (Engeström designed learning, whereas Raeithel designed software). However, both came up with different words for quite similar ideas. The major connection of interacting activity systems that Raeithel [32], later Wehner at al. [49], Clases & Wehner [36], suggests has the form of a process: The result (transformed object into an outcome) of one activity is becoming the object motivating another subject's activity. Engeström [42,43] himself emphasizes a shared object as major connection between two or more interacting activity systems. The idea of multivoicedness of activity systems emerges, i.e., different view on the same object are the drivers of conflict as well as innovation [43].

The interrelation between single actors and whole groups or organizations becomes essential in the second generation approaches. Therefore, they come to the conclusion that there are two main ingredients for the development: reflection (not only

[2]We term Leont'ev's work the first generation. This is not in accordance with Engeström's classification of first, second and third generation [42], because for our purpose, it makes sense to group Engeström's and Raeithel's approach into a category of its own as we will show.

individual but also collective) and communication/cooperation. Development means new forms of activity are coming into being; this is called innovation or knowledge generation. In order to grasp work activities in organizations the process of knowledge elicitation has to focus on both, on the needs, capabilities and activities of single individuals, and on the role of teams, collective activities, as well as the interrelationship between individual and collective activities.

The five remaining approaches (4 to 8) are mainly influenced by either Raeithel or Engeström, but seem not to take any additional concepts from Leont'ev or Vygotsky. We call those approaches third generation approaches, because, again, they incorporate other theories (the works of Weick, Suchman, Lave & Wenger and others are repeatedly merged into those AT approaches) or accentuate certain aspects like the interaction between activity systems on different context levels like Boer et al. [34] do.

When we describe here what all these approaches have in common (in accordance with the philosophical roots and the original works of Leont'ev and Vygotsky), we build a picture of constituents and processes that are immanent in an activity theoretical understanding of the world:

1) Activity is the mediated relationship between a subject and an object; there is no direct/unmediated relationship between subject and object.
2) Mediation takes place through societal forms like social and organizational structure or formal and informal rules as well as through operative forms like artifacts, tools, physical as well as symbolic means and media.
3) Activity is seen as the smallest unit of analysis that is needed to understand individual, group, and organizational behavior; only on the level of activity personal sense making can be grasped.
4) Context is important, mostly the activity itself with its internal structure and dynamics is seen as the context. When groups or organizations are considered, the interrelationship between several interacting activity systems as well as the multiple views of different stakeholders (multi-voicedness) are crucial for understanding the more complex knowledge processes within organizations.
5) The history (and in some approaches the anticipation of future) of an activity system has to be taken into account in analysis (and design) in order to understand present behavior and draw possible future paths; that can be seen as the timely interdependency of former, present and future activity systems as Boer et al. [34] put it.
6) Every activity is directed towards an object (except of Blackler's approach where activity is directed towards organizational routines meaning people act because they always acted like this); the term "object" is mainly used in a broad sense as a material or mental object that is aimed to be transformed somehow through the activity and the belonging actions and operations.
7) All approaches emphasize the dynamics of activity: the role of conditions/context for possible transformations of activity – action – operation etc. as well as the future possibilities of new forms of activities with new motives coming into existence.
8) Contradictions, dilemmas, crises, and conflicts within an activity system and between activity systems are seen as the motor of development. Therefore,

reflective, communicative and cooperative processes are especially focused on and fostered.

Figure 3 sketches the general structure of an activity system in interaction with other activity systems. An activity system consists of the following main components: a) an actor (be it an individual, a team or a whole organization, depending on the level of abstraction), b) an object that serves as a motive for the actor in question, can be described as follows, c) the mediating means (e.g., tools, symbols, language, a knowledge base etc.), d) the community (e.g., co-workers), e) explicit and implicit rules that mediate the relationship between the actor and the community, f) the organizational and role structure (in other terms: the division of labor).

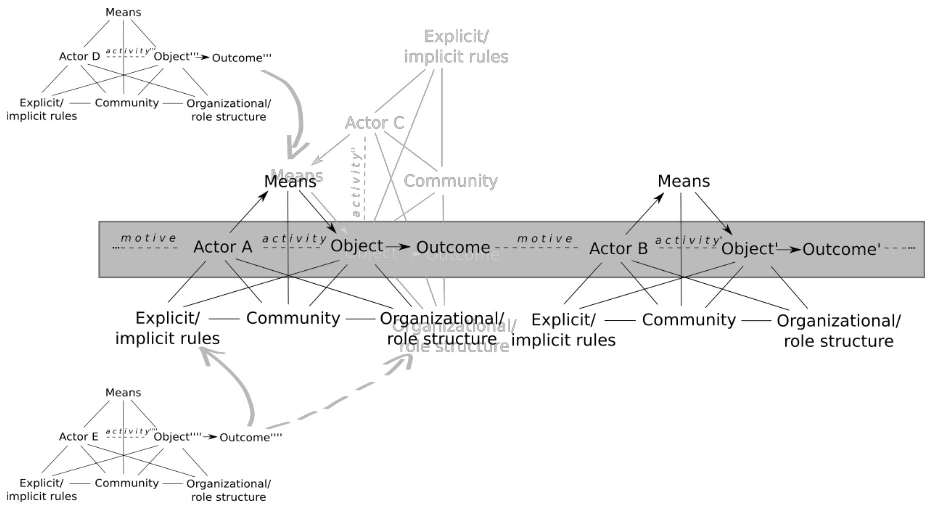

Fig 3. Structure of an activity system, embodied in its context

Figure 3 illustrates three exemplary types of interaction between activity systems: 1) Interaction between activity systems can have the form of a process, i.e., the object transformed by the activity of actor A serves a motive for actor B who engages in another activity transforming the object into an outcome. 2) Interacting activity systems can be bound together via an object-means relationship, i.e., the result of the activity of actor D might become part of the means in actor A's activity; alternatively, actor E's outcome might serve as new set of rules for communicating and cooperating with the members of the community (object-rules relationship). 3) More than one activity system is working on the same object (actor A and actor C) and interact via the transforming the same object. They might have different views on the same object and might be grounded in different group and professional cultures (rules) in their respective communities.

With respect to the home healthcare scenario, activity systems could capture the patient’s home setting and a medical care taking institutions, such as a healthcare center for cardiological risk patients:

- Actor A could be a patient knowledgeable about running his/her home healthcare (explicit/implicit rules in Fig. 3), and motivated to ensure a high level of his/her wellbeing. The patient is provided with knowledge and equipment to achieve this objective (Means in Fig. 3). His/her activities concern his/her wellbeing (Object in Fig. 3). Being a certain type of patient, e.g., assigned to a cardiological risk group (referring to Community in Fig. 3), he/she needs to follow a certain procedure regularly (referring to Organizational/role structure in Fig. 3), including operating his/her blood pressure measurement device. The results of this procedure allows him/her to decide whether further action needs to be taken or not (referring to Outcome in Fig. 3) to ensure his/her wellbeing. This outcome represents the interface to Actor B, in case further action needs to be taken.
- Actor B could be a medical care center knowledgeable about treating cardiological risk patients including handling requests from home healthcare patients (explicit/implicit rules in Fig. 3). Its medical staff is motivated to provide high quality services to provide support and care about the wellbeing of cardiological risk patients. The staff members are qualified and skilled to achieve these objectives (Means in Fig. 3). Their activities concern patient treatment and in-situ support (Object in Fig. 3). The care center is specialized to cardiological risk patients (referring to Community in Fig. 3), and the institutional help to be provided, ranging from advising patients to emergency visits (referring to Organizational/role structure in Fig. 3). The outcome of the center is high quality provision of services to patients leading to a minimal set of cases that cannot be handled by its staff (referring to Outcome in Fig. 3). This outcome represents the interface to further actors, e.g., for reporting to official health authorities.

