# Beyond the distinction between tool and sign: Objects and artefacts in human activity

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**Abstract**

Vygotsky's view of unity of sign mediation and tool use as the essence of complex human behavior has become topical because of the breakthrough of digital technologies. This chapter discusses the interpretations of the significance of objects and mediating artefacts in human activity. Mediating means form constellations of signs and tools that have been characterized as instrumentalities. In an instrumentality of an activity future–oriented concepts and models, and tools of different types are intertwined. The chapter analyzes the dynamics of such constellations in oral health care and in construction design. In the case of oral health care the discrepancies between different levels of means hindered the attempts to develop and change the activity. Building Information Modelling (BIM) is a new digital artifact used in construction design. It has multiple and shifting functions during the design process. First, it is a tool of design modelling of different design disciplines. Second it is a shared intermediary object or 'special object' of the designers in the cycles of design. Finally, it turns into 'as designed model' which becomes a tool of the construction activity.

**Keywords**: Mediation, sign, tool, object of activity, artifact, instrumentality, intermediary object, changing functions of digital tools

## 1 Introduction

This chapter addresses the significance of objects and artefacts in human activity. Vygotsky discussed object and objectification in his theory of creativity and imagination as well as in his discussion of the significance of object substitutes in the development of play and symbolic thought. It is, however, A.N. Leont'ev's concept of object of activity (1978) that has extensively been discussed and debated in the cultural-historical tradition (e.g. Mind, Culture and Activity, 2005) if not so much in the sociocultural tradition.

Vygotsky distinguished between internally oriented signs and externally oriented tools. He also, however, found that the integration and unity of sign mediation and tool use is "the essence of complex human behaviour" in human adults (Vygotsky, 1978, p. 24). We suggest that a much richer and versatile language than the one based on the distinction between sign and tool is needed to understand mediation in human activity in a changing society with increasingly complex objects and social challenges. Mediational means tend to form complex constellations of artefacts or instrumentalities, in which semiotic and practical functions are fused and intertwined in many ways. We also suggest that an analysis and redesign of these instrumentalities are essential for the transformation of human activities.

It has been customary to draw a distinction between two research programmes within activity theory and the Vygotskian legacy (e.g. Martin & Peim, 2009). The first, socio-cultural theory, has focused on mediation by signs and the use of language as a foundation of thought, communication and meaning making – often characterized as semiotic mediation. It is based on Vygotsky's seminal view of mediation by signs and the internalization of language as a foundation of higher psychological functions. This research programme has studied the dialogic nature of thought and self as well as communication, cultural mediation and human discourses.

The other research programme, that is, cultural-historical activity theory (CHAT) is based on the concept of object-oriented activity introduced by A.N. Leontjev. He adopted concepts of practice and work from Marx, in particular, as well as from Hegel. In his

*Economic & Philosophic Manuscripts* of 1844, Marx (1964, p. 177) stated that "the outstanding achievement of Hegel's Phenomenology is that it grasps the essence of labour (…) and comprehends objective man (…) as an outcome of man's own labour". Work is here understood as a prototype of practice, a creative transformation of the environment resulting in the development of new human capabilities. In this process, the objectification of human thought and activity into cultural artefacts plays a central role (Ilyenkov, 1977a; Lektorsky, 1980; Bakhurst, 1991). It creates "humanized nature", an environment composed of man-made and therefore meaningful objects, norms and institutions. The interaction between an individual and humanized nature has been analysed as co-evolution in terms of cycles of internalization and externalization. An individual not only internalizes or appropriates cultural resources and ways of acting but also participates in their transformation in creative work, where the results of an activity are objectified into new cultural artefacts and resources.

Vygotsky indicated the importance of analysing the intertwining of tool use and mediation by signs: (1978, p. 24): "Although practical intelligence and sign use can operate independently in young children, the dialectical unity of these systems in the human adult is the very essence of complex human behaviour." The challenge, however, lies in determining whether and in which ways a symbolic activity's organizing function "penetrates the process of tool use" (ibid). For our own studies, this is a 'natural' question to analyse since we have studied the development and implementation of new technologies in which materiality is constantly present and the repeated failures of experiments are a reminder of the objectivity of activity. In order to understand better the object-means relationship we will shortly discuss some concepts of objects developed in social sciences among them epistemic object (Knorr-Cetina, 2001), boundary object (Star & Griesemer, 1989) and intermediary object (Vinck, 2011). To elaborate the integration of different types of means we utilize Wartofsky's (1979) idea of functionally different kinds of artefacts and the concept of "instrumentality", that is, a constellation of different artefacts as suggested by Engeström (2007). In this paper we will analyse constellations of artefacts and instrumentalities in two activities, oral health care and construction design.

