Tools and Artefacts - Knowing 'Where-from' Affects their Present Use

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Abstract

This paper focuses on how past knowledge of tools/artefacts affect their present use. The discussion is based on Wartofsky's (1979) primary, secondary, and tertiary artefacts, and Engeström's (1990) subsequent activity theoretical elaboration. While Engeström identifies two different kinds of internal (mental) secondary artefacts, this paper identifies an additional kind of *tertiary* artefact – *'where-from' artefact* – that consists of experience based knowledge of the past. The conception of where-from, contributes to understanding, for instance, why people handle objects the way they do. This artefact, identified in a workplace study, also plays an important role in the process of learning through apprenticeship, since what novices are provided, in terms of instructions etc., partly depends on the more knowledgeable person's past experiences.

Keywords: tool, artefact, artefact categories, 'where-from' artefacts, learning, apprenticeship

Introduction

In the era of the prevailing computer metaphor for the mind, the role of artefacts/tools, especially in social interaction, was mainly left unattended, while, e.g., social processes and language have received much attention. Linguistic research, for instance, has resulted in a large number of theories on language development and construction, but there is nothing comparable for tool behaviour, which is largely an overlooked issue (Gauvain, 2001; Want & Harris, 2001). As pointed out by Wynn (1993, p. 392), "[t]here is almost no concern with how tools are made and used and there are no well-developed theories of how sequences of tool-use are constructed" (see also Preston, 1998). It is strange that the use of artefacts and tools has been neglected to such an extent, since, as argued by Woods (1998), one of the fundamental findings of cognitive science is that "artefacts shape cognition and collaboration" (p. 168) (cf. Clark, 2002; Kirsh, 1996; Malafouris, 2004; Vygotsky, 1960/1981).

Schiffer (1999), an anthropological theorist, is straightforward in his critique of scientists' blindness for artefacts:

"Might [we] not wonder how social scientists, who like all other people spend the entirety of their time engaged with artifacts (especially books and chairs and computers), could be so oblivious to the medium that envelops them? People's lives are spent shaping and responding to this *material medium*, yet social scientists cannot see it for what it is, much less understand its pervasive influence. Instead, human investigators lavish attention on the sounds that people produce, on the specialized artifacts that encode or record the sound, and on the social, cultural, and biological bases of sound production, reception, and interpretation. Preoccupation with these phenomena…has seriously skewed the study of human behavior. Apparently, total immersion in the material medium has blinded social scientists to the distinguishing characteristic of their species – of their lives". (p. 4)

Although Schiffer's critique concerns the social sciences, the same point certainly also applies to cognitive science. However, although Schiffer's argument applies to much research it would be presumptuous to claim that artefacts have been neglected altogether. On the contrary, several descriptions and perspectives on cognition and tool use are available (e.g., Baber, 2003; Goodwin & Goodwin, 1996; Engeström, 1990; Heath et al., 2000; Hutchins, 1995; Keller & Keller, 1996; Kirsh, 1996; Norman, 1988; Salomon, 1993; Scaife & Rogers, 1996; Zhang & Norman, 1994). For instance, the *distributed cognition* approach (Hutchins, 1995), places much focus on the role of tools in socio-technical systems. Nevertheless, although attention has shifted to consider the role of tools/artefacts in cognition, there are few theories on the issue, and even central terms such as tool, artefact, and tool use are often ill-defined and we lack a coherent view on their meaning (cf. Preston, 1998; Susi, 2006).

