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Information Tools for the Shop-floor

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Abstract: New production and work practices set new proficiency requirements for employees in operative organisations. Most of these requirements involve information and communication. We can train and educate people to meet with these challenges and design their physical and information environments to support and facilitate them in their work. New information tools play a central role in this development. But what kind of tools? How to apply these tools to enhance employees' learning by reflection. In this article we will discuss the emergency of shop-floor information environment from the sociotechnical point of view. In addition, the possibilities and limitations of electronic performance support as a solution are evaluated. Shop-floor information artifacts are tools used to produce, organise, store and distribute work related information in a shop-floor environment. They may be very simple like handwritten notes or user interfaces to extremely complex data management systems.

Keywords: Performance support; Electronic performance support systems; Human resource development; Multimedia; Flexible production; Learning organisation

1. Interactive Task Support System

We have developed an information technological tool to study the possibilities and limitations of multimedia based performance support on the shop-floor. The aim of the Interactive Task Support System (ITSS) is to provide all the task related information needed during the completion of a lightweight assembly task (Kasvi 1991, 1993; Kasvi *et al.* 1993, 1994; Ollikainen 1989; Ollikainen and Pulkkis 1989; Ollikainen *et al.* 1991). These documents can be used both to train inexperienced employees or to support experienced assemblers in their work.

The differences of training for a task and supporting it include:

Training	**Support**
Delivered separately from the task	Delivered during the task
Medium to long range goals	Instant goals
Based on the assumed information needs of the employee	Answers to employee's actual information needs
You must not forget what you have been taught	You can always check what you have forgotten
Suitable for static work environments and basic skills	Suitable for dynamic, learning work environments and skill apply details

The ITSS multimedia documents may be used for two purposes: training and performance support. When the system is used to orient new employees to new tasks it is not necessary to be next to a work site. The information within the hyperdocument is enough. When the system is used to support work actions, it has to be embedded right into a work site as shown in Fig. 1. This was observed with the old paper based support system, too. If the documentation was not present within the work site, people preferred even guessing to leaving the site to access the documentation.

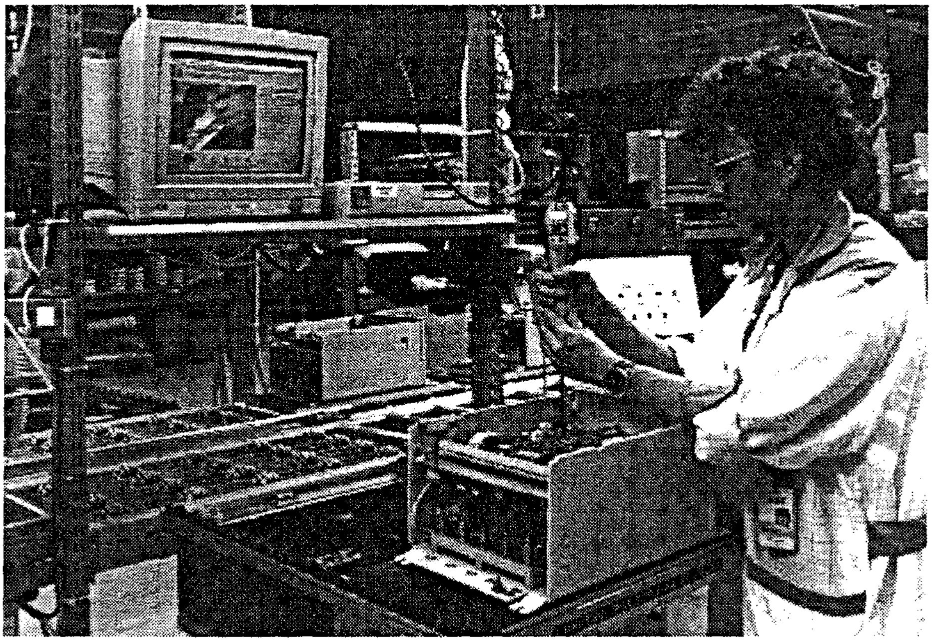

Fig. 1. Supporting DC drive assembly with the Interactive Task Support System in the Helsinki Power Electronics Plant of ABB Industry Ltd. (Picture courtesy of ABB)

1.1. Multimedia Artifacts

ITSS has two major user groups and two different user interfaces. One is used to author and maintain multimedia documents. This includes defining the hyperlink structure of the documents and providing their media contents. The other user interface is used to read and browse these documents.