We will proceed as follows. First, we analyse how the concept of an object of activity introduced by Leontjev has been used in activity theoretical studies. We think that without

an object of activity it is hard to understand the mediating artefacts and social forms of collaborative activity. We will discuss how the concept of the object of activity is related to certain object concepts introduced by the social sciences. Second, we discuss the relation between the concepts of sign, tool and artefact. We will discuss the function theories of artefacts and their relationship to the objectification. We analyse two examples of such instrumentalities. These instrumentalities comprise concepts, symbolic resources, standard procedures and different kinds of tools. In the first case, a new care model was not realized because the use of other artefacts in the instrumentality (manuals, care plan, diagnostic imaging) were not redesigned. In the second case, we analyse how a specific digital technology, Building Information Modelling (BIM), is implemented and used in construction design. It has multiple, shifting functions during a design process. It functions as a tool of individual designers, as an object of joint attention and problem solving, as well as an evolving intermediary outcome of the design work.

## 2 The object of activity and its uses in studying human activities

In his theory of imagination and creativity Vygotsky discussed external objects in two senses. First, he (Vygotsky, 2004, p. 20) postulated a cycle of imagination which is completed in external embodiment: ”Once it has been externally embodied, that is, has been given material form this crystallized imagination that has become an object begins to actually exist in the real world, to affect other things.” Vygotsky says that (2004, p. 41): ”The imagination’s drive to come embodied is the real basis and motive force of creation.” He (ibid.) cites and agrees with Ribot’s statement according to which ”creative imagination in its full form attempts to affirm itself by taking some objective form that exists not only for the creator himself but for everyone else as well.” This concept is an early formulation of the theory of objectification and externalization of thought that was subsequently developed by E.V Ilyenkov in his theory of the ideal (1977b).

Second, Vygotsky analyzed the role of objects in his theory of the development of play and symbolic thought. In this development the use of object substitutes help children to separate their thoughts from perceived objects and events (Karpov, 2005, p. 122). As an example Vygotsky (1978, p. 98) provided a stick used as a horse by a child: ”He cannot

detach meaning from the object, or a word from an object, except by finding a pivot in something else. Transfer of meaning is facilitated by the fact that the child accepts a word as the property of a thing (…). For a child, the word ”horse ” applied to the stick means ”there is a horse”, because mentally he sees the object standing behind the word.” The followers of Vygotsky developed further the idea of the role of object substitutes in the development of symbolic thought (e.g. Elkonin, 2005).

A.N. Leontjev introduced the concept of the object of activity and object-orientedness in activity theory. Russian and German languages have separate words for an object (‘objekt’ in both languages) that is an existing material thing and an object of activity (predmet, Gegenstand), that is an object of conscious transformation by humans able of resisting the projections of the humans (Kaptelinin, 2005). In the English language, the term object is used for both meanings, which is a cause for confusion. Leont’ev (1978, p. 52) gave two basic meanings to the concept of “object of activity”. Firstly it has a dual nature as something given, and, as something imagined and projected.

> Thus the object of activity is twofold: first, in its independent existence as subordinating to itself and transforming the activity of the subject; second, as an image of the object, as a product of its property of psychological reflection that is realized as an activity of the subject and cannot exist otherwise. (Leont’ev, 1978, p. 52)

This definition aims at surpassing the Cartesian dualism between the objective (given) and the subjective (imagined). It underlines that human thought needs to be studied as a part of practical activity, that is, as bodily transformative interaction with the environment which can be characterized as objective activity.

Secondly, Leontjev stated that the “object is a real motive of activity” and that an activity is recognized based on its object (Leontjev, 1977, p. 52):

> The main thing that distinguishes one activity from another lies in the difference between their objects. It is the object of activity that endows it with

> a certain orientation. In the terminology I have been using the object of activity is its *motive.*

This statement was related to Leontjev's distinction between the goal-oriented actions of individuals and groups, and collective activity based on a division of labour. When Engeström (1987) further developed Leontjev's ideas into a theory of expansive learning, he located these concepts in the context of the political economy, that is, in the context of the production and consumption of commodities in a capitalist society (e.g. Engeström & Blackler, 2005). In this way the concepts developed in psychological theory became a means of analysing the transformation of work activities in society and were applied in the study of various types of work such as health care, teaching, scientific research and the design of ICT systems (Engeström, 1990; Miettinen, 1998; Kaptelinin & Nardi, 2006).

In the context of the development of work, the term 'object of activity' assumed a double meaning. On the one hand, it referred to the "purpose" or aim, in other words the motivating background rationale of an activity: it is a horizon for actions that constantly need to be reinterpreted in a changing society (Engeström, 1990). The joint reflection on the changing historical circumstances of an activity, defining its contradictions, and the formulation of "a new model of activity" (or a model of a zone of proximal development) in interventionist studies serve such a historical reinterpretation. The second meaning of object of activity was a concrete object of activity, something that is designed and produced in the form of a product, a service or a commodity. The relation between these two was sometimes characterized by saying that a concrete object to be constructed is an 'instantiation' of the motive of the activity (Nardi, 2005) or a separate type of a 'project object' (Hyysalo, 2005). The expression "construction of an object" (a product, service, IT system, building) was partly formulated because of the influence of the constructivist science and technology studies that theorized and analysed the production of facts and technological artefacts.[1]