However, neither is this paper concerned with tool use theories or definitions of the mentioned terms. Instead, its contribution lies in furthering our understanding of tools and cognition by focusing on, and elaborating, a specific artefact categorisation, formulated within the frame of the cultural-historical school of thought (e.g., Leontiev, 1978; Vygotsky, 1978). In line with this perspective, and based on a categorisation proposed by Wartofsky (1979), Engeström (1990) has formulated a three-level artefact categorisation, which comprises external as well as internal artefacts. For some, the term 'internal artefact' might seem an awkward one, especially when considering that what is mental (in the context of cognition and tool use) is more commonly termed internal psychological *tools*. However, in Wartofsky's and Engeström's terminologies, the term artefact is mostly used when referring to what is external and material, and to that which is internal and mental, such as heuristics and (mental) models (notably, however, Engeström uses both terms for external objects). In the following, the existing terminology will be followed. It should also be noted that the issues presented in this paper are part of a larger framework regarding the significance of tools in cognition and cooperation (Susi, 2006).

The rest of the paper is organised in the following way. The next section describes Wartofsky's (1979) three-level artefact categorisation, and its elaboration as formulated by Engeström (1990). The following section describes a case

study which illustrates the mentioned categorisations and also identifies an additional category, which subsequently extends Engeström's description. The paper ends with a discussion.

Artefact categories

A well-known categorisation of artefacts is Wartofsky's (1979) primary, secondary, and tertiary artefacts. *Primary artefacts* are ones used directly in production, such as axes, needles, bowls, etc. *Secondary artefacts* are internal and external representations of primary artefacts, and they are created and used "in the preservation and transmission of the acquired skills or modes of action or praxis by which this production is carried out" (p. 202). As such, secondary artefacts are representations of these modes of action. 'Representing a mode of action' also means that these artefacts are related to conventions, as in rules and norms. *Tertiary artefacts* are 'imaginary' artefacts such as art or 'free' play or game activity. Such artefacts have 'lost' their original role of representation, since they have become "abstracted from their use in productive praxis" and from their "direct representational function". Therefore they no longer appear directly practical.

Wartofsky's categorisation has been further elaborated, from an activity theoretical perspective, by Engeström (1990). In his formulation, primary artefacts are termed *what-artefacts*, and they are basically the external entities used in an activity, such as documents and marks on computer screen (the examples used here are from Engeström's study in a health care centre). He further differentiates between two types of secondary artefacts, i.e., *how-artefacts* and *why-artefacts:*

o *How-artefacts* are specific types of artefacts (routines, procedures, etc.) that tell us *how to handle a certain object* of an activity, in this case a patient, with a corresponding primary artefact. How-artefacts can be both external and internal. For instance, routines for computer use may be found in a written form, while people also have their personal internal versions of them. These how-artefacts, then, tell how to handle a corresponding primary artefact, for instance, routines for how to handle computer data on a patient.

o *Why-artefacts* are general types of artefacts that inform us *why the object of an activity behaves the way it does* (e.g., a patient), which justifies the selection of some specific primary artefact. These why-artefacts are internal, mental explanatory models, but they can also be (although not always easily identified) externalised in words, gestures, etc. As described in Engeström's health care centre study, the explanatory model (of a patient's illness) held by a doctor, emerges from his/her expectations and preconceptions, and initial data (e.g., the patient's medical record). On the basis of the first impression and the patient's own account, the doctor constructs a meaningful pattern and "makes sense of the accounts with the help of some more or less consciously held explanatory model of illness" (Engeström, 1990, p. 183). The meaningful pattern

is subsequently transformed into a diagnosis. In other words, the doctor forms a hypothesis concerning the patient's illness, which is accomplished through examination and testing. Hence, the hypothesis justifies a certain kind of examination, which, in turn, depends on the doctor's knowledge and mastery of the procedures for certain examinations and tests.

Engeström (1990) also identifies tertiary artefacts, which he terms *where-to-artefacts*. These are artefacts that "go beyond the explanatory or diagnostic 'why' function" (p. 194), and as such they are close to Wartofsky's imaginary (tertiary) artefacts. Where-to artefacts can be described as projections into the future, or a vision of what will follow from, e.g., demanding changes in tools. The primary psychological importance of where-to-artefacts, we are told, may be their power of motivation; an analysis and vision of the future is important for motivating acceptance and implementation of new tools. The different categories of artefacts are summarised in Table 1.

