Interaction through clusters of artefacts

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ABSTRACT
We find that most approaches analysing and designing computer artefacts, including our own, have been too narrowly focusing on understanding and designing ONE computer artefact, whereas such singular artefacts are less and less frequent in the world around us. Accordingly this paper introduces the concept of clusters of artefact to focus, analytically and design-wise, on multitudes of interconnected computer artefacts surrounding us. In particular, the paper uses two empirical studies of cooperative work and its artefacts in elaborating this topic. The paper further discusses common information spaces as clusters of artefacts around which a web of use activities unfolds. Theoretically, the paper takes its starting point in activity theoretical concerns over mediation and context.

INTRODUCTION
Individual computer applications, with no connections to other applications, appliances or systems are less and less frequent in the world around us. Mobile phones connect with web-sites and with applications on PCs such as calendars. Word documents are moved between computers and opened in other applications. When a new computer application is introduced in an organization, there are already running applications and hardware platforms. Yet, HCI tends to focus on one user, one application, one computer; Information Systems development tends to focus only on the particular application being developed, raising e.g. questions about existing hardware platforms late in the development process. Even CSCW studies tend to focus on one application at the time, though in this case one that is shared between users.

Though common information spaces may seem to be an exception to this rule, they are often, implicitly or explicitly, viewed as something that can be accessed in toto from one (of many) location. As pointed out by Schmidt & Bannon (1992), providing a common information space is not a matter of providing overview and uniform access independent of physical location to a shared database. Many studies of physical document and of classification structures (e.g. Bossen submitted, Schmidt & Wagner, preprint) show how e.g. document structures and physical location are meta-artefacts structuring the use of other artefacts. They may at the same time serve a multitude of purposes, e.g. the work plan of a hospital ward (Bossen, submitted) serves to mediate between the three daily work shifts, to assign patients to individual nurses, and to structure treatments that happen over longer time periods, e.g. chemotherapy. And the work plan is used together with numerous other artefacts, e.g. the nurses’ personal notes and the patient record.

In approaching a more detailed understanding of how we may conceptualise such multitudes of artefacts, purposes and actors, we make use of the notion of mediation from activity theory: Computers as well as other artefacts mediate our daily activities, whether these are in relation to things or other human beings (See Kapteinlin, 1996, Bødker 1991, 1999, Bannon & Bødker, 1991, Kuutti & Bannon, 1993, Bertelsen, 1996). Human activity is mediated by socially produced artefacts, e.g. tools, language and representations. This means that in their immediate relation with their surroundings, human beings extend themselves with artefacts that are both augmentations of and external to the person, and some of which are entirely internalised and carried only through people, e.g. language, and procedures (Karpachof, 1984). Since we take purposeful acts as the basic unit in our analysis of artefacts, we have to study what happens when users focus on their job (or other purposeful act) while applying the computer artefact. With the hierarchical structure of activity this means that the ideal situation tends to be when the object of the users (conscious) action is the same as the object of work, whereas the user direct unconscious operations to the mediating artefact. The computer artefact becomes a transparent tool. A work object, in activity theoretical terms, always has two sides, the material and the outcome, and that it is exactly the shaping of the outcome from the material, that instrumental mediation is about.

CASE STUDIES
We introduce two cases studies in order to further study the interplay between multiple artefacts in actual use situations. The two cases differ from, e.g. the hospital ward and most of the cases used in the literature on classification in the sense that the involved artefacts do not present a clear level structure derived from the distinction between work and articulation work (Bødker & Mogensen 1992).

The two cases have both been studied through longer empirical projects, where observation, as well as various workshops and participatory design techniques were applied (Bertelsen & Bødker 2001, Bertelsen & Nielsen 1999, Nielsen & Søndergaard, 2000, Petersen & Madsen 1999, Buur & Bødker 2000, Bødker et al 2001). The issue of mediation in these cases and others have been dealt with further by (Bødker & Bøgh Andersen, in preparation). Our examples are extracted from this rich
material, some as generic reconstructions and others being exact empirical records.