[1] Nardi (2005, p. 40) argued that "the notion of *constructing* an object is ambiguous in much of the activity theory literature". According to her, "we speak of constructing an object when we mean

In the 1990s and 2000s, new dimensions and meanings of an "object" of activity were introduced. These include its complex and contradictory, open-ended, multifaceted, and expanding nature. This complex and contradictory nature (referring to the functional complexity of the objects to be constructed) was discussed in product development literature and in science and technology studies (Hobday, 1998; Miettinen, 1999). Complex products are composed of subsystems whose design and construction call for the contribution of a different kind of expertise. Correspondingly, different actors have different interpretations of the object. The contradictory nature of objects refers to the tension between use and exchange value in them, as well as to the differing interests of the participants that need to be negotiated as a part of the object construction (Miettinen & Virkkunen, 2005).

In science and technology studies, Karin Knorr-Cetina introduced the concept of an epistemic object analogous to an object of inquiry in science, in which "the lack in completeness of being is crucial" (Knorr-Cetina, 2001, p. 182). Knorr-Cetina argues (2001) that in a contemporary knowledge society, the objects of professional work are rapidly changing. Compared with mass products or services, these objects are ever more complex, dispersed and in constant need of being redefined. This is why they can be characterized in terms of open, constantly unfolding epistemic objects. The theme of the open and expansive nature of objects has been further developed by introducing the term 'runaway object', ambiguous large-scale global phenomena which are not in anyone's control and which have far-reaching consequences that are difficult to anticipate (Engeström, 2008). Completely new forms of transnational distributed agency are needed in order to tackle such objects and problems. The increased complexity of objects is evident both in the construction industry and the ICT industry. The sheer size of buildings and the complicated devices and technology embedded in them has increased the number of contributors and correspondingly the need for coordination and collaboration.

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*formulating* it, that is, figuring out what it should be. *Instantiating* an object then refers to the work that goes into realizing a particular object, to achieving an outcome."

The increased number of relevant stakeholders has created the need for understanding how they are able to collaborate and coordinate their actions. The concept of boundary object originally introduced by Star and Griesemer (1989) has been used to make sense of this problem (Gal at al., 2008; Whyte & Lobo, 2010). In terms of activity theory, this concept mostly refers to the means or infrastructure of activities, not to the object of an activity. A lesson from the discussion of the object of activity is evident. The increasing complexity of the object of activity requires increasingly versatile constellations of means and artefacts and new forms of collaboration.

## 3 The relationship between language and tool use in Vygotsky and in studies of work

Vygotsky (1978) made a basic distinction between two types of mediational means: tools and signs. Tools and signs are both cultural means; they differ in the way that they orientate an activity. Tools are externally orientated and are used to transform objects (mastering their nature). Signs are used to coordinate the actions of individuals in a collaborative activity. Signs are also used as psychological tools, that is, to direct and control an individual's behaviours and actions (mastering oneself). In addition, Vygotsky says (1978, p. 55) that these two activities are mutually linked "just as man's alteration of nature alters man's own nature". He analyses this in terms of the integration of practical intelligence and sign use (speech) in child development where "the creation of these uniquely human forms of behaviour later produce the intellect and become the basis of productive work: the specifically human form of the use of tools" (ibid. p. 26).

In their essay *Tool and symbol in child development* (1994), Vygotsky and Luria criticize the prevailing "zoologist" approach to the study of child development, in which the preverbal forms of child development are compared to those of apes. They conclude that "[t]he child's use of tools is comparable to that of ape's only during the former's pre-speech period" (1994, p. 108). The planning and self-regulation function that speech brings to problem solving is missing from the apes. The main thesis is to show that (1994, p. 116) "[t]he transition from the biological to the social way of development constitutes the central link in this process of development, the cardinal turning point in the history of child

behaviour." The transition becomes visible in the uses of egocentric speech in problem solving by the young children. This is used for arguing for the emergence of the specifically human higher psychological functions that constitute a foundation for a psychological science.

Many authors have pointed out (Wertsch, 1985; Leiman, 1999; Arievich & Stetsenko, 2014) that Vygotsky and Luria do not deeply analyse the preverbal intelligence of children. Vygotsky and Luria (1994) use various terms for it: practical intelligence or thinking (p. 102), instrumental thinking (p. 102), tool use (p. 109), elementary process or function (p. 144), primitive processes of problem solving (p. 131) and finally, in their conclusions, a *biological line of development* (p. 148), which then is integrated with a "social or cultural" line of development based on the use of signs. We think that this rhetorical distinction does not give justice to the social and cultural nature of preverbal behaviour of the children, to which Vygotsky himself refers (1978, p. 30).[2] A one-year-old child imitating the voice of an engine when playing with a toy car is evidently a cultural phenomenon. The child's operations with objects are mediated by interaction with the mother and other significant people and with the cultural environment, and they acquire a cultural meaning and emotional colouring through these interactions.[3] This acquisition of the meanings of objects might well be characterized as an early form of semiotic mediation (Leiman, 1999). Also Lektorsky (1999, p. 111) suggests, based on studies on the education of deaf and blind children, that a baby can only appropriate genuine speech after appropriating meaningful social modes of dealing practically with man-made objects.