Table 1. Summary of artefact categorisations by Wartofsky (1979) and Engeström (1990).

Wartofsky	Engeström
Tertiary artefacts Imaginary artefacts	*'Where-to' artefacts* Vision of future (consequences of new tools in organisation)
Secondary artefacts Internal and external representations of primary artefacts	*'Why' artefacts* General type, why object behaves as it does. Justifies selection of certain primary artefact: e.g., hypothesis – examination *'How' artefacts* Specific type, how to handle object with corresponding primary artefact: e.g., routines for computer use – computer data on patient
Primary artefacts Directly used in production	*'What' artefacts* External physical entities (marks on computer screen, documents)

In sum, Wartofsky's categorisation provides a general description of three kinds of artefacts: material entities, their (internal and external) representations, and imaginary ones which may no longer be directly practical. This categorisation has been further elaborated by Engeström, and also applied to a work context. In his formulation, the categories describe a) material entities, b) general and specific types of internal and external artefacts, which justify and guide the selection of corresponding material entities, and c) visions of what will follow from changes brought onto an activity.

A case study

A case study was conducted in a naturalistic setting, in the control room of a Swedish grain silo (Lantmännen Ek.för). The study's duration was 3 weeks, in the course of which data was collected through interviews, observations, and video recordings (8 hrs in total). Six staff members participated in the study, two women and four men, of which 2-3 people work at the same time in two or three shifts. Their ages varied from 19 to 60 years, and their experience of working in silo control rooms varied from none to 26 years; two of the workers were highly experienced, and four were novices (the case study is discussed in more detail in Susi, 2005; 2006).

Among the many tasks and procedures carried out by the staff is to coordinate the off-loading and conveyance of grain into (one of 29) different silos. Roughly, the conveyance procedure is as follows. Upon delivery, the grain is off-loaded into one of three pits, and for each delivery the staff prints a number of documents which are placed on a desk while the grain is being conveyed. Basically, the procedure, and the whole plant, is controlled and operated through a control panel located in the control room. The transportation process itself is started by pushing a sequence of 12-15 buttons on the control panel (the number of pushes required depends, e.g., on the machinery's status). Which buttons to push is indicated by lines in different colours representing transportation shafts, along which the buttons are placed. While tracing the line itself is easy, the timeliness of each push depends on the underlying machinery (type of engine, its condition, etc.). This aspect is not visible on the control panel, and instead requires thorough knowledge of the relations between the panel and the machinery. The conveying process is monitored through the control panel (which indicates the status of the machinery) and scale displays (numbers showing the weight of the grain that has been conveyed).

Of all the tools and procedures to be learned in the control room, the control panel requires the most effort. The efficiency of handling work tasks related to the control panel hinges on knowledge of how the panel (its buttons and switches) is related to the underlying machinery it operates. The machinery is complicated and it takes two years or more to gain in-depth knowledge of the functional relationships between control panel and machinery, which is necessary in order to operate the panel properly. Furthermore, the panel can be flexibly operated, provided a worker has sufficient knowledge of its different options. Novices learn the trade through a process of apprenticeship, in which more experienced workers explain and show how to carry out tasks. Thus, novices learn by watching, asking questions, and through hands-on experience.

Obviously, the control panel is an important tool in this setting, but the following paragraphs will focus on some *psychological* artefacts, which play an important role when handling material artefacts such as the control panel. Moreover, these psychological artefacts also affect the way experienced and less experienced workers, respectively, operate material artefacts. Specifically, focus will be on one of the mentioned artefact categories, and its elaboration. This new category, which was revealed when analysing the collected data, is termed *where-from artefact*. Eventhough the term 'artefact' may bring *material* objects into mind, it is important to note that here the term refers to both internal mental and external material artefacts, in accordance with the terminology formulated by Engeström (1990).