The design case
Our first case deals with a usability design group, which has chosen to experimentally rearranging their use of space and design artefacts, to provide more efficient means of sharing design documents and artefacts and of peripherally monitor the work of others in the group. The company is a leading manufacturer of audio-visual equipment, primarily installed in private homes. The work has been characterized by a high degree of division of work and qualifications: industrial designers design, engineers build prototypes, and psychologists test (Bærentsen & Slavensky, 1999). The main point of coordination between these groups is meetings where all groups would contribute to the discussion of prototypes.

The group has created a workshop, the design collaboratorium: a joint room where people can cooperate or work alongside each other. The room is the physical framing of workshops with users, usability evaluation sessions, meetings, and work activities of smaller groups of usability professionals, designers, and engineers—in parallel or interleaved with each other (Buur & Bødker 2000). Thus the room is used extensively by all group members, and serves a series of purposes. The room is equipped with a number of whiteboards of varying sizes. Further, it holds prototypes of earlier and present projects. The layout of the room has a traditional meeting table with whiteboards on the surrounding walls and prototypes positioned on shelves on the walls. In this design collaboratorium the presence of prototypes from present and previous projects serve to support awareness in the group of ongoing projects. Exemplar previous products provide a sense of history of the company line. The design knowledge in the group is summarized in a set of principles for good interface design, which are kept an A3 sheet of paper, pinned on one of the boards in the room, annotated with notes on a small whiteboard.

The wastewater plant
Our second case deals with the study of a wastewater treatment plant. We have conducted workplace studies and we apply an interventionist approach through the construction of prototypes for new computer support for the running and optimisation of the wastewater plant. Our prototyping experiment has been focusing on how to get and maintain a local overview of parts of the plant while moving about, and on compiling and interpreting information that is massively distributed on meters and dials (Bertelsen & Bødker 2001, Nielsen & Søndergaard 2000).

The basic mediation in the wastewater plant is simply that the plant mediates the process of turning wastewater into clean water. As analysed in (Bertelsen & Bødker 2001) it is the plant manager, together with a small group of workers, who are the acting subjects as regards the overview and optimisation of the wastewater process. Nonetheless, many of the steps in the re-mediation process are carried out by other actors, and it is only through the entire chain that controlling the plant is possible.

Figure 2: The wastewater plant

ONE ARTIFACT IN MULTIPLE CONTEXTS
As part of the daily round of one of the workers at the wastewater plant, a specific gas motor is looked at and listened to, and as such it is part of the context of the daily round of the worker, what Bertelsen & Nielsen (1999) calls the contextual unit. However, the same motor, when it is taken down for repair, constitutes a contextual unit of its own. Further, the motor is part of the section of the plant transforming gas in the sludge into electricity. This gas production is a contextual unit from one perspective, but at the same time an important indicator of the load of the whole plant.

This particular gas motor demonstrates how it is necessary to study more than one use situation and contextual unit in order to understand the complexity of use.

In the design case, we make distinction between the situation and contextual unit of users watching TV, and that of usability people or designers studying use, or of making a prototype TV as such. Yet the TV prototype is part of all three contextual units, and is a significant artefact of all three situations.
Lesson 1: use is more than one use situation, and use situations and contexts are non-hierarchical, overlapping, transient and heterogeneous.

Many actions on the same object, many artefacts and actors
One morning before dawn at the wastewater plant, the manager asks a worker to go and look at particular basins. This basin has been automatically shut down, probably because a wire pulling the sludge scraper is broken. The manager needs to know where the wire is broken to determine which preparations are needed before the blacksmith can do the repair. The worker checks the wire, cleans the basin, and tells the manager where the wire is broken. The blacksmith arrives and starts working to splice the broken wire. He has to operate the winch holding the wire. The winch motor is, however, only controllable from a terminal in the central control room. Thus, the smith phones the central control room, which, incidentally, is occupied by one of the unskilled workers, and asks him to start the motor.

The workers attempt to start the winch, however, has no effect. He suspects a failure in the control system and calls the foreman, who was working outside the plant that day, to let him know about the problem with the system. The foreman explains that the winch often gets stuck, and asks the worker to tell the smith to call him on the telephone so that he can guide him through releasing the wire. In addition to the information on how to unblock the wire, the foreman explains to the smith how to short circuit a few cables in the motor to bypass the central control of the motor locally.