We find a sign- and language-bound conception of semiosis to be limited. First, it seems that the concept of an object is underdeveloped in semiotic approaches to cultural

[2] "This complex human structure is the product of a developmental process deeply rooted in the links between individual and social history" (Vygotsky, 1978, p. 30).

[3] Evidence of the beginning of the social and cultural development of human fetuses and newborns is accumulating. During the last trimester of pregnancy human fetuses develop sensitivity to melody contour in both music and language. A newborn prefers his or her mother's voice over other voices and distinguishes prosodically different languages based primarily on melody (e.g. Mampe et al., 2009).

mediation. Semiotic relationships are often seen from the point of view of symbols and language, which themselves, however, include indexical and practical relationships. Peirce's seminal works on semiotics define a sign as mediating between its object and interpretant, or roughly, its meaning (Peirce, 1998, p. 477-491). He defines semiotic relationships not just with symbols but also with indices; that have a physical connection to objects and with icons, that represent objects with their characters. Human beings use not only talk, but gestures, bodily dispositions and affordances or semiotic features of the environment in their activities (Goodwin, 2000).

The excessive focus on speech, narrative and discourses also makes activity theory vulnerable to the critique of pragmatism, phenomenology and ethnomethodology that underlines the significance or primacy of habits, skills and embodied forms of intelligence. These approaches argue that human practice is composed of bodily ways of acting, or of habits. Reflection and the use of language are needed primarily when a habit breaks, or to legitimate the ways of acting. According to these approaches, learning skills and tool use may take place by imitation and by trial and error without systematic instruction and the use of language.

A recurrent observation of studies of practitioners and professionals in work is that they are unable to formulate verbally why they do as they do (e.g. Engeström & Engeström, 1986). A key statement of the pragmatism-inspired theory of professional knowledge by Argyris and Schön (1978) is that professional practitioners present verbally an "espoused theory" which deviates from the real way of acting, a "use theory" that can be uncovered by studying the actual work process. These findings question the idea that a speech or a verbally formulated plan in itself is able to guide the uses of tools. They rather suggest that there may be incompatibilities or loss of interaction between future-oriented "where-to" models (Engeström, 2007) and meanings embodied in different types of artefacts already used in work. If cultural means – as we will suggest – comprise complexes of various means having different origins, it is likely that there are tensions and contradictions between them. This leads us to the analysis of different kinds of means and their interaction activity.

## 4 Artefacts and the concept of instrumentality

In sociocultural psychology and activity theory, it has become customary to refer to both signs and tools with terms such as mediational or cultural means, instrument (e.g. Engeström, 1987) and artefacts (Cole, 1996).[4] The concept of artefact refers to a man-made object that has a meaning and constitutes a part of our culture.[5] Engeström adopted (1987) the concept of an artefact from the historical epistemology of Marx Wartofsky (1979). Wartofsky draws a distinction between primary, secondary and tertiary artefacts. Tools and related bodily skills are primary artefacts. Secondary artefacts, typically models, are "distinctive artefacts created for the purpose of *preserving* and *transmitting* skills, in the production and use of 'primary' artefacts" (Wartofsky, 1979, p. 201). Tertiary artefacts are alternative imaginative perceptual models, "a representation of possibilities which go beyond present actualities" (ibid. p. 209). Although Wartofsky's levels have not been extensively used in empirical research and provide only a rough classification, they are important in suggesting that artefacts have different functions in an activity beyond the distinction between sign and tool.

Engeström (2007) has used Wartofsky's term "tertiary artefact" characterizing it as a where-to type of cognitive artefact that is used to orient to the future and to imagine and define alternative forms of activity. He (ibid., p. 34) has also made a distinction between epistemologically different levels of orienting models used in work and in teaching. For example, procedural models included in guidelines and instruction books mainly express the order in which actions and operations are to be done. They do not provide knowledge of why the defined order is selected nor of the nature of the object of the work. Answers to

[4] The root of the term instrument may be found in Vygotsky, who speaks about instrumental as synonymous with "artificial" and in opposition to natural (1981, p. 137). He also uses the term "artificial device" (ibid.).

[5] Miller (2011) warns about the danger of using the concept of artefact, because it hides the distinction between sign and tool. This interpretation seems dichotomic in studying such modern mediational means discussed in this chapter as a care plan or a digital model of a building.

these issues require systems models or theoretical models. For the development of activities, it is a major challenge to study empirically the functions of various artefacts and their interdependencies.