The model of activity is useful for work knowledge elicitation because it is a model of structural relations and content-free in its nature (cf. [53]). It shows relations between elements that hold or are considered true for every (work) activity and can be applied to every (work) domain (cf. [3]). Whereas knowledge elicitation is often done either through the lens of a tool language (by which the tool sets the limits, but not human experience), as for example in the case of traditional knowledge engineering techniques, such as CommonKADS [54], or through the subjective lens of knowledge elicitation facilitator (by which the mental model of the facilitating person sets the limits, but not the people who are engaged in the work tasks) knowledge elicitation with the help of AT is done through the lens of human experience. Each work activity, regardless of the (knowledge) domain it belongs to, can be viewed under the lens of this structure. The components and their relations enable to look in specific directions, e.g., to collect information about the availability and usage of means, about implicit and explicit rules and how they foster or impede communication and cooperative learning, about organizational structure that is either enabling or hindering the activity of a subject, etc. With the help of this content-free structural model, the knowledge elicitation facilitator is able to elicit task and stakeholder relevant knowledge for further modeling and design processes from the genuine perspectives of the actors in the activity system(s) with only little biases through domain dependent or personal (pre)conceptions.

Knowledge is seen as something dynamic being part of every activity. Knowledge generation emerges through the interaction between subject and object that is by activity. The dynamic character of knowledge can be explained by borrowing Raeithel's metaphor of knowledge being both at the same time, the river as well as the river bed. The river flows and forms the river bed, at the same time the river bed is directing the river flow. Knowledge, especially tacit knowledge, is part of both and, in that sense, changes its state (from liquid to solid and vice versa). This has major implications for the process of knowledge elicitation: knowledge is never fix, it is always changing and always dependent on the societal, organizational, personal and objective circumstances – at the same time building and changing those circumstances itself. Knowledge from the point of view of AT is therefore situated and contextual, it is activity itself [26,37]. In that sense, knowledge is individual as well as collective. It can be in a more fluid state (expressed in behavior or communication patterns) or in a more solid state (when means, rules or structures are analyzed).

What are the consequences that follow from AT and its understanding of work knowledge for the knowledge elicitation process and for designing software? In accordance with Raeithel [32], Engeström [42,43] and Wehner et al. [49] and their design suggestions we draw the following conclusions. The knowledge modeling and software design should allow for a high amount of openness and flexibility. From the point of view of AT, (new) software should enable the development of new forms of activity by supporting individual and collective reflection, by encouraging individual as well as collective experimentation in single situations to solve problems, by facilitating multiple forms of communication between different stakeholders, and by making visible contradictions, crises or conflicts as initial drivers of the development of innovations.

The development of artifacts should contribute to learning. Of course, development and learning are not only a matter of developing and applying artifacts like software but also of nurturing an open organizational culture where people respect each other, are encouraged to discuss and learn from mistakes, are animated to try out new procedures, experiment with new tools and have enough freedom to decide how they accomplish their tasks. AT can serve as a framework for thinking about methodological approaches to knowledge elicitation in human work settings in order to foster sound analysis and design.

2.2 Eliciting Human Work Knowledge

In the previous section we have shown the common ground of different approaches and generations of AT. In this section we want to focus on what can be deduced from this analysis for the elicitation of human work knowledge. We suggest twelve overarching activity theoretical principles for knowledge elicitation (cf. [51]) based on a conceptual analysis on the one hand, however, triggered by our experience (teaching knowledge elicitation) but flawed by the practical facilitation process of knowledge elicitation on the other hand. The conceptual analysis was done by comparing not only the core notions of AT (e.g., activity, subject, object, context) and their usage in different AT approaches, but we were looking especially for an AT understanding of knowledge-related processes (e.g., what is knowledge in terms of

AT, where is it represented, how can the process of knowledge generation be described in terms of AT). The twelve principles we came up with can be understood as an activity theoretically informed framework for the process of knowledge elicitation.

The benefit of such a theory-driven conceptual approach allows various implementations from a method perspective which is of particular importance in actual development settings. AT principles need to be operationalized, i.e. put into practice by applying different methods, e.g., Critical Incident Technique or Repertory Grids [55,56], depending on the situation, capabilities, and project constraints. Hence, the AT framework provides constitutive elements for work knowledge elicitation from stakeholders that can be addressed by specific elicitation methods in different ways. From an AT point of view there is quite an openness towards methods from different traditions (cf. [3]), as far as they are not prescribing but exploring.

The AT principles allow a context-sensitive knowledge elicitation of work processes in organizations. They show how AT meets the challenges of today's knowledge society by enabling to take into account the dynamic, ever changing nature of human work knowledge as well as the social, cultural-historical, and temporal intertwining of work activities. Since AT presents us a domain unspecific inner structure of activity systems using a rich vocabulary (cf. [3]), it allows us to model work processes in a flexible as well as structured way without losing either the whole picture or important details, considering both personal sense making as well as interrelations and multiple perspectives, and moreover, being expandable in its nature (AT sees itself as natural subject to change and development, cf. [9]).

In the following we elaborate on the twelve principles and their meaning for eliciting human work knowledge. Since each principle is derived from findings detailed in the previous sections, we do not replicate the respective references. The meaning of the mentioned terms and concepts corresponds to those introduced above.

(1) *The object-orientedness of activity:* Work activity can only be understood when analyzed according to both points of view: a) from within the view of the actor (subject) – personal knowledge, personal sense making, tacit personal needs – as well as b) from outside (object) – domain knowledge, „objective" context, organizational needs. Only by understanding work activity in its dynamic nature expressive (software) design is possible. Since each activity is directed towards an object („Gegenstand") which is transformed through actions by one or more actors into an (organizational) outcome, the search for the common object is crucial for detecting the starting point of the elicitation process.

(2) *The mediated character of activity:* All activity is mediated through knowledge, means (tools) as well as social rules, i.e., each activity is changing according to the knowledge, means and rules that are applied throughout the working process. Every new software – moreover every new design, product or service – changes the original activity since applying a new means starts a new mediation process that cannot be predicted. New means can affect the activity system as a whole by possibly touching the gentle balance of organizational structures, business processes, functional roles, cooperation patterns, human needs, knowledge and sense making, as well as technical tools and instruments. The elicitation process therefore does

not end with modeling an existing activity, but starts (again) with applying (prototypical) new means.

(3) *Activity systems as units of analysis:* Since activity systems with their universal inner structure and interrelations of element categories (cf. Figure 3 above) reproduce or come into life through conscious actions and unconscious automated operations conducted by actors, the activity itself can be understood as the background against which concrete actions, knowledge or human/organizational needs have to be viewed as a Gestalt. Only by putting the elicited work knowledge in relation to all other elements of one or more interacting activity systems, sound design choices might be made.