This situation is one where many actors are involved in the repair process. The wire continues to be the main focus, but several actors perform a number of actions in order to repair it. The manager does an overall inspection and hypothesizes that it is broken. One worker is sent out to clear the tank so as to do further examination. He confirms that the wire is indeed broken. The blacksmith is called in. He inspects and repairs the wire, but needs advice on how to move the wire so as to check how it is functioning. By calling the random person in the control room he gets in contact with the foreman, who, from a remote location, tells him how to shortcut the control system and test the wire. This shows how the actions of many actors are carried out, and organized, around the particular object of work.

Lesson 2: many actors and artefacts mediate the same activity/focus on the same object.

Objects turn artefacts
In the design case, the usability engineer materializes decisions in his personal notebook, at the same time as they are partly written down on the whiteboards in the design collaboratorium room. Because he carries these notes around, they can be made useful in other activities, such as the casual encounters he has with engineers in the hallway or design meetings that he holds with the engineers in their office.

Design meetings take place in offices or production areas with the purpose of furthering the design process. Participants make joint sketches and develop prototypes based on ideas developed in brainstorm meetings, or they discuss problems with the implementation of design decisions.

As illustrated by this example, the personal notes become a main artefact of other activities, not least design meetings where they are brought along.

Lesson 3: the outcome of one activity becomes the artefact of others.

Chains of mediation
Throughout the design process, the designers build functional TV-prototypes that capture their ideas and are explored in the design meetings. No notes are ever made from these meetings. Instead the TV-prototype is changed to reflect the discussion, and this new prototype is used as a mediator of the discussion in the next meeting.

A prototype like this is a straightforward example of something drifting between being object and being mediating artefact. Not in the sense of the Heideggerian analysis of the tool, but rather in the sense of what Bodker & Bøgh Andersen (in preparation) call remediation in their analysis of the wastewater case.

In this case the following occurs: The daily report for the gas generators is represented by a row in the monthly report table, one for each gas generator. This report is left in the room where the relevant meters are located. The report contains readings of e.g. oil temperature, oil pressure, errors and the power produced (in kW). When he has calculated the result, the worker furthermore brings them to the control room and confirms with computer readings. Only then are they entered into a paper protocol left on the table in this room.

The paper is carried around and ends in a room, where the accumulated numbers are entered into a paper protocol publicly inspectable on a desk.

The paper protocol contains accumulated figures for all days of the month. The paper mediates the production of the protocol. The protocol makes possible (mediates) the inspection of the state of the plant, and it mediates the structuring of numbers to be entered into the computer system.

Based on these numbers, the computer mediates the regulation of the water purification process. What in one activity is the outcome is the mediator in the second one and material in the third one, and a long chain of such role shifts contribute to the mediation of the ultimate work object, the wastewater.

Hence the concept of re-mediation was developed to illustrate how artefacts in the plant are part of a chain of artefacts and objects, that together help regulate the plant and ultimately fulfill the overall purpose of wastewater processing, to turn wastewater into purified water (see also Bodker & Bøgh Andersen, in preparation).
Lesson 4: The overall activity may be carried out through chains of objects turn artefacts, i.e. remediation.

**Substitution of artefacts**

The production of the lab report and the comparison of results across days, are examples of activities essential to the running of the wastewater plant and the cleaning of water. In some cases the manager may run the plant just by looking at the alarms in the control system; in many other instances he needs to send somebody out to read a meter or to do a particular lab test.

Exactly the relation between the wastewater plant as mediator and the whole chain of remediation illustrates that in some instances the manager may, infrequently, use just one artefact to clean the water – the wastewater plant. In numerous other instances, this mediation is substituted by a number of other artefacts, the use of which all serve purposes that may be directly connected to cleaning the water or not.

In a non-hierarchical fashion, the personal notebooks and whiteboards substitute each other in the design case: it is possible to return to past discussions using either or both, though certainly what happens in the activity greatly depends upon whether the past notes are available in a shared form on the whiteboard, or mainly through the reproduction in people’s personal notebooks.

Lesson 5: Substitution happens and may or may not be hierarchical.

**Juxtaposition of artefacts**

From the design case we know that both notebooks and the whiteboard are used to reconstruct a past discussion. In such a situation both artefacts are part of mediation of the activity, in a way that they could not have been without each other. Such juxtaposition of artefacts is further ways in which analysis of individual artefacts become too limited.