A new category of artefacts

Applying the previously described artefact categorisation by Engeström (1990) to the control room, a number of these different kinds of artefacts are identifiable. Firstly, *what-artefacts* (primary) are the external entities used in an activity, in this case, the process of conveying grain. These include, for instance, documents, marks on computer screens, and scale displays.

Secondly, there are two types of secondary artefacts, that is, how- and why-artefacts: *How-artefacts* indicate *how to handle* a certain object (the grain about to be transported into a silo) with a corresponding primary artefact (the control panel). How-artefacts can be both external and internal. In this case, there are no external how-artefacts such as instructions for how to operate the panel/machinery, only (personal) internal ones for how to transport the grain. Such internal how-artefacts are most clearly expressed in the different ways different workers handle the machinery. These internal how-artefacts tell the workers how to handle the corresponding primary artefact, that is, the control panel. *Why-artefacts* are general types of artefacts (internal, mental explanatory models) that inform the workers *why* an object of an activity (e.g., the grain) behaves as it does, which justifies the selection of some specific primary artefact. If, for instance, the flow of grain suddenly stops (indicated, e.g., by the numbers on the scale display not changing), a worker constructs an explanatory model of why it has stopped (the model may be externalised in words). In line with Engeström's (1990) argument, it can be said that the explanatory model emerges from the worker's expectations and available data (e.g., type of grain, the control panel's status, numbers on the scale display). Thus, from these 'first impressions', he/she constructs a meaningful pattern, which is subsequently transformed into a hypothesis concerning why the process has stopped, e.g., that there is a break-down in an engine. The hypothesis justifies the selection of certain primary artefacts (e.g., a specific engine and parts of the panel related to it), and the selection of a certain kind of examination and testing, which, in turn, depends on the worker's knowledge and mastery of their procedures. Importantly, however, the explanatory models constructed by the workers are not necessarily correct with regard to why an object actually behaves the way it does.

Thirdly, *where-to-artefacts* are described as projections into the future, going beyond the explanations and diagnostics of why-artefacts. These are visions of what will follow from, for instance, demanding changes in tools. No such artefacts were identified since there were no plans for any changes in the control room at the time of the study.

In addition to these different kinds of artefacts, described by Engeström, I have identified an additional category not included in his model. This new category consists of internal, *experience based knowledge*, which can be termed **where-from artefacts.** As workers gain experience they

also gain knowledge of the past, i.e., how things used to be, and the changes that have taken place (organisational, tool implements, etc.). For instance, before the event of control panels, every control room was equipped with a chalk board containing a representation of the silos, used for noting the types of grain stored in them (Figure 1). However, such representations and the machinery for operating the silos were not integrated at all.
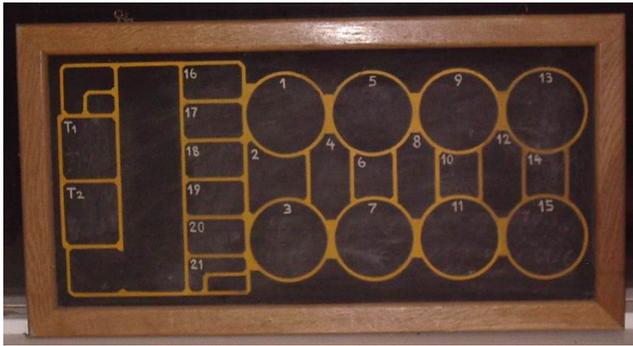

Figure 1. Chalk board of the kind that used to be in all control rooms. It represents the different silos and was used for marking the kind of grain stored in each silo.