(4) *Contradictions as driving forces:* Contradictions are integral, historically grown tensions within and between activity systems which are seen as an important source of development and learning. During the elicitation process, contradictions might show as reported conflicts, problems or difficulties, or as subtly observable uncertainty, confusion or ambivalence. By focusing those tensions throughout the elicitation process, new practices and possible design solutions might become evident. Since activity systems are open systems they can incorporate new elements like a new tool. This new tool should solve an existing contradiction and by that contributes to an organizational learning step –, but might also induce new contradictions itself. In that sense, learning is an organization's as well as humans' life-long process.

(5) *The dynamics of activity systems:* Activity systems are dynamically changing, its components transform into one another according to (inner and outer) context changes: Actions might become operations through practice and automation or, vice versa, operations might become conscious actions through a change of environmental factors. Mediating rules might become the object of an activity, as well as an outcome of an activity might become the mediating tool for another activity. Every time a component changes into another or something new is incorporated into an activity system, the meaning of the activity system and its components might change. This has consequences for the knowledge elicitation process: The elicitation process itself becomes part of the context. The elicited knowledge is only interpretable within the frame of reference of the respecting activity system. Methods used for knowledge elicitation must be sensible to changes in knowledge, as well as enable to make the changes graspable in order to draw conclusions for software design.

(6) *Interdependency in time (culture-historicality and future anticipation):* Activities change over time and inhere their own history and their own possible future paths. For the elicitation of work knowledge, comparisons of different states (of the activity system or its components) in time can help to view similarities and differences and by that understand what the key concepts or driving forces in an activity are. In order to draw conclusions for software design, comparisons of the old and the new as well as the past, the present and possible future options are useful for understanding possible developmental options.

(7) *Social character of activity:* All activities are intrinsically social. That does not only refer to visible cooperative activities such as team work, but to all activities, even the apparently loneliest one like writing a book. Our thinking is seen as existing only as a social activity because language, tools and other means are only created in interaction between humans and then, one day, become internalized as some sort of cognitive models. Thus, all work knowledge can be seen as social in its nature. Metaphorically spoken, the individual knowledge is the river that flows in a collective riverbed. The riverbed makes certain paths more likely than others. Domain knowledge (which is a sort of collective knowledge) is important to understand certain individual ways of doing things. At the same time, the river (that is the personal knowledge) shapes the riverbed itself. Individual and collective knowledge have to be brought together and to be viewed in context of each other.

(8) *Multivoicedness of activity:* Organizational activity systems encompass multiple points of view of different stakeholders, i.e., the system is multi-voiced. The multiple perspectives are both a source of conflicts and a source of innovation and learning. The elicitation of work knowledge has to take into account the multiple viewpoints of different stakeholders as well as their interrelations. Elicitation methods that help to see things from different perspectives (like circular questions do [57]) can help to bring diverse perspectives together.

(9) *Interdependency of different context levels:* Every work activity in organizations can be viewed as an activity system on a more abstract or a more concrete context level. Every organization can be analyzed as one (abstract) activity system or as many (concrete) systems like that of its teams or individuals. The context levels influence each other. Depending of which context level is focused, different things become evident. Moreover, for the elicitation of relevant work knowledge it is not only necessary to pay attention to the local activity system(s) of the organization, but to the broader global activity system(s) of the relevant domain including the tools, concepts etc.

(10) *Personal sense making of knowledge:* Knowledge is bound to a personal sense. Therefore, knowledge elicitation should always start from an individual activity system (motivated by a certain need) in order to understand the knowledge in its personal sense making. Actions or unconscious operations are part of the activity system and are surely part of the knowledge, but do not suffice as units of analysis. The personal sense making (only to be understood when an activity is the unit of analysis) is the context of meaning of the (elicited) knowledge and important for the transfer of the elicited knowledge to abstract models as well as to other people. Often the most critical step in knowledge transfer is that new actors have to embed the acquired new knowledge into their own sense making.

(11) *Elicitation of tacit knowledge as a form of externalization of activities:* The elicitation of knowledge as a process can be viewed as a process of externalization, i.e., our thinking, mental models, personal constructs etc. shape all practical activities and the creation of material tools, structures and

objects. The counter process is that of internalization, i.e., how practical activity and the usage of tools influences our thinking and the creation of mental representations of things and activities. Since the philosophical roots of AT is dialectical materialism meaning the practical activity is seen as primary to thinking, the elicitation of work knowledge should connect to concrete experience in order to evoke mental models.

(12) Organizational learning as development of new forms of activities: (Organizational) Learning in an AT sense means that individuals, teams or organizations create new activities (above all new objects and motives). Learning that eventually comes up with new activities or even new forms of activities can take several forms: from experimenting with alternative solutions for ongoing problems via "misusing" tools or concepts from other activities in new ways, up to creating new tools, prototypes and new mental models. The elicitation of work knowledge itself is part of this learning process since it encourages reflection and by that possibly opens up new future pathways.

Through these principles, AT is presented as a framework for knowledge elicitation, especially for the elicitation of human work knowledge. By that, AT can be understood as a sort of glasses through which work knowledge can be located, important aspects of interrelated knowledge are considered and the elicitation process can be seen. These principles are meant to help the elicitation of work knowledge in a holistic and context-sensitive way taking into account the dynamic, changing nature of knowledge as well as the impossibility of knowing in advance how new tools (like a software) will change the context, the activity, and the knowledge itself. Moreover, these principles emphasize that the elicitation process itself becomes part of the context.

3 Work Interaction Development Support

In this section, we study how models and specification approaches can support activity-based design of socio-technical systems, as they aim capturing work knowledge in terms of how tasks can be accomplished. In addition, specification should allow (i) representing context, and (ii) refining behavior-relevant knowledge from elicited representation to implementation-relevant execution schemes. The latter supports prototyping and generating artifacts. We build upon findings from model-based design approaches as they aim to incorporate context information including task and user characteristics while taking an implementation-oriented engineering perspective on development (cf. [58-60]).

In the following sub sections we introduce a workflow-oriented development approach and demonstrate how activities encoded in behavior representations can be used to construct socio-technical facilities. The starting point is contextual inquiry enabling to shape behavior entities that finally could be refined for role-specific execution of dynamically evolving systems.

3.1 Contextual Inquiry and Activity-system-based Behavior Refinement

In this section, we discuss the application of the overarching AT principles to task acquisition and analysis techniques with respect to task- or role-based development. In particular, we reveal consequences to

(i) the setting and procedure, and
(ii) fundamental entities and relationships designers need to tackle.

Both aspects have an impact on how designs develop and allow representing a work setting from a socio-technical perspective. The setting and procedure provides the scope of acquisition and frames the activities and their sequence to be set for eliciting task knowledge. The fundamental entities and relationships address the content, in particular its structure that designers utilize when acquiring task-relevant knowledge. In the following, we refer to fundamental properties of the AT and the selected principles when discussing each of the aspects (i) and (ii).

Setting and Procedure. According to the principles derived from AT considerations in section 2, designers capture work processes in and of organizations in a context-sensitive way. More specifically, AT advises designers to account for the dynamic nature of these processes. They need to recognize human work knowledge in its continuously changing nature according to its specific social and cultural-historical context. For task-oriented interaction design framed by AT, designers needs to consider an organization as an activity system, where design work is embodied, while AT defines the setting for eliciting, representing, and processing work knowledge, but does not prescribe domain-specific or inner structures of this system. Hence, respective development support should allow developers generating models of work processes

- in a flexible as well as structured way
- keeping the 'big picture' of task accomplishment while
- recognizing relevant perspectives and elements (including their relations) that
- make sense to members of an organization as they understand the organization and the work processes they are part of.