Lesson 6: There is more than one artefact at a time, working together to mediate the activity, i.e. juxtaposition.

**Artefacts modifying artefacts**

In several examples described in (Bertelsen & Bødker 2001, Bertelsen & Nielsen 2000) we see how, in the wastewater case, many activities dealing with trouble shooting are carried out through juxtaposition: in one of our observations at the wastewater plant two workers see that the wastewater looks grey. Yet, no action is taken until the lab results have been produced, and it is only through the juxtaposition of the lab results with the watercolour, that makes for a decision about possible actions.

In general the lab report form, with its past results, as well as power paper protocol are artefacts that modify other artefacts. The readings of the current day give little actual indication of whether the plant is running smoothly and efficiently. It is only when the numbers are written down in the appropriate columns underneath readings and calculations from the previous days that the overall activity of monitoring and optimising the wastewater plant may be mediated.

Lesson 7: Artefacts modify other artefacts.

The first seven lessons from our empirical analyses show how there are many ways in which a particular artefact is situated in several contexts of actors, objects and other artefacts.

**OPEN AND HETEROGENEOUS ARTIFACTS**

While one might think that providing cleaned wastewater is the overall objective of wastewater cleaning, it turns out that clean water is but one of many parameters that rule the running of the plant. The plant is built for a much smaller daily production of waste, and must handle a continuous overload of 25-50 pct. Accordingly; the plant is the scene of an ongoing experimental optimisation process. As part of this optimisation process we have studied how the workers create and make use of local context by moving about in the highly dispersed geographical space (Bertelsen & Bødker 2001), how they deal with a large variety of different representations/artefacts when they undertake particular tasks in particular locations, and how, accordingly, the plant is the basis for very different action possibilities for the different workers.

The water in the various water basins at the wastewater plant is a very important mediator of the purification process. It is essential for trouble shooting, because differences in smell or colour are indicators of something wrong (some chemicals being brought into the plant through the inlet water, some part of the sludge separation process going wrong). Yet it is not easy to say exactly what aspect of and how the water mediates these activities. This means that even the best of sensors are unlikely to replace the actual look and feel of the water, even though most people would rather not have to come near the water.

The wastewater worker handles a large number of dials and meters (Bertelsen & Bødker 2001) every time he calculates the amount of produced electricity: All the instruments/meters that need to be read are visible (i.e. not behind panels or doors). The meters are read differently: some of the meters are just counters/numbers where others have a needle pointing at a scale or are light bulb-buttons. Some values are read instantly while others need to be focused on for several seconds before the values are written down.

In the design case we see how the notes on a board serve several activities – as notes forming a design, as reminders of past discussions, as mediators when individuals make personal notes, and as general reminders of what has happened in the room lately.

Lesson 8: Artefacts lend themselves to open and heterogeneous uses, where the artefacts are used

- in other ways than they were intended,
- differently depending on purpose,
- and in manners that are difficult to anticipate.
In both our cases, we are dealing with artefacts that are used more or less continuously within a particular community of practice, yet the artefacts are in other ways rather different: The waste water is there, for everybody to see and smell, the whiteboard notes in their specific form come and go, and they are unstructured and differ in form. None of them, however, are deliberately “wrapped up” for later use by others, in contrast to how Bannon & Bødker (1997) talk about openness and closure in relation to items left in a common information space, such as a web-site.

**MULTIPLE PURPOSES OF ARTIFACTS**

In the design case, we further see how the design process is one where people cooperate to materialize a product that is not yet there. Accordingly, the sketches and representations used continuously serve the double purpose of mediating the cooperation between the designers, between designers, implementers, and users etc., at the same time as these same representations help build the products. The TV, which is itself from the outset a mediation, serves the purpose of capturing ideas, and holding on to decisions made by the group. (Petersen & Madsen 1999)

Lesson 9: One artefact mediates many purposes at once.

**Primary, secondary and tertiary artefacts**

Every morning one wastewater worker measures the water at different stages of the process. He collects water samples, processes them in the lab, enters the into the control system. In the lab, he enters all lab test results into a form that is stationary on the desk. While entering the numbers, he compares them with the results from the past month, and he is expected to let the manager know if there are any major discrepancies. The lab results are furthermore transported to the manager’s office where he types them into the computer.