With technical development, chalk boards were replaced with control panels through which the machinery is operated, and they also contain integrated representations of silos and machinery (Figure 2). In addition, over a period of some 10-15 years new technical features, and their representations, have been increasingly added to the control panel. While there is no chalk board in use in this specific silo anymore[1], it has contributed to the present 'where-from' knowledge held by the most experienced workers. The silo was originally built at a time when there were only four different kinds of grain to handle, and, as explained by one of the experienced workers, it used to be easier when grain could be put directly into one of the silos, without having to "manipulate the machinery" too much. Today they handle eleven different types of grain which requires a flexible use of transportation shafts, from three different pits to the plant's 29 different silos. With all sorts of grain stored in the silos, one single load often has to be conveyed through more than one shaft before it reaches its final destination. There is no fixed way to handle the machinery, or the facility as such, and there is an unspoken or tacit agreement that things can be done in different ways. Subsequently, people have their own ways of doing things. As one worker explained, referring to the process of drying grain, "it is smooth to run it this way…this is how *I* run it, but somebody else may run it in a different way"[2]. The same worker also said (his emphasis in italics and clarifying comments in brackets):

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[1] In some facilities chalk boards are still in use, in parallel with modern control panels.
[2] The participants' quotes have been translated from Swedish by the author.

"Everything is so complex … the machines, and what we're dealing with here are from *1967* … things have been added to the panel and it's been remade a number of times ... and we have all the sources of error following from *that* ..."

"... from the 50s until some ... ten years ago ... everything was operated mechanically [in silos in general] ... one went in and started things here and there in the plant ... hatches were regulated by pulling ropes ... that was the 50s, then we got engines for opening the hatches ... [the way] many things are operated and controlled remain from the 50s ..."

Figure 2. The electronic control panel, with integrated representations of the silos (upper left) and the machinery, through which the plant is operated.

Workers who have experienced the changes from manually operated machinery to electrically driven machines operated through a control panel, and new technical features being added to the existing machinery, have learned how things are related to each other and how to run the plant efficiently. Hence, due to their first-hand knowledge of the functional relationships they know, for instance, how the control panel functions beneath its surface appearance. With this kind of in-depth knowledge, they know *why* things appear the way they do.

This kind of knowledge is a crucial element in understanding how the facility works, and being able to operate it smoothly. Novices and less experienced workers lack this kind of 'deep' knowledge and instead act on the basis of their surface level knowledge, that is, what they have been instructed to do and how they think things work. Subsequently, novices encounter many more problems, since they do not realise the effects of all the control panel's buttons and switches, and often miss when it indicates that something is wrong. As one of the novices said, "I don't know what some buttons are for, but I push them anyway because they're supposed to be pushed'.

Due to the complexity of the control panel, errors in handling it are common, and they ensue from both external and internal (mental) factors. While some problems are

caused by the control panel's complex appearance, which provides guidance for certain actions but also leads to errors, other problems are caused by a lack of knowledge and understanding of the underlying machinery. Although a more comprehensive understanding of the panel emerges with experience gained over time, the kind of knowledge developed by novices may also depend on the quality of the explanations and instructions they are provided. Where-from artefacts are subjective and vary from one person to another, which is reflected in individual variations and flexibility in the way experienced workers perform their tasks. Novices acquire their knowledge mainly from verbal explanations and demonstrations, but also by observing how the tools in the control room are used, and through their own practical experience. Considering the subjective nature of the experienced workers' knowledge and performance, the kind of knowledge acquired by the novices partly depends on *who* is instructing them in their tasks. Hence, the 'quality' of their knowledge (partly) depends on the verbal explanations and demonstrations provided by the experienced workers, as well as the novices' own practical experience. This means, the novices' learning is affected by how skilled and knowledgeable his/her colleague is, and the extent of that other person's 'where-from' knowledge.

The kind of experience based knowledge discussed here is an important psychological artefact, which can be termed a *where-from-artefact*. Similar to Engeström's where-to artefacts, where-from artefacts go beyond the explanatory or diagnostic 'why' function, and they are also close to Wartofsky's imaginary (tertiary) artefacts. Where-from artefacts consist of knowledge constructed from past events, providing a 'true' explanation and understanding of why the object of activity behaves the way it does. As such, they are abstracted from their use in productive practice, and have no longer a direct representational function of primary artefacts.