The object-orientedness of activity (1) has an effect on the setting as both perspectives, the actor's and domain expert's of the organization need to be captured. *Activity systems as units of analysis* (3) contain both conscious actions and unconscious automated operations conducted by actors. As activities represent the background against which concrete actions, knowledge, its elicitation, as well as human/organizational needs have to be put in relation to all other elements of one or more interacting activity systems. They finally also represent or enable developing design alternatives framed by relevant context elements.

Both principles have an effect on the procedure, as each activity is part of an activity system and directed towards a work object. This object is transformed through actions by one or more actors into an (organizational) outcome. Hence, the starting point of the elicitation process needs to be the common object. Although thereby the data (exchange) play a crucial role, the object is considered in the context of a role accomplishing a task involving the object, and thus, in line with the setting given by AT.

The dynamics of activity systems (5) raises the awareness that every analysis and design have to be considered as snapshots in time. Not only that activity systems are dynamically changing, each intervention (including acquisition and design) transforms components and relations. These changes might have an impact to the meaning of the activity system and individual sense-making processes. The major challenge in knowledge acquisition therefore is recognizing it as part of the current context. Modeling approaches used for knowledge elicitation have not only to capture the relations being correct at a certain point in time, but also adaptable for future designs. The models themselves provide the structural means that developers activate at a certain point in time.

Consequently, adaptability needs to take into account the *interdependency in time* (6) as changes of activities have their specific history and trigger specific developments. In order to preserve acquired knowledge of work processes, development repositories or design memories keep development context, such as stakeholder data and time, besides the actual content, e.g., task models. They help to avoid running through similar development cycles without being effective in design and development. Consequently, o*rganizational learning as development of new forms of activities* (12) has to become integral part of development methods. It enables individuals and collectives to proceed or initiate development activities (cf. double loop) while operating in their work activity system. New activities (above all new objects and motives) need to be reflected before being embodied into new socio-technical work practice [61]. From a method perspective, knowledge claims referring to underlying problems or assumptions, and design rationales need to be acquired and documented for each learning step.

The mediated character of activity (2) has essential impact on how to acquire and process knowledge. In this context the problems of as-it-is and as-it-should-be pops up. Once design is understood as inherent to the activity system, it is an intervention on-the-fly. This holds for acquisition as reflection as-it-is as well as for brainstorming as-it-could/should-be. Each activity in that system is changing according to the knowledge, means and rules that become evident when analyzing work processes. New tools or services are an intervention, starting a new mediation process that becomes part of design and development. This dynamic (and non-predictable) nature of design is rarely reflected in usability life cycle considerations. In particular, domino-effects beyond individual work tasks or procedure up to reflecting sense-making are rarely part of methodological designs.

Contradictions as driving forces (4) play a crucial role in that context, since, as grown tensions within and between activity systems, analysis and design can be a learning endeavor for all stakeholders of the system. These tensions can reveal practices and designs that have not been considered so far. They lay ground for social, technical, and organizational innovations and change, e.g., in terms of coordinating actions, IT tool support, and role assignments, respectively. Even if technical artifacts, such as novel technologies trigger change and interventions in an activity system, the *social character of activities* (7) needs to be recognized.

According to the analysis in section 2, the social character also holds for individual task accomplishment, since a work result is considered as some form of expression from (in terms of a cognitive model) and in a social context (we produce a result for other humans). Traditionally, work knowledge is not considered as social in its nature, as acquisition, analysis, and design consider tasks as goal oriented activity that needs to be evaluated in terms of its objective results, e.g., a good or bad service. It is even de-humanized.

In that context we have to consider the *multi-voicedness of activity* (8). Accepting individual mental models and thus cognitive representations of human work and socio-technical systems, developers need to respond to different perspectives resulting from each stakeholder's way handling tasks, tools, and organizational settings. As part of contextual inquiry acquisition techniques need to elicit viewpoints of stakeholders as well as their interrelations.

Not only are various perspectives a methodological concern, context is represented at certain levels of abstraction. As each of the elicited work activities can be considered an activity system on a more abstract or a more concrete context level, the *interdependency of different context levels* (9) can influence analysis and design. Specific items, such as role behavior or tool characteristic, can have specific meaning according to the considered level of context, e.g., individual task accomplishment and department. In terms of contingency theory, each activity system encapsulates another. As such, it might influence sense-making processes of stakeholders. *Personal sense-making of knowledge* (10) is likely to influence knowledge elicitation, as it reveals the personal meaning and the needs that an activity system fulfills for an individual. As many actions might be performed unconsciously, the *elicitation of tacit knowledge as a form of externalization of activities* (11) requires methodological consideration.

Acquisition techniques should comprise externalization of mental models. Underlying motives and constructs triggering practical activities influence the way we deal with tasks, goods, services, material, tools, and people. Externalization also captures previously internalized activities, as due to routines or task complexity they have become encoded into mental models. According to AT, the activity should be the unit of elicitation and analysis, as it allows asking for the personal sense of task accomplishment. Sense-making finally represents the context of meaning of the (elicited) knowledge, i.e. how acquired information needs to be understood. It is an inevitable source for the non-reductionist transfer of elicited knowledge to formal or diagrammatic models, and subsequently to technical system features. In this way, this knowledge is communicated to other people, either directly through representation, or indirectly, through user behavior when interacting with technology.

Fundamental entities and relationships. The setting and procedure provide the frame for content that designers need to address from an AT perspective. In the following, we apply to task- and stakeholder-centered design the developed principles given in section 2, as elicitation entities and their relationships are essential for developers when creating task-effective digital support systems or interactive artifacts.

Activity systems as units of analysis (3) defines the scope of elicitation and representation, as an activity provides the background against which concrete actions become their form (Gestalt). Models need to capture the inner structure and interrelations of element categories besides the categories themselves, in particular the actions performed by actors. All elements of a particular activity system designers have to address also from a relational perspective, as they could provide the context to other elements of one or more interacting activity or activity systems.

For elicitation, representation and execution of work knowledge for design and implementation, the *object-orientedness of activities* (1) plays a crucial role. Work activities serve as context element for actions from an actor (subject) perspective (role – functional, formal, semi-…), and from external (object) perspective according to the domain, sector or type of organization at hand. Since each activity is directed towards an object that is transformed through actions by one or more actors into an (organizational) outcome designers need to ask for the effect on the activity system and also specify required input and output data. However, the search for the common object is crucial for detecting the starting point of the elicitation process. It influences the perspective, level of abstraction, and scope an acquisition procedure takes.

As all activity is mediated through knowledge, developers need to elicit means (tools) as well as social rules valid for a working process *(mediated character of activity (2))*. They also need to represent design knowledge in a way that the effect of new software or design, can be evaluated before implementation, since it changes the original activity. From the *dynamics of activity systems* (5) a new process of mediation is started. Although, then the elicitation process does not end with modeling an (existing) activity, it starts (again) with applying (prototypical) new means.