The information content of the ITSS multimedia documents is based on experiences gained from computer based training. As our original model we used the five step task training method (Vartiainen 1987) that is based on action regulation model (Hacker 1973) and has been well tried in Finnish industries. The contents begin with orientational material and end with control. Currently the information provided by the system is divided into five “chapters”

1. **Introduction** contains basic information about the product and production.
2. **Tools** describes the tools needed and their safe use and maintenance.
3. **Parts and materials** describes the parts and materials needed.
4. **Task description** has two levels. The first level describes the stages of the task and the second gives details of execution for each stage.
5. **Quality factors** chapter stresses critical quality issues.

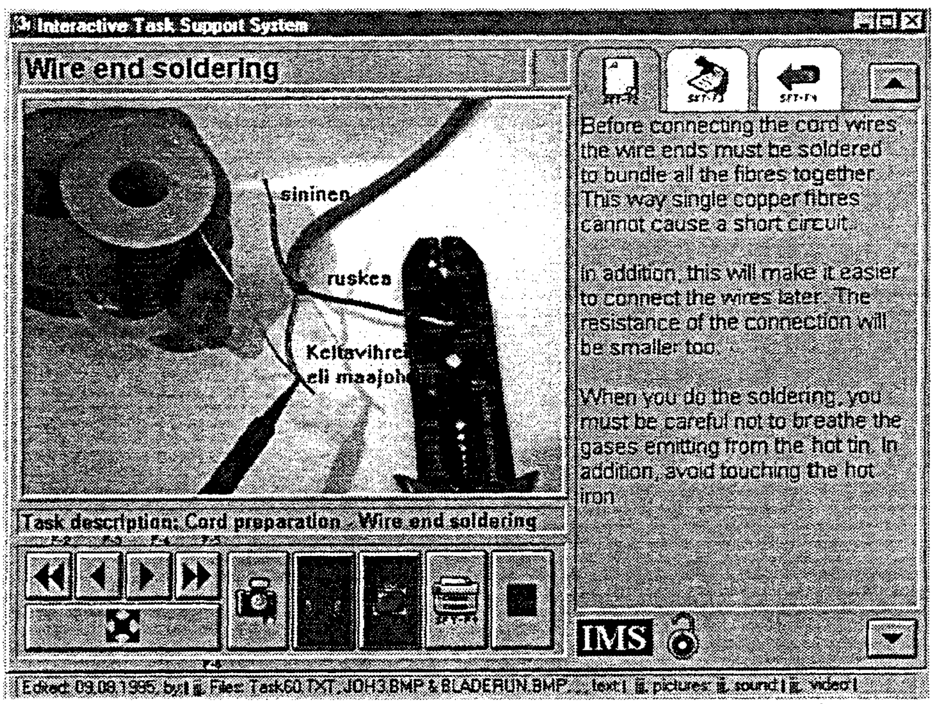

Fig. 2. The ITSS user interface.

Each chapter consists of "pages" that contain information related to one subject, for example a tool. These pages combine different media. The available media include text, still video pictures and digitised sound (Fig. 2). Text is used for technical details that are difficult to show with pictures.

Still video pictures are the most important media of ITSS documents. Their status is cognitively motivated as pictures leave degrees of freedom for individual cognitive operations. One should observe that textual information is not always used when there are pictures available (Nieminen *et al.* 1995).