It could be argued that where-from artefacts are similar to why-artefacts, but there are important differences. Even though both of them concern the matter of 'why an object behaves the way it does', why-artefacts are *secondary* artefacts, while where-from artefacts are *tertiary* artefacts:

- Why-artefacts are internal and external representations of primary artefacts. They are based on expectations and available data which are transformed into an explanatory model, and workers make use of why-artefacts even without previous experiences (in fact, most of us construct explanatory models, even of things unfamiliar). The role of experience in forming explanatory models is not explicated in Wartofsky's and Engeström's concepts of secondary and why-artefacts.
- Where-from artefacts, in contrast, are qualitatively different. Although these are also internal models of why things appear and function the way the do, they are *tertiary* artefacts, that is, they are imaginary and no longer represent primary artefacts. Where-from artefacts are also based on previous experiences which allow the construction of knowledge that relates previously existing tools with new

implements, and an understanding of their functional relationships.

Considering the role of experience, it could be argued that 'where-from artefact' is just another label for memory. However, these artefacts do not concern memory in general as implied by the term itself. Instead where-from knowledge concerns specifically tool/artefact related experiences/ knowledge that affect present tool use. Since where-from artefacts emerge out of experience, it is plausible to assume that they contribute to current tool use in a manner different than do why-artefacts. Being experience based, they are likely to provide a more 'correct' understanding than the explanatory why-artefact, which is based on impressions, available data, etc. Workers construct explanatory models based on available 'facts', whether they are experienced or not, and without in-depth knowledge, available data may not lead to a correct understanding or, in the worst case, it might result in mere 'guess-work'.

In sum, besides primary ('what') and secondary ('how' and 'why') artefacts, two different types of tertiary artefacts can be distinguished; where-to (vision of the future) and where-from (knowledge of the past). The different types of artefacts are summarised in Table 2, with examples from the control room setting.

Table 2. A three-level categorisation of artefacts (Engeström, 1990; Wartofsky, 1979), expanded with a new type of artefacts.

Tertiary artefacts Imaginary artefacts	'**Where-from**' artefacts Experience based knowledge of the past, why objects function or appear the way they do, e.g., panel/machinery '*Where-to*' artefacts Vision of future (consequences of new tools in organisation)
Secondary artefacts Internal and external representations of primary artefacts	'*Why*' artefacts General type, why object behaves as it does. Justifies selection of certain primary artefact; e.g., numbers on scale display do not change – examine scale '*How*' artefacts Specific type, how to handle object with corr. primary artefact; e.g., internal model of process – control panel
Primary artefacts Directly used in production	'*What*' artefacts External physical entities (marks on computer screen, documents)

Discussion

Based on Wartofsky's classification of primary, secondary, and tertiary artefacts, Engeström (1990)

describes a three-level artefact categorisation, which includes what, how, why, and where-to artefacts. These comprise internal and external artefacts, and their relations within an activity. In addition to these, a new category of *where-from artefacts* has been identified. A where-from artefact consists of knowledge of the past, that is, experience based knowledge of why things function or appear the way they do. This new category adds a dimension that contributes to understanding why someone handles an object in a certain way, that is, the effect of experience based knowledge on a tool's current use. Furthermore, from the point of view of learning by apprenticeship, this knowledge plays an important role in the learning process, since where-from knowledge, or the lack of it, affects how tasks and procedures are explained, and subsequently, the kind of explanation/knowledge novices are provided. Finally, although this specific artefact is internal, it plays an important role in the way material tools are handled in the tasks performed in this setting. This also points to the fact that artefacts, whether mental or material, cannot be considered as isolate entities; artefacts and tools, and their use, can be understood only when considered in relation to their users and the context of their use.

Acknowledgements

References

Baber, C. (2003). *Cognition and tool use: Forms of engagement in human and animal forms of use of tools*. Boca Raton: CRC Press.

Clark, A. (2002). Towards a science of the bio-technical mind. *Int. J of Cognition and Technology*, 1(1), 21-33.