The prevailing theory of artefacts both in philosophy and in design studies, is a theory of the functions of artefacts. In design theories, designers deliberately create the functions of an artefact or organize material affordances in order to satisfy the needs of the users (e.g. Norman, 2002). The function theory in analytic philosophy also analyses the functions or capabilities and dispositions of cultural artefacts (Preston, 1998; Houkes & Vermaas, 2004). A multiplicity of functions of artefacts emerges when users invent uses that depart from the focal use planned by the designer. The function theories are compatible with the theories that regard the objectification of human activity into artefacts as a central mechanism of cultural development. Ilyenkov (1977a, p. 277) suggests that "all forms of activity (active faculties) are passed on only in the form of objects created by man for man". Actor network theory has studied the agency of material artefacts and the delegation of human functions and norms to objects (Latour, 1992). According to Latour (1994, p. 31), technical artefacts have a script, an affordance, a function or a programme of action and goals.

Dewey (1991/1938, p. 52) finds that: "A tool or a machine, is not a simply a simple or complex physical object having its own physical properties and effects, but is also a mode of language. For it *says* something, to those who understand it, about operations of use and their consequences." Dewey underlines that the utilization of embodied norms of and understanding the consequences require the learning of embodied skills. Lektorsky's characterization includes three objectified elements (1980, p. 137): "The instrumental man-made objects function as objective forms of expression of cognitive norms, standards and object-hypotheses existing outside the individual." However, these general definitions do not uncover how specific functions are embodied in different artefacts and how these different artefacts together constitute what is needed in a mediated collaborative activity. Engeström has introduced the concept of instrumentality (2007). The concepts, models and tools in work "are not separate meditational entities, but form integrated toolkits, (…) tool constellations or instrumentalities" (ibid., p. 33). They (Engeström 2005, p. 188) "include multiple cognitive artefacts and semiotic means used for analysis and design, but

also straightforward primary tools used in the daily practice and made visible for examination, reshaping and experimentation". The term instru-*mentality* reminds us that intellectual and practical, embodied functions are inseparably and in various ways interconnected in an instrumentality and even in single artefacts within it.

The concept of instrumentality has an analogy in Elinor Ostrom's (2007) concept of a *rule constellation* or *rule configuration* which is used in the analysis of institutional change in self-organizing resource governance systems. Ostrom underlines the configurational nature of rules (2007, p. 18): "One needs to know the basic contents of a *full* rule configuration, rather than a single rule, to infer both the structure of the resulting situation and the likely outcome of any particular rule change." For the examination of the transformation of rules, she has made a distinction between seven clusters of rules according to the element of action and the decision-making situation they directly affect (2007, p. 11).

After the emergence of the Internet, ICT researchers have likewise pointed out that digital objects cannot be studied as separate, stand-alone or single artefacts or tools (Henfridsson & Bygstad, 2014). Digital artefacts are relational and modular and tend to form complex systems, mediate activities of several organizations and knowledge domains, and create connections between distant data sources through the Internet. Information systems research suggests that information or digital infrastructures constitute a new type of information artefact (Henfridsson & Bygstad, 2014). These views agree on the 'expansive potential' of the systems: because of their inherent digitally enabled scalability and flexibility, they are generative: they grow and evolve. To enable the integration of new modules into the evolving systems, gateways and standards must be core elements of the infrastructures (Hanseth & Lyytinen, 2010, p. 4).

## 5 A new vision does not suffice: a failed remediation in oral health care

A conscious change in an instrumentality as a part of developing an activity has been characterized as remediation. Remediation includes the formulation of a vision or a model of an alternative way of approaching an activity (a where-to model or a working

hypothesis) as well as a change in the whole constellation of artefacts and social forms of collaboration (Miettinen & Virkkunen, 2005). To clarify this, we will shortly analyse an example of an attempt to develop dental care for adults with periodontal diseases in Finland.

As a result of demographic change and a more inclusive level of dental care, periodontal and gum diseases have become the most frequently encountered oral health problem among the adult population in Finland. In a study of adults over 30 years, 64% of the studied adults had periodontisis to some degree of difficulty (Teräs & Nuutinen, 2010, p. 56). Periodontitis is a serious gum infection that damages the soft tissue and destroys the bone that supports the teeth. Periodontal and gum diseases call collaboration between dentists and oral hygienists as well as active preventive self-care by patients. A new model, called a health-centred teamwork model, was outlined for dental care in two projects in the years 2007-2010 by representatives of a university dental clinic, an oral hygiene clinic of a university of applied sciences, and a city dental-care clinic. The model was defined in a graphic form in the thesis of one of the participants in 2009. It envisioned three kinds of transformations in the care: first, a transition from individual care to teamwork; second, from a pathogenesis-based orientation to a health and preventive orientation; and third, from expert-centred to patient-centred and activating care. The key elements in the graphic model were "Preventive advancement of the health of the mouth" and "An environment that supports health behaviour" (Teräs & Nuutinen, 2010, p. 55).