Digitised speech is used to stress critical quality and safety issues, as speech is easier and faster to interpret than text. Critical issues have to be duplicated in the text as ITSS users may pass the page in question without pressing the speech button.

Live video or **animation** has not been used, partly because of the technical requirements they would place on the hardware, partly because the same information is easier to present with still video pictures. In fact, a live video presentation may contain too much and too detailed information, diminishing the available degrees of freedom of the people supported.

1.2. Some Experiences

The Interactive Task Support System has been studied in two industrial settings. The DC drive assembly line of the ABB Industry Ltd. in Helsinki, Finland and the Audio equipment production line of Bang & Olufsen A/S in Struer, Denmark. In addition to these cases a commercialised version of the system, Task Supporter from Brainware Oy, has been implemented by several Finnish companies.

In the ABB case we studied usability and utility of the system through communication analysis, log files, surveys (communication, usability), interviews and observation with video logging. The studies involved 10 shop-floor employees of the ABB Industry Ltd.

In the B&O case the production environment has been too turbulent to study for the time being, and our studies have been limited to discussions and interviews with the end users and some log file analysis.

In the ABB case the need for a new medium to deliver supportive information arose from the design of a new DC drive product and production line. The number of product variations was high, and the time available to start production was extremely short. New DC drives were sold before the prototypes were finished, and the assembly line had to be finished before the product itself was completely designed. Both the product and the assembly procedures were in constant flux during the first months of operations.

The problem on the assembly line was: how to provide right information to the right person at the right time? All the people interviewed complained about disruptions in the communication between organisational units and their actors. For example, the sales did not know the capacity of the production unit and whether products could be delivered in time.

The communication analysis showed that the ITSS system was applicable as a task supporter. If an employee did not remember how to assemble the product she used and found the instructions from the system. The ITSS, however, only partly covered the whole information network in the organisation. It seems necessary to widen the system's functional area.

When the task support documents were used for orientation or hands-on-training, all the five chapters of the documents were used; but when the documents were used to support task performance, most of the browsing concentrated on the task description chapter. Especially easily forgotten detailed information was accessed (Nieminen *et al.* 1995).

The need for orientational material diminished as novice users turned into experts. This needs to be taken into account in the design of all performance support systems. A support system should provide suitable browsing means for both these groups.

Frequency of use depended on the employees' situation. When employees were using the system to orientate to the task, they proceeded quickly from one page to another. An average of 139 events were recorded in the log file in 20 minutes during orientation. It seems that trainees were constructing a new model of the assembly task (Nieminen *et al.* 1995).

From performance support point of view the most important observation was that even if the use of the system diminished when an employee gained expertise in the task, the system was still used, albeit not so often.

Still video pictures were used as the most important information source. The users were heterogeneous in their media usage. Some users read all the texts, some resorted to them only if everything else failed.

The use of pictures and speech was most important in the hands-on training (Nieminen *et al.* 1995). This became most evident with foreign test subjects, trainees from ABB's Chinese subsidiary using multimedia documents consisting of pictures, partly translated speech and Finnish text. The results indicated that a major part of a complex assembly task can be completed without any textual information.

Even though a lot of effort had been put to the selection of the most meaningful functions and information for the ITSS system, it still had too many chapters and functions for the end users' purposes. Further simplification is in order. On the other hand, the information content of the system was sometimes inadequate. More detailed and targeted information was required.

Finally, we observed that the uniformity of the physical environment and the virtual environment of the multimedia documents was of paramount importance. Inexperienced employees became confused if, for example, a part in the still video picture was different from the part at hand. The difference could be minor like colour, but still the users thought that they had made an error and turned to their co-workers or supervisors for help.

From the company point of view, the absence of paper documentation was the most important effect of the system. The production involved only one piece of paper, the report of the automatic testing system. In addition, the foreperson interviewed told that the system allowed them to shift people from one task to another more easily and eased the update and delivery of the assembly instructions.