The protocol sheets used for the daily records at the wastewater plant represent the process of reading the meters and doing the calculations.

In this sense they are secondary artefacts, in the terms introduced by Bertelsen (1998, 2000), when looking at artefacts as clusters of primary, secondary, and tertiary artefacts (Wartofsky, 1973). In this terminology primary artefacts are utilized directly, secondary artefacts are representations of the way we act productively with the primary artefact, whereas tertiary artefacts are only indirectly tied to production through the reformation of perception which in Wartofsky’s concepts is a mode of outward action.

In most situations there will be a sort of secondary artifactness tied to a primary artefact in the sense that the tool points to or represents its own use. The protocol sheets go further than that. In the way they provide columns for writing up readings and calculations, they demonstrate how these readings should be made in consistent ways from day to day (independent of the worker doing the job). Yet nothing prevents the worker from doing readings and calculations differently.

As an example of the tertiary artifactness in mundane work arrangements consider the following: The workers operating the sludge press spend long time scraping sludge from the press when the water has been extracted. The amount of effort needed for this task partly depends on how much polymer is added. In situations when the workers find that the pressed sludge is coming off easily, they may be asked by the manager to adjust the addition of polymer anyway. Hence, a tension between easy working and optimal running is created. The adjustment of polymer becomes a tertiary artefact for creation of visions like “the effortless workday”.

In some cases, the cluster of primary, secondary and tertiary artefacts is distributed into a chain of artefacts modifying each other.

Lesson 10: Artefacts are clusters of primary, secondary and tertiary artefacts.

Artefacts are, as we have seen used with different purposes and they are in some instances mediators of explaining and changing the use of other artefacts. Artefacts point to the present practice of use as well as to potential futures of this practise.

**MEDIATION THROUGH CLUSTERS OF ARTIFACTS**

Studies of computer artefacts in use need to focus on the narrow use activity and the handling of the computer artefact as well as the wider context of use and design. One of the forces of activity theory is that it allows for studies of all these levels of activity to be combined. It allows us to change scale and study connections on multiple levels of activities where computer artefacts are used and designed, without establishing a permanent hierarchy in the analysis (Raithel 1992, 1996, Bardram 1998).

In the above examples we have considered clustering of artefacts along several dimensions:

**Chains of mediation in multiple contexts:**
- artefacts are part of more than one use situation,
- use situations and contexts as non-hierarchical
- many actors focus on the same object
- many artefacts mediate the same activity
- the outcome of one activity often becomes the artefact of others
- remediation happens
- substitution happens and may or may not be hierarchical
- juxtaposition: there are more than one artefact at a time
- artefacts modify other artefacts

Open and heterogeneous uses where the artefacts are used
- in other ways than they were intended,
Multiple purposes of artefacts:

- differently depending on purpose,
- and in manners that are difficult to anticipate.

Through our analyses we have illustrated how different chains of mediation unfold; chains of mediation where the same object is mediated by many artefacts and many users, where outcomes become artefacts for further mediation of the total activity, and where artefacts modify artefacts. Clustering of multiple artefacts in one artefact is important to our mapping out the multi-mediational nature of artefacts. In this manner it is possible to identify particular clustering of artefacts in the entire web of activity of e.g. the wastewater plant or the design process. Though overlapping in actual artefacts the artefact clustering of the daily inspection of the wastewater is different from that of a particular repair. And similar with a design meeting and a user test.

In the wastewater study, workers actively construct the common information space that is necessary for them in order to run and not least to optimise the running of a wastewater plant. This active construction requires cooperation while moving about in the geographically dispersed plant, exploring and experimenting with optimisation of the plant, while being more or less peripheral to this experimentation process. In a previous analysis of the wastewater plant, Bertelsen & Bødker (2001) conclude that overview, predictability and peripheral awareness are all related to how people move about in the plant and not to a particular location. The wastewater plant is dealt with through movement, and movement as a precondition for learning, participation and experimentation. This illustrates how one access point to the information space is a very limited perspective. The artefacts clusters constitute different access points and do not necessarily mediate the access to any available artefact in the plant or design collaboratorium. In particular there are many instances where something is a primary artefact for somebody and a secondary artefact for others, without this being a permanent distinction (see similar discussion in Bødker & Mogensen 1992). In some instances the geography of the wastewater plant provides the overall structuring artefact of access to the plant, in other situations, it is the logical structuring. As pointed out by (Bertelsen & Nielsen 1999) these are neither hierarchical, nor permanent.