The model was planned to be experimented on and put into practice in an interim period in a dental clinic in the city of Helsinki. In the interim period, dental students and oral hygienist students together cared for adult patients under the supervision of their teachers. Two patient care trajectories of nine sessions were recorded and analysed in a study (Teräs, 2015) to find what kind of changes took place in the collaboration and in the division of labour between the professionals and in the interaction between the professional and the patient. The study provided an opportunity to study whether and in which ways the new model, to use Vygotsky's expression, "penetrated the process of tool use". For that, the instrumentality used in the collaborative care activity needed to be characterized. A distinction can be drawn between seven types of means:

1) The model of health-centred teamwork
2) Instructions and manuals defining good practice – one for the dental students (PARO Manual) and one for the oral hygienist students (instruction for the care of adult patients)
3) Diagnostic means: 1) x-ray imaged, 2) digitized pictures and, 3) an instrument for measuring the depth of the gum pockets
4) A care plan: the patient's diagnosis (see Figure 1) and a plan of care measures.
5) The means of evaluation
6) The instruments for caring for the teeth and gums
7) The instruments used by the patients in self care

The researchers (Teräs & Nuutinen, 2010, p. 58) used the concept of a 'script' to characterize the tools of the second category (instructions and manuals). They provided a description of the phases of the care process and characterized the actions and operations included in each of the phases. A decisive means in this system is without doubt the care plan. The details of the diagnosis are assembled in it (see Figure 1), which provide a basis for the plan of care measures, most important of which are removing the dental plague and cleaning the gum pockets. The care plan combines an object hypotheses (analysis of the state of the disease) and an operational plan for care.