The absence of paper documentation did not disturb the end users. In fact, when all the end users were interviewed they preferred electronic work instructions to paper based documentation.

Unintended effects included harmonisation of task related vocabulary. Originally product designers and assemblers had different words for several parts and materials. In the end, the vocabulary became more uniform.

2. Individuals, Groups and Organisations Need Support

2.1. Why are Information Tools Needed?

There have been two separate developments that have increased the information requirements of shop-floor work:

1) *Flexible, customer oriented production:* Quick and unexpected changes in markets require enterprises to react to new situations so quickly that no training system can cope with it. Tasks that have traditionally required experiential learning-by-doing are becoming more and more reflective.
2) *Expanding work contents:* The new ways to organise work expand the scope of required professional expertise beyond the cognitive limits of an unsupported human mind. New, complex tools and products increase the expertise requirements even further.

The DC drive production case is a good example of the requirements that flexibility can set. The theoretical number of different ABB DC drive variants amount to two million, even if only some hundreds are manufactured in practice. In addition, both the quantitative output of the line and the variation mix fluctuates depending on the sales. Personnel has to be shifted from one line to another to react to end-customer demands.

The human centered trend in production design is to create both mentally and physically complete, stimulating and purposeful tasks that allow employees to see the end results of their labours. These complete tasks, often enhanced with job enrichment, job rotation and teamwork, require a lot more information and knowledge than the tayloristic tasks of old.

For example an ABB DC drive unit is assembled by a single individual. It takes some three quarters of an hour to put one unit together. The amount of product variations and the shifting of personnel ensure that there is no way for an individual assembler to remember all the information he needs in his work. In spite of the complexity of their tasks, the assemblers take care of production management details, too.

Information tools are needed, artifacts to process the information overload; memory aids, information sources and pre-processors to arrange and integrate data (Fig. 3).

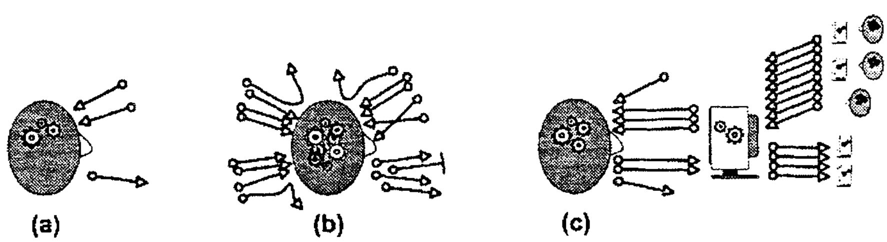

Fig. 3. (a) Communication and information processing is in employee's control. (b) Information overload results in stress and fatigue. Information may become lost or corrupted. (c) Performance support manages and pre-processes the overload.

The problem with the increase of expertise and information demands is to find the optimal mental workload. How much and what kind of mental load is beneficial for learning. When applied improperly, mental workload can become harmful instead of invigorating and stimulating (e.g. Meshkati and Loewenthal 1988). These harmful effects include stress related symptoms that diminish individual productivity and quality of life.

2.2. The Four Sources of Individual Support

Traditionally, supportive information has been extracted from three different sources: own memory, physical environment and social environment. As information becomes a central part of any product or task, we have to expand our model to include the information technological tools and their information content, i.e., the information environment (Fig. 4).

Individual, often tacit knowledge is stored in one's own memory. It is gained through years of work experience, training and reflective thinking. These skill related knowledge representations may be divided into declarative knowledge consisting of facts about world and procedural knowledge referring to how we do things (Anderson 1990).

A great deal of work-related social, especially motivational and emotional support is received from the social environment consisting of co-workers and supervisors. The knowledge on tasks and work environment is shared between individual minds and distributed from one to another when needed.

Personal memory is complemented with physical tools, parts and surroundings. A well designed physical environment can be a valuable source of support. For example, the placement and type of assembly tools hint at correct working methods.