Many recent approaches, context has been looked at as important for analysis and design, yet the notion and delimitation of such context often remains weak. We find it necessary to be much more precise about context and contexts in order to undertake appropriate analyses and designs of clusters of artefacts, hence we further develop the notion of contextual unit as part of our analyses. Through the focus on clusters of artefacts, it is possible to be precise more about contextual units that cut through the entire web of activities, so that we may focus on one mediation capacity in its context, on the background of other mediation capacities. This helps delimit the total context must be considered e.g. when designing a new artefact, though an exhaustive inventory of the relevant context cannot be produced.

**RECONSIDERING COMMON INFORMATION SPACES**

Bertelsen & Bødker (2001) look at the distribution and geographical spreading of the information space, and the ways that workers organise their activity around this. Bannon & Bødker (1997) discuss some of the many problems of the general, idealised assumptions made about common information spaces. As discussed by Bertelsen & Bødker (2001) many considerations regarding common information spaces in contrast seem to relate to this notion of providing one-point access to the entire information space.

A type of common information space such as the wastewater plant has a structure that mediates the overall access to the information, and access to the actual information subordinate to this. This double-level mediation resembles the classical common information space where often a classification scheme (Schmidt & Wagner, preprint) structures and mediates the access to individual documents. If we look at a classification scheme as discussed by Schmidt & Wagner (preprint) we, more precisely, find three ways in which the classification scheme mediates access to the actual information items or documents:

- It helps create a juxtaposition between the information items by indication topical similarities,
- In this way it also may be seen as an artefact that modify the information items, by placing them in a context.
- The classification scheme is a secondary artefact that describes how the information items should be placed and retrieved.

On the one hand this yield to possibility for more specific analyses of such classifications as well as for design of such. On the other hand, it is obvious from the above analyses that most of the classical common information system studies have a limited focus analytically and design-wise because they rely on a two level analysis in accordance with Strauss’ concept of articulation work (Star & Strauss 1999). Such analysis may be extended through a more profound focus on clusters of artefacts.

We have already mentioned how the wastewater plant provides not one, but several structuring artefacts, and how these contain primary, secondary as well as tertiary artefacts. The design case is even more ad hoc in how it offers access to the multiple artefacts and hence to the common information space. Furthermore, clusters of artefacts yield a focus on juxtaposition of artefacts, e.g. the whiteboard and the personal notes, on how artefacts structure access to other artefacts in other ways than through one hierarchy, and even through artefacts that are not of a classical taxonomical character.
It is common to analyses of common information spaces that the common information space is seen as detached from the world of physical artefacts. As illustrated by our two cases an inclusion of physical artefacts and spaces is important from the perspective of clusters of artefacts, as the same time as the concepts introduced here helps making this analysis in the specific.

Focus on clusters of artefacts in webs of activity vis-à-vis classical studies of common information spaces emphasizes the need to focus on artefact clustering. In analysis as well as design it is an open question which of the many different ways in which clusters of artefacts may be seen, that help us make informed choices. Yet this paper has illustrated how the concern for clusters of artefacts helps us focus on

- various cuts into the common information space as clusters of artefacts yielding different action possibilities
- location in physical and information spaces,
- handling of many artefacts and juxtaposition of physical and information artefacts
- multiple structuring mechanisms in particular other than formalisms, taxonomies and categories.

CONCLUSION

Our research in information spaces that are profoundly embedded in distributed physical spaces point to a number of issues that are different from the discussions of formalisms, taxonomies and categories most often seen in the world of common information spaces. In a similar manner we propose that the delimitation in terms of focus on multiple actors and purposes brings about new issues that are essential for the development of artefacts in the current technical condition where individual artefacts and systems become less and less important.

The paper leaves a number of open questions regarding how we may turn this itemized list of ways of clusters of artefacts into a design framework, in particular how the concept of contextual unit may be further developed vis-à-vis the above mentioned cuts in the space of action possibilities.

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