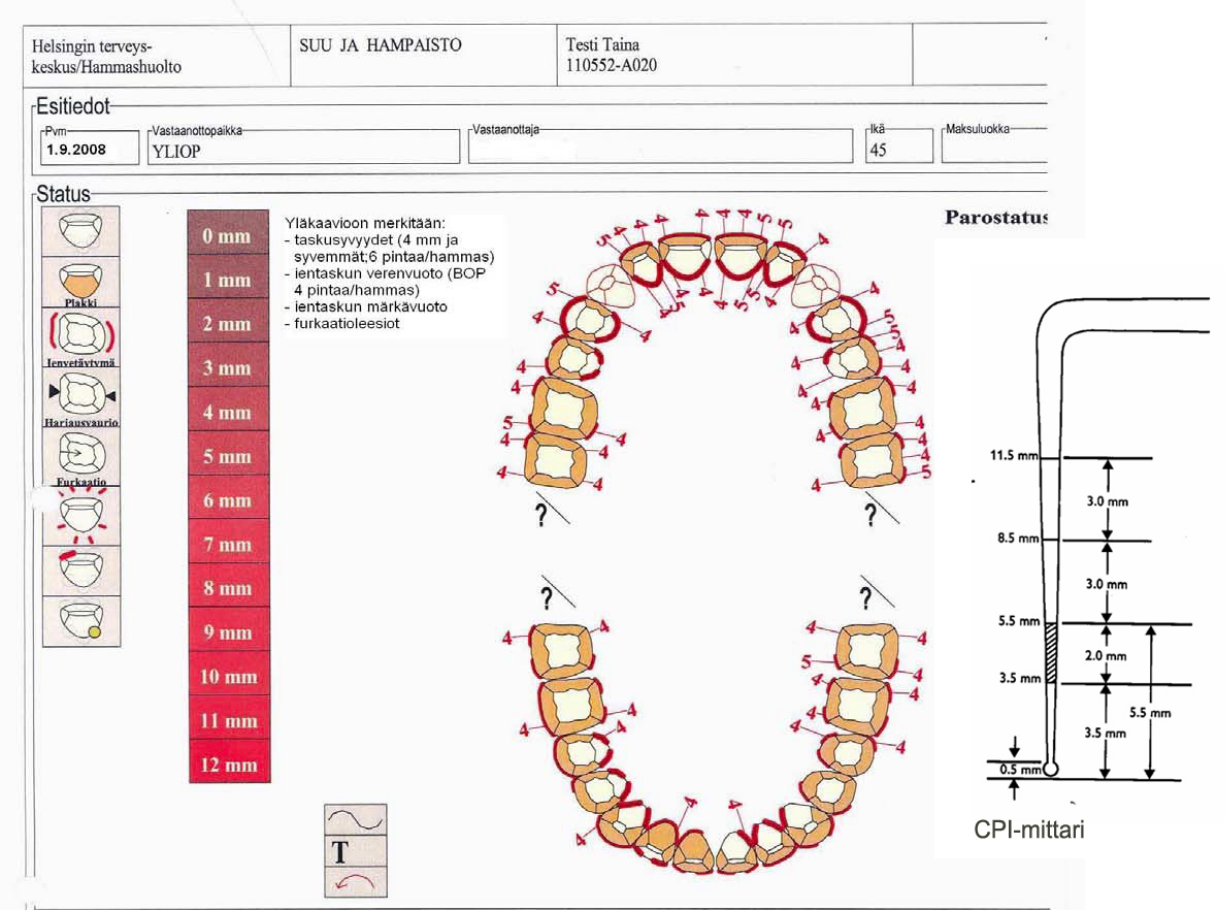


**Figure 1**: Status of the gum disease defined in the care plan

The results of the analysis of the communication and tool use during the care trajectories show that the new ideal model of collaborative patient-centred model tended to remain an 'espoused theory'. An important reason for this is that the ideas presented in it were not included in the manuals that regulate the care activity. For example, although consultation and dialogue with the patients to stimulate self-care was a central goal in the model, no space was reserved for this in the care process defined in the manuals. Nor were the diagnostic pictures of the patient's teeth used in the consultation to clarify the status of the disease for the patients. The care plan was not shown to the patient, who, according to the new model, was supposed to take increasing responsibility for the care. The care plan remained a means of the professionals. The short discussions with the adult patient focused on very elementary measures of caring for the teeth and questions covered topics

such as smoking, the use electronic toothbrush or flossing. As mentioned before, no information of the state of the disease whether illustrated in pictures or defined in the care plan was shown to the patients. The ideals presented in the new model and the traditional ways of professional work embodied in the instruction manuals were in gross contradiction. The exclusive use of diagnostic tools and the care plan by the professionals also contradicted the model.

## 6 Shifting multiple functions of Building Information Modeling

We have been involved in studying the implementation of Building Information Modelling (BIM) in the construction industry in Finland (Miettinen & Paavola, 2014). BIM is a new technology that combines 3D-digital representations of a building with parametric data of the objects (parts) of the building. BIM tools allow new levels of spatial visualization and – as a result of the parametric data of the objects – simulations of the behaviour of the building such as energy consumption and lighting. BIM was developed from standards that allow interoperability of information between 'native' design models and data sharing (at least potentially) between various partners in the construction process, that is, between architects, structural engineers, HVAC (heating, ventilation, air conditioning, electricity) engineers, customers, contractors, and site engineers. The most important of BIM standards is the IFC (Industry Foundation Classes) data format, published in 1997. The standard enables the creation of a unified model or data repository shared by all stakeholders during the planning process and the lifecycle of a building (Miettinen & Paavola, 2014). According to the proponents of BIM, this possibility will revolutionize the collaboration both between designers and between designers and other stakeholders in the construction industry, but it requires the development of new ways of working with BIM. It is expected to lead to an integrated way of working and to the increased productivity of the industry.

Like most digital artefacts, BIM is not a separate entity. It is composed of a number of different software programs, most of which may be used interactively thanks to the

standards. In the Finnish construction project that we studied, the designers used nine different software programs from seven different providers (Table 1).

**Table 1.** BIM-related software used in a Finnish construction project in 2011-2012.

| **Software** | **Main users** | **Main uses and outcomes** |
|---|---|---|
| 1. ArchiCAD | Architects | Architect model |
| 2. Tekla Structures | Structural engineers | Structural model |
| 3. Tekla BIM sight | Structural engineers Architects | Creating a combined model and checking the compatibility of the native models (1 and 2) |
| 4. MagiCAD | HVAC engineers | HVAC-models (electricity, plumbing, ventilation) |
| 5. Dialux | HVAC engineers | Lighting |
| 6. NavisWorks | HVAC engineers | Combining HVAC models and checking the compatibility of the native models (4) |
| 7. Solibri Model Checker | BIM expert | Creating combined models of all native models and clash detection lists |
| 8. Solibri Model Viewer | All designers | Viewing the clashes (7) |
| 9. Riuska | HVAC engineers | Energy simulations |

Each program has specific pre-planned functions, such as allowing architectural design, calculating energy consumption, and viewing the clashes between the models. BIM is not an established infrastructure or a system. New special purpose software is continually emerging and different firms configure their own unique systems of them to meet their needs and develop their own particular expertise and organizational forms to utilize these programs. The process resembles the creation of enterprise information systems, which have been characterized as architectural or configurational technologies

(Fleck, 1994). Typically, parts and modules developed by several vendors are combined and adjusted to meet the local needs of the users. In addition, in each construction project, the key partners must agree on which software will be used in the project and how. That is why we characterize BIM as an evolving, configurational and constantly re-negotiated instrumentality.

The software is used to produce native models (plans of the building) that play a central role in its design. These models work as intermediary artefacts or objects in the design work and collaboration. The term 'intermediary object' has been used to refer to the open and evolving nature of the design process instead of the traditional model of design as a linear and sequential process (Boujut & Blanco, 2003; Ewenstein & Whyte, 2009; Vinck, 2011). The term intermediary object depicts the nature of the design process as composed of cycles of collaborative design during which the disciplinary native models (architectural, structural, HVAC) produced by different design disciplines using special-purpose software (see Table 1) are fused into combined models. The models are simultaneously a partial outcome of joined work and a means of joined reflection and problem solving concerning the following cycles of design. The function of BIM changes during the design cycles from a tool used by the designers to an intermediary object and back to a tool again.