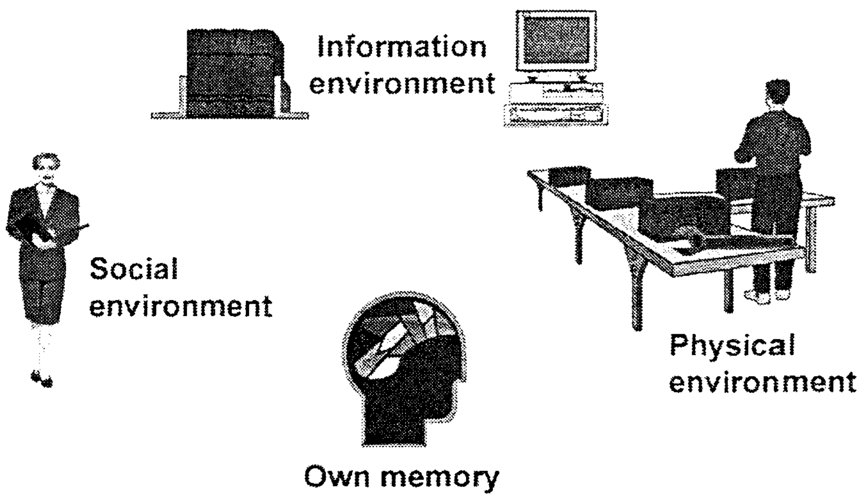

Fig. 4. The sources of support in work environment. The support is provided or accessed through interaction between the person supported and his environments.

The importance of social, often informal organisational networks as a source of information, has to be underlined as opposed to the traditional definition of electronic performance support (Grey 1991; Raybould 1990).[1] Instead of minimizing social interaction, performance support systems should enhance these networks. Properly applied information technology can both intensify old communication lines and create new ones by connecting geographically or logically distant groups and individuals.

The information environment consists of artifacts that are used to produce, organise and distribute work related information. These include hand-written notes, handbooks, work instructions, quality standard files and computer based information support systems, just to mention a few.

2.3. Regulating and Facilitating Actions

The action regulation theory (Hacker 1973) provides a model to understand the need of support on an individual level. Work behaviour is composed of separate actions directed at certain goals. An action is a whole of sensory, cognitive, emotional and motor processes. Actions are executed according to action programs or mental models[2] at three different levels (intellectual, perceptual-conceptual and sensomotoric) and have specific phases: orientation, planning, execution, and control.

According to the action regulation theory jobs and tasks should be structurally complete to enhance human development. Scarce information that hinders orientation and planning leads to negative mental load and decline of qualifications.

In addition to orientation and planning, other kinds of performance support is required during performance and control phases of action (Fig. 5). For example, when two or more individuals interact, communication support tools are also needed.

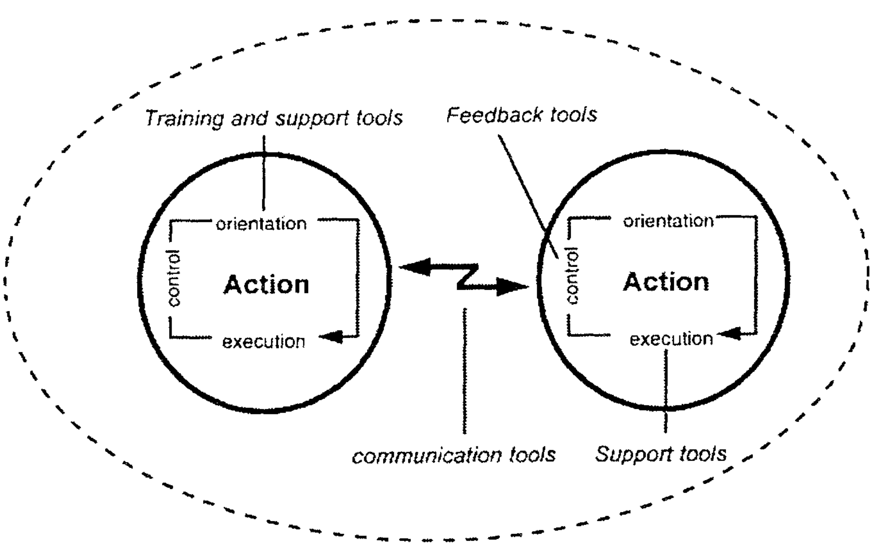

Fig. 5. An employee needs support from his activity environment for the action preparation, execution and control, and for communication.