For implementing *interdependency in time (culture-historicality and future anticipation)* (6) - when activities change over time and inhere their own history and their own possible future path - changes need to be captured on a meta-level. It would allow observing all developments over time, and thus, facilitate collective learning processes which brings o*rganizational learning as development of new forms of activities* (12) into play. It is also a question of system dynamics. It requires direct addressing of underlying drivers or mediators of work. In that context *(4) contradictions as driving forces* have a special quality, as it is not very likely that all members of an organization agree on proposed changes nor that a learning step is free of conflicting elements. Hence, contradictions need to be kept as an input pool for further analysis or design.

When the *social character of activity* (7) is addressed explicitly, notations used for elicitation and specification need to capture respective elements and relations. Although from an AT perspective all activities are intrinsically social, social interaction with other actors could be represented and modeled explicitly, e.g., as done in subject-oriented business process modeling [62]. The latter allows encapsulating actors, actions, and objects/tools through corresponding abstraction. The granularity hereby could be identified from an individual perspective as it facilitates sense-making of represented knowledge (*Personal sense-making of knowledge* (10)) – see next section.

The other principles, in particular *(8) Multivoicedness of activity* and *(9) Interdependency of different context levels* have been considered as part of the setting and procedure in the previous subsection, as they are not part of elicitation and specification process directly. For *(11) Elicitation of tacit knowledge as a form of* *externalization of activities*, elements could be generated through using specific methods, such as Repertory Grids (cf. [12]). Asking for knowledge categories, such as values, that become evident on tasks or actors, could lead to novel content items and design elements (cf. Stary, 2014).

3.2 Behavior Encapsulation and Interaction Design

In the following we model activity systems as set of behavior encapsulations according to the idea of implementing organizations as system of (social) actors. Once an activity system has been elicited it can be refined in a non-disruptive way [63]. Each activity system consists of active elements or actors (modeled as action systems in AT) and their relations for communication and interaction.

We follow the approach of Subject-oriented Business Process Management (S-BPM) [62]. It allows representing simultaneously acting components in any type of organization. They operate as active, autonomous, concurrent behavior entities. Such entities can be a human, a piece of software, a machine (e.g., a robot), a device (e.g., a sensor), or a combination of these, such as intelligent sensor systems. Action systems are termed subjects according to the S-BPM approach. For the sake of intelligibility we denote them S-BPM subjects in the following. S-BPM subjects can execute local actions that do not involve interacting with other S-BPM subjects, as well as communicative actions that are concerned with exchanging messages between S-BPM subjects, i.e., sending and receiving messages. Messages also can contain business objects, and thus, are carriers of data manipulated by the actions of an activity system.

S-BPM involves all stakeholders concerned by the actions of an activity system in terms of their task-specific roles. They are represented by S-BPM subjects and are one of five core symbols used for specifying S-BPM models. Based on these symbols, two types of diagrams exist in S-BPM which can be produced to conjointly represent an integrated system: S-BPM Subject Interaction Diagrams (SIDs) and S-BPM Subject Behavior Diagrams (SBDs):

- *Subject Interaction Diagrams* (SIDs) provide an integrated view of an activity system, comprising the S-BPM subjects involved and the messages they exchange.
- *Subject Behavior Diagrams* (SBDs) provide a local view of the process from the perspective of individual S-BPM subjects. As they refine actions, they capture AT operations. They include sequences of states representing local actions and communicative actions including sending messages and receiving messages. Since SBDs also implement rules through the flow of actions, the conditions under which operations are set can be captured in an integrated way. Dedicated handler can be added to handle complex events.

An activity system or situation can be structured in S-BPM as an interacting set of action systems, encoded in S-BPM diagrams according to their communicating with each other. When these action systems need to communicate directly via message (containing business objects) with another action system, as e.g., required in case of Personal Scheduler, a S-BPM subject-behavior diagram also encodes this link. It is executed during runtime once being implemented. On the modeling layer, the corresponding activity is a request sent to another S-BPM subject. The sending S-BPM subject waits until it receives an answer. Then, it processes the received answer – see Figure 4 for that pattern. The rectangles denote the messages that the action systems exchange.

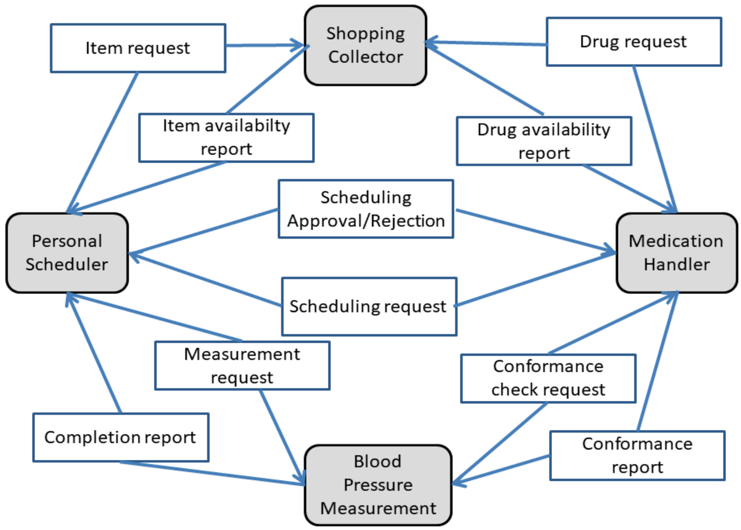

Fig. 4. Detailed activity system 'Patient' refined as set of AT actions based on interacting S-BPM subjects for personal assistance in home healthcare

Figure 4 shows a Subject Interaction Diagram (SID). SIDs provide a global view of an activity system, comprising the S-BPM subjects (shaded rectangles) involved and the messages (white rectangles) they exchange. They represent activity-system specific actions as actors (S-BPM subjects) involved in communication when considering a patient at home coordinating several digital healthcare support systems as activity system:

- Personal Scheduler coordinates all home healthcare tasks. As a subject Personal Scheduler is a behavior abstraction of an action system and can either be performed by humans, digital devices or services. In design we abstract from actual implementations. The Personal Scheduler handles all patient tasks to be set in a certain period of time, and can be set public to other concerned stakeholders, such as relatives, medical experts, and social services.
- Medication Handler takes care of providing the correct medication at any time and location and is collaboratively controlled by medical care takers and the patient.
- Blood Pressure Measurement is a healthcare instrument supporting services to recognize the medical condition of the patient. They are linked to their provider companies or producers, ensuring proper operation.
- Shopping Collector serves as container for all items to be provided for medication and wellbeing.

Since each of the action systems need to follow a certain task logic, e.g., identifying the demands from existing medications when making a shopping list, each of them needs to be refined accordingly through Subject Behavior Diagrams (SBDs). The refined view on individual subjects represents sequences of operations, including communication with other action systems (sending and receiving messages). Sequences are represented as arrows, with labels indicating the outcome of the preceding operation (see Figure 5). The part shown in the figure represents a scheduling request to the Personal Scheduler subject from the Medication Handler subject. It also reveals the choreographic synchronization of behavior abstractions, allowing to represent action systems in parallel while being synchronized through operationally required message passing.