Engeström, Y. (1990). *Learning, working and imagining: Twelwe studies in activity theory*. Helsinki: Orienta-Konsultit Oy.

Gauvain, M. (2001). Cultural tools, social interaction and the development of thinking. *Human Development*, 44, 126-144.

Goodwin, C. & Goodwin, M.H. (1996). Seeing as a situated activity: Formulating planes. In Y. Engeström & D. Middleton (Eds.), *Cognition and communication at work*. Cambridge: Cambridge University Press.

Heath, C., Knoblauch, H. & Luff, P. (2000). Technology and social interaction: The emergence of 'workplace studies'. *British Journal of Sociology*, 51(2), 299-320.

Hutchins, E. (1995). *Cognition in the wild*. Cambridge, MA: MIT Press.

Keller, C.M. & Keller, J.D. (1996). *Cognition and tool use*. Cambridge: Cambridge University Press.

Kirsh, D. (1996). Adapting the environment instead of oneself. *Adaptive Behavior*, 4(3/4), 415-452.

Leontiev, A.N. (1978). Activity, consciousness, and personality. Englewood Cliffs, New Jersey: Prentice-Hall Inc.

Malafouris, L. (2004). The cognitive basis of material engagement: Where brain, body and culture conflate. In E. DeMarrais, C. Gosden & C. Renfrew (Eds.), *Rethinking materiality: The engagement of mind with the material world*. Oxford, UK.: Oxbow Books.

Norman, D. (1988). *The psychology of everyday things*. New York. Basic Books.

Preston, B. (1998). Cognition and tool use. *Mind & Language*, 13(4), 513-547.

Salomon, G. (Ed.) (1993). *Distributed cognitions*. Cambridge: Cambridge University Press.

Scaife, M. & Rogers, Y. (1996). External cognition: How do graphical representations work? *Int. J. of Human-Computer Studies*, 45, 185-213.

Schiffer, M.B. (1999). *The material life of human beings*. London: Routledge.

Susi, T. (2005). In search of the Holy Grail: Understanding artefact mediation in social interactions. In B.G. Bara, L. Barsalou and M. Bucciarelli (Eds.), *Proceedings of the 27th Annual Conference of the Cognitive Science Society* (pp. 2110-2115). Mahwah, NJ: Lawrence Erlbaum.

Susi, T. (2006). *The puzzle of social activity – the significance of tools in cognition and cooperation*. Doctoral dissertation. University of Linköping/University of Skövde, Sweden.

Susi, T., Lindblom, J. & Ziemke, T. (2003). Beyond the bounds of cognition. In R. Alterman and D. Kirsh (Eds.), *Proceedings of the 25th Annual Meeting of the Cognitive Science Society* (pp. 1134-1139). Mahwah, NJ: Lawrence Erlbaum.

Vygotsky, L.S. (1960/1981). The instrumental method in psychology. In J.V. Wertsch (Ed.), *The concept of activity in Soviet psychology*. Armonk, New York: M.E. Sharpe.

Vygotsky, L.S. (1978). *Mind in society*. Cambridge, Mass.: Harvard University Press.

Want, S.C. & Harris, P.L. (2001). Learning from other people's mistakes: Causal understanding in learning to use a tool. *Child Development*, 72(2), 431-5443.

Wartofsky, M.W. (1979). *Models: representation and the scientific understanding*. Dordrecht: D. Reidel Publishing Company.

Woods, D.D. (1998). Designs are hypotheses about how artifacts shape cognition and collaboration. *Ergonomics*, 41(2), 168-173.

Wynn, T. (1993). Layers of thinking in tool behavior. In K.R. Gibson & T. Ingold (Eds.), *Tools, language and cognition in human evolution*. Cambridge, MA: Cambridge University Press.

Zhang, J. & Norman, D. (1994). Representations in distributed cognitive tasks. *Cognitive Science*, 18, 87-122.