The action facilitation model (Meijer and Roe 1993) proposes even more specific principles for performance support. Action facilitation means that the individual's performance is improved or at least maintained, if his mental and physical efforts decrease. To ease his efforts, the employee looks for support from his activity environment, his workplace, in every phase[3] of a task.

The action facilitation model suggests that the orientation on the tasks and the design of action programs should be facilitated by inserting relevant information into the activity environment. In addition, different kinds of support can be provided to ease the analysis, problem solving and decision making phases.

2.4. Support for a Learning Organisation

A comprehensive performance support system can be regarded as the memory of the organisation. It contains all the performance related information the organisation has learned. In fact, information management and support tools are a structural prerequisite for a learning organisation. They enable the individual and team learning processes.

In addition to serving as an organisational memory, a performance support system has to provide tools for reviewing existing knowledge and to support the synthesis of new information. Examples of such tools include idea generator software or brainstorming techniques.

While such advanced information tools may lead to a more democratic information environment, they may also instrumentalise people. Even their personal tricks and tips are no longer their own, but belong to the organisation.

While some of these questions can be answered with technology, most of them require an organisational approach. A set of fixed practices and procedures has to be created.

3. Guidelines for the Design of Computerised Task Support Artifacts

Our studies suggest that design of performance support systems requires modelling of the activity environment and its cognitive requirements on individual, group and organisational levels. The wider the production process and tasks to be supported, the broader and multi-leveled the analysis of the demands needs to be.

The first source to look for information is one's own memory. When it does not provide the information required, one usually looks around to see if the physical environment offers any clues (see e.g. Norman 1990). If this fails, too, people usually turn to their co-workers for information. And finally, when even the colleagues or superiors do not have the answer, one turns to information environment for help.

The design of any support system should reflect this natural process. Each new query for information adds a new level of complexity to the situation.

3.1. Analysis Required

The action facilitation approach suggests that to know, what kind of support is needed on the shop floor, the related tasks and actions, the structure of the employees' mental regulation and the context they work in has to be analysed. The first step of the analysis usually includes the **analysis of work processes and information flows.** Then it turns to **task analysis**, which elicits descriptions of what people do and what kinds of critical incidents they possibly meet during the task execution.

The next step, **cognitive task analysis** helps to describe functions of our intellect, such as the declarative and procedural knowledge that people have or that they should have to complete the task. Cognitive task analysis recognises that some of the performed actions are physical (such as pressing buttons) but some include cognitive operations (such as selecting a working method), decision-making and problem-solving.

It is well-known that tasks may differ from very simple and repetitive to very complex problem solving. In the former case, simple memory support is enough. In the latter case, decision making support with algorithmic and heuristic rules is required.

3.2. Active and Passive Support

When should support be offered for an employee? Should it be continuous or available only when a person feels he needs help? **Active support** provides automatically support that follows the employee's steps, i.e., the program monitors the employee doing his task and interprets his actions.

Passive support provides help-on-demand for the employee. The employee poses questions to the program when needed (Senge 1990).

There are no clear observations until now what kind of support the employees prefer. The hypothesis is that both types of help are needed to support work. It is, however, important to leave the final decision, what kind of support to use, and the amount of its detail, for the employee involved.

3.3. Usability Criteria

From an individual point of view, the usability of a support system is the single most important detail to address. In the development of the ITSS system, its usability has been of great importance. The expected user population has no previous computing experience. The most proficient, middle-aged employees are usually not fluent with new information tools.