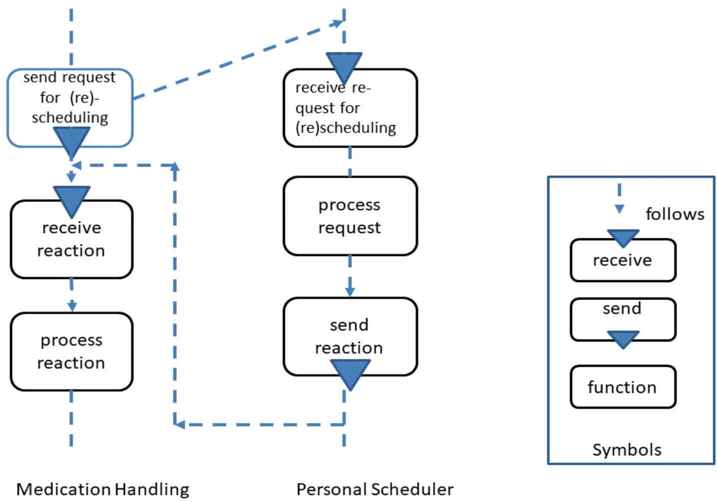

Fig. 5. Scheduling request to the Personal Scheduler subject from the Medication Handler subject on the operation level when refining action systems

Given these modeling capabilities, subject-oriented designs (S-BPM models) capture work interactions through simple communication protocols (using SIDs for an overview) and (ii) standardized behavior structures (enabled by send-receive pairs between SBDs), which (iii) scale in terms of complexity and scope. In addition, all required data are represented along the interaction paths. In this way, subject-oriented process integration is adaptive, as it allows meeting ad-hoc and domain-specific requirements, once a corresponding interaction behavior can be identified.

As validated behavior specifications can be executed without further model transformation, stakeholders can control the entire process, ranging from elicitation to specifications of executable domain-specific work flows, and even can make ad-hoc changes by replacing individual S-BPM subjects during runtime. As long as the interaction interface between S-BPM subjects hold, their internal behavior (i.e. operations and actions being part of an activity system) can be modified. Figure 6 gives an example for handling a monitoring task when connecting a dedicated device, such as Blood Pressure Measurement, to a Personal Scheduler on request, or when incorporating intelligent sensor systems in ambient environments.

The subject-oriented system structures, such as integrated blood pressure measurement devices in personal health scheduling support systems, according to their communicating with each other. When these devices need to communicate directly with the cloud, e.g., as required in case of maintenance, or calling a specialist for medication, this link is encoded in the subject behavior diagram, and executed during runtime after technical implementation. On the modeling layer the activity is a request sent to another subject, waiting until an answer is received, and processing the received answer (see also Figure 6 for that pattern).

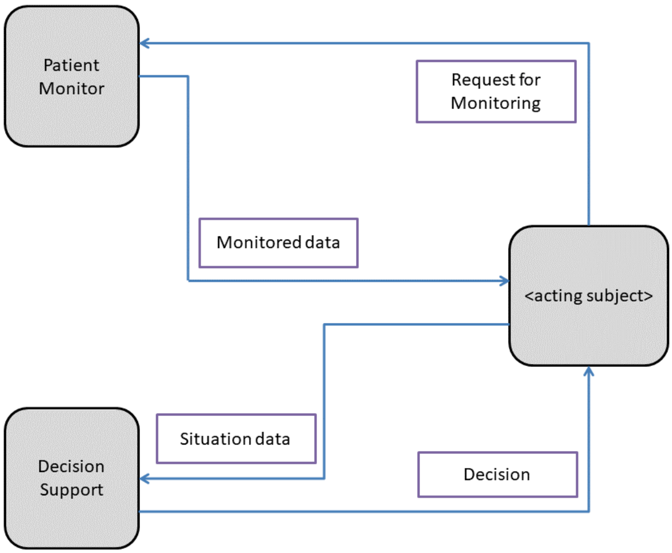

Fig. 6. Monitoring request processing (SID)

Once an SBD, e.g., the Blood Pressure Measurement subject is instantiated, it has to be decided (i) whether a human or a digital device (organizational implementation) and (ii) which actual device is assigned to the subject, acting as technical subject carrier (technical implementation). Typical subjects as edge devices are smart devices which can have Internet connectivity, including smart phones, tablets, laptops, healthcare devices, etc.

Figure 7 provides a schematic visualization of this constellation, as it can be used for implementing the sample home healthcare support system (see also [14]). Infrastructure nodes are subject carriers representing resources including hardware (compute, networking and storage) capabilities. They provide 'local' real-time data processing capabilities, and can, despite multi-tenancy, execute applications in isolation to prevent unwanted interference from other action systems. Policies to control service orchestration, filtering, and for adding security can be implemented dedicating a specific control subject. In case the open source engine UeberFlow [64] (download at: http://www.i2pm.net/interest-groups/ueber-flow/home) is utilized for execution, operations and thus, actions are ordered in the sequence as defined through S-BPM models.

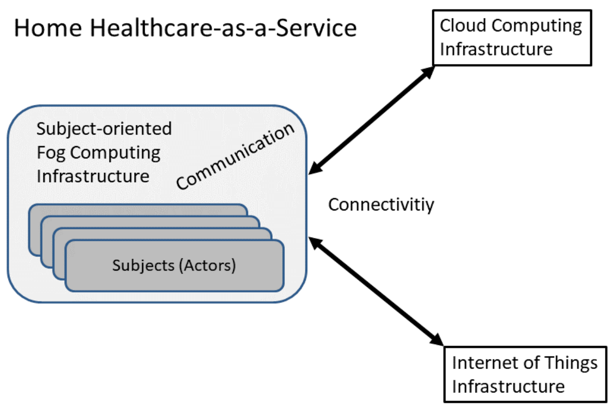

Fig. 7. Execution Computing Architecture

The approach takes into account the structured findings revealing that perspectives on the situation trigger

1. *actions of activity systems* encapsulating behavior by focusing on actions needed to be performed to achieve an objective or implement an intention (usually referring to some task), and thereby, establishing some functional role
2. *operations* as refinements of actions allowing to detail functional/technical services for task accomplishment
3. *communication acts* identifying which action system(s) needs to be interacted with
4. the *mutually adjustment of encapsulated behavior specifications*, as it plays a crucial role not only for acting as a collective in a specific situation but also to complete work tasks or reach intended goals.

Subject-oriented design models contain interactions in a flexible as well as structured way – SIDs keep the 'big picture' of task accomplishment while recognizing relevant perspectives and elements (including their relations) that make sense to members of an organization as they understand the organization of work tasks and related behaviors. When using subject-oriented representations throughout elicitation implementing the 12 principles detailed in section 2.2 can be actively supported – set the relevant text to italics: A SID is able to represent an *action system as units of analysis* for a specific actor, e.g., patient. When defining the scope of work task interaction, S-BPM also implements the principle of *object-orientedness of work activities*. New means can be captured by changing S-BPM models, probing them as novel work practice. Hereby the *social* and *mediating character of activi*ties is captured through exchanging messages and business objects. *Contradiction as driving forces* can be documented on the collective and individual layer through SIDs and SBDs.

Since each stakeholder can generate individual subject behavior (*personal sensemaking of know*ledge) framed by identical communication patterns, S-BPM models, *multivoicedness of activit*ies can be documented, even their *interdepencence in time*. Subjects allow behavior encapsulation on various levels of abstraction, enabling *interdependency of different context level*s. Finally, the *dynamics of activity system*s can be managed by adapting settings in a subject-oriented way. The adaptation become essential when *externalizing activities stemming from tacit knowledge* is supported, and *learning cycles at the organizational level lead to new forms activities.*

4 Conclusions

In our analysis we presented AT as a framework for acquiring knowledge and representing human work tasks and their arrangement for meeting specific goals. The defined principles allowed us to understand AT as a context-sensitive way to locate work knowledge and ask for important aspects of interrelated items. Development techniques have to take into account the dynamic, changing nature of knowledge, modifying the context of tasks and their accomplishment on-the-fly.