The BIM software and models are used in the design process in the following ways:

1) *As tools for design work within each design discipline:* The designers of different fields, individually and as a group, construct native models using BIM software (software 1,2,3 and 5 in Table 1).
2) *As tools of constructing combined models* (software 2, 6 and 7 in Table 1)
3) *The combined models function as tangible and indexical objects of joint problem solving* and reflection, and as intermediary outcomes of joint work (see Figure 2)

4) *The combined models function as means of coordination* of the further work of the designers [6]
5) *The models function as a data source* for *a)* simulations of the behaviour of the building (energy, lighting), b) for cost calculations, c) for project planning and, d) for completing the orders from the suppliers.

A simple distinction between sign and tool can hardly be used to characterize BIM. The designers use BIM software as the main operative tool to produce the native models. The software is packed with symbolic and operative knowledge. Energy simulation software, for example, embodies theoretical knowledge of the physical properties of construction materials and is used as a tool to provide calculations of the energy consumption of the building alternatives to the clients. In the area of engineering design, the uses of sketches, paper drawings and plans have been seen as tools of collaboration and communication as the designers engage with these artefacts in design meetings in indexical and even tactile ways (Ewenstein & Whyte, 2009; Henderson, 1999). The use of BIM models does not change these basic functions and uses of design plans. The combined models are not only symbols but modifiable intermediary artefacts, or "special objects" (Ilyenkov, 1977a, p. 280), that are revised collaboratively during the design process**.** Ilyenkov (ibid.) characterizes a special object using the example of the drawings in an architect's work: "In changing it he potentially alters the real house, i.e. changes it ideally, potentially, which means that he alters *one sensuously perceived object instead of another*."

We consider one novel feature of BIM models as intermediary artefacts to be their capacity to provide new means for collaboration and to play several functions in the course of a design process: a tool of disciplinary design work, a tool of collaborative problem solving as well as an immediate object of reflection, and an evolving intermediary object to

[6] The definition of the functions of the combined models depends on the temporal perspective. In a joint meeting of designers, they are immediate objects of attention, from the point of view of the following cycle of design they are means of coordination, and from the point of view of the entire design process they are intermediate objects or outcomes.

which the outcomes of the cycles of design are objectified. The modifiable, updatable, modular and variable nature of digital artefacts allow this flexibility (Kallinikos et al., 2010). This changing status is compatible with the activity theoretical view, according to which any entity may gain different functions depending on its position in the structure and course of an activity. In the temporal process of an activity an object can become a tool and a tool can become an object. The most evident transformation takes place when an outcome of the design phase, an as-designed model, is handed over to the constructors and becomes a tool of the construction work. Because of the modifiability of digital artefacts, the transitions between functions seem to be much more flexible than when using traditional tools.

## 7 Conclusions

In the activity-theoretical tradition, the distinction between sign and tool drawn by Vygotsky has been a central starting point. Vygotsky, however, found the intertwining and unity of sign mediation and tool use at the centre of complex human behaviour. Our cases indicate the increasing significance of preparatory work and planning in professional activities. In preparatory work, models and plans are typically worked on as 'special objects' instead of a final object. These tend to be hybrids fusing intellectual and practical-operational functions, as in the cases of a care plan or modelling software. In addition, artefacts of different types and levels within an instrumentality complement each other.

Since the artefacts within the constellation have, however, been adopted at different times and have different origins, different meanings and operational logics have been embodied in them. Our example of the instrumentality of the oral care of adults showed that different artefacts can be incompatible. The old artefacts in use, relations of power and traditional ways of professional thinking and acting resisted the implementation of a new model or an idea of activity. For the transformation of an activity, it is therefore essential to achieve a sufficient fit and coordination between the artefacts. If this is not done, the 'tertiary' or where-to artefacts, or the verbalized visions of alternative practices, risk remaining utopias unable to become the practical transformation of an activity. It seems to

us that analyses of instrumentalities, that is, the different levels and types of artefacts, their specific functions and their interdependencies characteristic of different activities, are needed to enlarge our understanding of semiotic, practical and cultural mediation. Such analyses are also important for well-informed remediation in interventionist studies.

The study of BIM revealed that the constellation of artefacts not only constitutes complex constellations, but the artefacts also constantly evolve, are locally configured and call for constant negotiations between partners in collaborative projects. The building information modelling also showed that during the cycles of design BIM software functioned as a basic tool of design disciplines, an immediate object of collaborative problem solving, an intermediary outcome of joint work as well as a means of collaboration. BIM models as intermediary artefacts play several functions in the course of a design process. The modifiable, updatable, modular and variable nature of digital artefacts contributes to the flexibility of their functions.

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