A usable system is easy to learn, efficient to use, easy to remember, subjectively pleasing and few errors happen during its use (Nielsen 1993). For the avaluation of performance support systems we have defined a more specific set of usability criteria (Nieminen *et al.* 1995). These criteria include:

- **Learnability:** Users of the support system should be able to navigate in the system after having used it for 30 minutes. A short introduction (max. 15 min) can be arranged before that. Users are supposed to be non-expert computer users.
- **Efficiency:** Because the system should support information finding, this should be possible with minimal effort put to search. The minimum level is that it must be faster and easier to use the system than to search information from traditional paper based work instructions.
- **Memorability:** Memorability is supposed to be at a reasonable level because of the high demands on learnability.

- **Few errors:** Errors can be divided into two categories: operation and goal errors. Operation errors can be restricted to minimum by creating a simple user interface with only a few most necessary functions. These functions must be visible and users must not be forced to pass non-meaningful parameters to them. Goal errors are related to the instructions of the system hierarchy. System hierarchy needs to be presented in the training material of the system and in the layout of the user interface.
- **Subjectively pleasing:** This subject can and should be studied with interviews or simple questionnaires. The users must prefer computer based support to paper-based instructions.

We found that the most critical usability choice was the selection and definition of functions. They have to be as few and focused as possible in the activity environment in question.

In addition to the usability of the system, one should concider the usability of the information content of the system, too. Selecting the details critical for the task supported and presenting them with optimal media mix is as important as designing the system to deliver them.

3.4. Other Requirements

In addition to usability, we found several other critical requirements for a performance support system. The most important ones include:

- The system should be applicable also as a training tool.
- The people supported should be involved in the development of the support system and the authoring of the information content of the system.
- The information content and structure of the system has to correspond with the mental models of end users (Fig. 6).
- The virtual environment the multimedia documents has to be uniform with the physical environment of the work site.
- The vocabulary of the information content has to be understandable by all the user groups.
- The information content of the system has to be easy to create, update and maintain.

We should also remember, that instead of just supplying and transferring information, an effective performance support system provides a learning environment. That is, it provides interactions that enhance knowledge construction within the community of practice. This agrees with the social constructivist view of learning (e.g. Nilsson 1995).

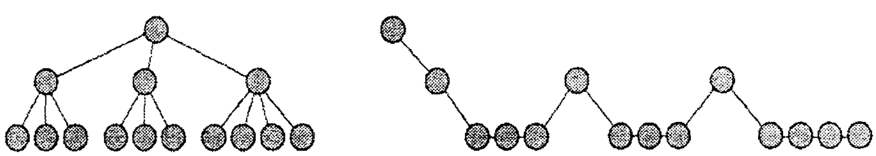

Fig. 6. Our original hierarchical model of a work task (left) and how it had to be refined to fit into shop-floor employees' more sequential mental model of their assembly tasks.

3.5. A set of Theses

But, alas, all these guidelines are just details. A more holistic, organisationally oriented angle is called for. As a conclusion we propose a set of theses for an organisation that is about to be involved with EPSS:

- **Attitude:** The best practical experience and expertise is on the shop floor. We should utilise it when we develop our task support tools and materials.
- **Expertise:** Good authoring tools are useful, but skills of a scriptwriter, photographer and task analyser and developer are also needed.
- **Approach:** Detailed analysis and documentation of a work task requires determined work with any tools. It is no secondary task.

Notes

1. An EPSS is an electronic system that provides integrated, on-demand access to information, advice, learning experiences, and tools to enable a high level of job performance with a minimum of support from other people.
2. Mental models refer to those models people have of themselves, others, the environment, and the things with which they interact. People form mental models through experience, training and instruction.
3. From the action facilitation model point of view, the phases of an action are: orientation, design of action programs, decision making, execution of action, supervisory activities and use of feedback.

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