The developed principles help to reflect on current elicitation and explore capabilities of development techniques. We have investigated the setting, procedure, and representational elements. Taking into account the coupling of actors, actions, and objects is facilitated by an activity-system-centered development approach. Behavior encapsulations represent task-relevant roles and work tasks, while business objects are part of interactions between actors or technological artifacts. Finally, change and learning require meta-level representations and processes, in order to sustain and keep already achieved insights in those processes.

However, further research is required, in particular coupling elicitation and acquisition procedures implementing an activity-system perspective to design patterns and development languages. To that respect modeling skills on various levels of abstraction are required. User support could stem from tangible digital media as already prototyped for work modeling (cf. [65]). The refinement of activity systems into actions and operational procedures may require deeper analysis and novel instruments for articulation support (cf. [66]). Finally, for understanding motives underlying individual value systems should be elicited and aligned with already externalized knowledge integrating explicit with tacit knowledge, e.g., through Value networks (cf. [56]).

References

1. White, G. R. T., Cicmil, S. (2016). Knowledge acquisition through process mapping: factors affecting the performance of work-based activity. *International Journal of Productivity and Performance Management*, *65*(3).
2. Cash, P., Hicks, B., Culley, S. (2015). Activity Theory as a means for multi-scale analysis of the engineering design process: A protocol study of design in practice. *Design Studies*, 38, 1-32.

3. Clemmensen, T., Kaptelinin, V., Nardi, B. (2016). Making HCI theory work: an analysis of the use of activity theory in HCI research. *Behaviour & Information Technology*, 35 (8), 608-627
4. Nardi, B. A. (1996a). Activity theory and human-computer interaction. In B. A. Nardi (Ed.), *Context and consciousness: Activity theory and human-computer interaction* (pp. 7-16). London: MIT Press.
5. Nardi, B. A. (1996b, Ed.). *Context and consciousness: Activity theory and human-computer interaction.* London: MIT Press.
6. Nardi, B. A. (1996c). Studying context: A comparison of activity theory, situated action models, and distributed cognition. In B. A. Nardi (Ed.), *Context and consciousness: Activity theory and human-computer interaction* (pp. 69-102). London: MIT Press..
7. Kaptelinin, V. (1996). Activity theory: Implications for human-computer interaction. In B. A. Nardi (ed.), *Context and consciousness: Activity theory and human-computer interaction* (pp. 103-116). London: MIT Press.
8. Kaptelinin, V., Nardi, B. (2012). Activity theory in HCI: Fundamentals and Reflections. *Synthesis Lectures Human-Centered Informatics*, *5*(1), 1-105.
9. Kaptelinin, V., Nardi, B. A. (2006). *Acting with technology: Activity theory and interaction design*. MIT Press.
10. Barab, S., Schatz, S., Scheckler, R. (2004). Using activity theory to conceptualize online community and using online community to conceptualize activity theory. *Mind, Culture, and Activity*, *11*(1), 25-47.
11. Hemmecke, J., Stary, C. (2004). A framework for the externalization of tacit knowledge embedding repertory grids. In *Proceedings OKLC-2004, 5th European Conference on Organizational Knowledge, Learning and Capabilities, Innsbruck* (Vol. 56).
12. Hemmecke, J., Stary, C. (2006). The tacit dimension of user tasks: elicitation and contextual representation. In *Task Models and Diagrams for Users Interface Design* (pp. 308-323). Berlin, Heidelberg: Springer.
13. Ackerman, M., Goggins, S., Herrmann, T., Prilla, M., Stary, C. (2017). *Designing healthcare that works: a sociotechnical approach*. Academic Press.
14. Stary, C., Fleischmann, A., & Schmidt, W. (2018). Subject-oriented fog computing: Enabling stakeholder participation in development. In Proceedings *2018 IEEE 4th World Forum on Internet of Things (WF-IoT),* IEEE, 7-12.
15. Zhang, W., Kumar, M., Yu, J., & Yang, J. (2018). Medical long-distance monitoring system based on internet of things. *EURASIP Journal on Wireless Communications and Networking*, *2018*(1), 176.
16. Yi, S., Li, C., Li, Q. (2015). A survey of fog computing: concepts, applications and issues. In *Proceedings of the 2015 Workshop on Mobile Big Data, ACM*, pp. 37-42. Blackler, F. (1993). Knowledge and the theory of organizations: organizations as activity systems and the reframing of management. *Journal of Management Studies*, 30 (6), 863-884.
17. Huang, D., T. Xing, H. Wu (2013). Mobile cloud computing service models: A user-centric approach. In *IEEE Netw.*, 27 (5), 6–11.
18. Shi, Y., Ding, G., Wang, H., Roman, H. E., Lu, S. (2015). The fog computing service for healthcare. In *2nd International Symposium on Future Information and Communication Technologies for Ubiquitous HealthCare (Ubi-HealthTech), IEEE*, pp. 1-5.
19. Hackos, J. T., & Redish, J. (1998). User and task analysis for interface design. Wiley & Sons, New York.
20. Hacker, W. (1992). *Expertenkönnen: Erkennen und Vermitteln*. Göttingen: Verlag für Angewandte Psychologie.
21. Büssing, A., Herbig, B., Ewert, T. (1999). Implizites Wissen und erfahrungsgeleitetes Arbeitshandeln: Konzeptualisierung und Methodenentwicklung. Berichte aus dem Lehrstuhl für Psychologie der TU München Nr. 48. München: Lehrstuhl für Psychologie der TU München. Available at http://www.psy.wi.tum.de/LS-Berichte/Bericht-48.pdf (May 30, 2016).
22. Senge, P. (1990) The fifth discipline: The art and science of the learning organization. *New York: Currency Doubleday*.
23. Nonaka, I. (1994). A dynamic theory of organizational knowledge creation. *Organization Science*, 5 (1), 14-37.

24. Kim, Y. J., Chaudhury, A., Rao, H. R. (2002). A knowledge management perspectice to evaluation of enterprise information portals. *Knowledge and Process Management*, 9 (2), 57-71.
25. Karanasios, S. (2018). Toward a unified view of technology and activity: The contribution of activity theory to information systems research. *Information Technology & People*, 31 (1), 134-155.
26. Blackler, F. (1993). Knowledge and the theory of organizations: organizations as activity systems and the reframing of management. *Journal of Management Studies*, 30 (6), 863-884.
27. Jonassen, D. H., Tessmer, M., Hannum, W. H. (1999). *Task analysis methods for instructional design*. Mahwah, New Jersey: Lawrence Erlbaum Associates.
28. Leont'ev, A. N. (1978). *Activity, consciousness, and personality*. Englewood Cliffs, New Jersey: Prentice-Hall. Available at http://lchc.ucsd.edu/mca/Paper/leontev/ (May 30, 2016).
29. Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, Massachusetts: Harvard University Press. (edited by Michael Cole, Vera John-Steiner, Sylvia Scribner, Ellen Souberman).
30. Bourguin, G., Derycke, A., Tarby, J. C. (2001). Beyond the interface: Co-evolution inside interactive systems—A proposal founded on activity theory. In *People and Computers XV—Interaction without Frontiers* (pp. 297-310). London: Springer.
31. Dahme, C., Raeithel, A. (1997). Ein tätigkeitstheoretischer Ansatz zur Entwicklung von brauchbarer Software. *Informatik-Spektrum*, 20, 5-12.
32. Raeithel, A. (1992). Activity theory as a foundation for design. In C. Floyd; H. Züllighoven; R. Budde; R. Keil-Slawik (eds.), *Software development and reality construction* (p. 391-415). Berlin: Springer.
33. Uden, L., Willis, N. (2001). Designing user interfaces using activity theory. In *Proceedings of the 34th Hawaii International Conference on System Sciences*. IEEE Computer Society Press.
34. Boer, N.-I., van Baalen, P. J., Kumar, K. (2002). An activity theory approach for studying the situatedness of knowledge sharing. In *Proceedings of the 35th Hawaii International Conference on System Sciences*. IEEE Computer Society Press.
35. Clases, C. (2003). Eine arbeitspsychologische Perspektive auf soziale Dynamiken kooperativer Wissensproduktion. In H.-W. Franz, J. Howaldt, H. Jacobsen, R. Kopp (eds.), *Forschern lernen beraten: Der Wandel von Wissensproduktion und -transfer in den Sozialwissenschaften* (pp. 303-324). Berlin: edition sigma.
36. Clases, C., Wehner, T. (2002). Steps across the border: Cooperation, knowledge production and systems design. *Computer Supported Cooperative Work*, 11, 39-54.
37. Hasan, H., Gould, E. (2001). Support for the sense-making activity of managers. *Decision Support Systems*, 31, 71-86.
38. Sukumaran S., Chandran K., Chandran K. (2014). Knowledge Management Strategy Using Activity Theory for a Law Firm. In Uden L., Wang L., Corchado Rodríguez J., Yang HC., Ting IH. (eds.), *The 8th International Conference on Knowledge Management in Organizations*. Springer Proceedings in Complexity (pp. 521-531). Springer, Dordrecht.
39. Uden, L. (2009). Activity Theory for Knowledge Management in Organisations. In A. Zilli, E. Damiani, P. Ceravolo, A. Corallo, G. Elia (eds.), *Semantic Knowledge Management: An Ontology-Based Framework* (pp. 201-215). IGI Global.
40. Blackler, F. (1995). Knowledge, knowledge work and organizations: An overview and interpretation. *Organization Studies*, 16 (6), 1021-1046.
41. Blackler, F., Crump, N., McDonald, S. (2000). Organizing processes in complex activity networks. *Organization*, 7 (2), 277-300.
42. Engeström, Y. (1987). *Learning by expanding: An activity-theoretical approach to developmental research*. Helsinki: Orienta-Konsulit.
43. Engeström, Y. (2001). Expansive learning at work: Toward an activity theoretical reconceptualization. *Journal of Education and Work*, 14 (1), 133-156.
44. Virkkunen, J., Kuutti, K. (2000). Understanding organizational learning by focusing on „activity systems". *Accounting, Management and Information Technology*, 10, 291-319.
45. Kelly G. A. (1991). The Psychology of Personal Constructs. London: Routledge (Reprint, New York: Norton, 1955).
46. Leont'ev, A. N. (1989). The problem of activity in the history of soviet psychology. *Soviet Psychology*, 27 (1), 22-39. (Originally published in Russian in Vopr. Psikhol. 4/1986, 109-120.)

47. Leontjew, A. N. (1982). *Tätigkeit, Bewußtsein, Persönlichkeit*. Köln: Pahl-Rugenstein. Available at http://www.kritische-psychologie.de/1982/taetigkeit-bewusstsein-persoenlichkeit (May 30, 2016).
48. Raeithel, A. (1983). *Tätigkeit, Arbeit und Praxis: Grundbegriffe für eine praktische Psychologie*. Frankfurt am Main: Campus Verlag.
49. Wehner, T., Raeithel, A., Clases, C., Endres, E. (1996). Von der Mühe und den Wegen der Zusammenarbeit: Theorie und Empirie eines arbeitspsychologischen Kooperationsmodells. In E. Endres; T. Wehner (eds.), *Zwischenbetriebliche Kooperation: Die Gestaltung von Lieferbeziehungen* (pp. 31-58). Weinheim: Beltz Psychologie Verlags Union.
50. Hasan, H. (2003). An activity-based model of collective knowledge. In P*roceedings of the 36th Hawaii International Conference on System Sciences*. IEEE Computer Society Press, New York.
51. Hemmecke, J. (2012). *Repertory Grids als Methode zum Explizieren impliziten Wissens in Organisationen: Ein Beitrag zur Methodenentwicklung im Wissensmanagement*. PhD thesis, Vienna University. Available at http://othes.univie.ac.at/27576/ (May 31, 2016).
52. Leont'ev, A. N. (1975). *Deyatelnost, soznanie, lichnost*. Available at http://www.psy.msu.ru/people/leontiev/dsl/index.html (May 30, 2016).
53. Jonassen, D. H., Beissner, K., & Yacci, M. (1993). *Structural knowledge: Techniques for representing, conveying, and acquiring structural knowledge*. Psychology Press.
54. Schreiber, G. (2000). *Knowledge engineering and management: the CommonKADS methodology*. MIT press, Boston, MA.
55. Stary, C., Maroscher, M., Stary, E. (2012). *Wissensmanagement in der Praxis:-Methoden-Werkzeuge-Beispiele*. Carl Hanser, München.
56. Stary, C. (2018) Transactional Value Analytics in Organizational Development. In *Analytics and Knowledge Management*, eds. S. Hawamdeh, H.-C., Chang, CRC Press, Boca Raton, 241-270.
57. Schlippe, A. von, Schweitzer, J. (2006). *Lehrbuch der systemischen Therapie und Beratung*. Göttingen: Vandenhoeck & Ruprecht.
58. Paternò, F. (1999). *Model-Based Design and Evaluation of Interactive Applications*. Berlin: Springer.
59. Dittmar, A., Forbrig, P., Heftberger, S., Stary, C. (2004). Support for Task Modeling–A "Constructive" Exploration. In *Engineering Human Computer Interaction and Interactive Systems* (pp. 59-76). Berlin, Heidelberg: Springer.
60. Stary, C. (2009) Model-based Tools: A User-Centered Design-for-All Approach. In C. Stephanidis (ed.), The Universal Access Handbook (ch. 25). London: Taylor & Francis.
61. Firestone, J. M., McElroy, M. W. (2003). Key issues in the new knowledge management. Routledge.
62. Fleischmann, A., Schmidt, W., Stary, C., Obermeier, S., Börger, E. (2012). *Subject-oriented business process management*. Berlin: Springer.
63. Stary, C. (2014). Non-disruptive knowledge and business processing in knowledge life cycles–aligning value network analysis to process management. *Journal of Knowledge Management*, *18*(4), 651-686.
64. Krenn, F., & C. Stary (2016). Exploring the potential of dynamic perspective taking on business processes, *Complex Systems Informatics and Modeling Quarterly* 8, 15-27
65. Oppl, S., & Stary, C. (2014) Facilitating shared understanding of work situations using a tangible tabletop interface. *Behaviour & Information Technology*, *33*(6), 619-635.
66. Oppl, S., & Stary, C. (2019) *Designing Digital Work - Concepts and Methods for Human-Centered Digitaliization*, Palgrave Macmillan.