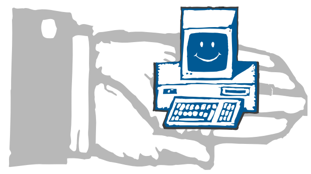
Performance Support on the Shop Floor



by Jyrki J.J. Kasvi and Matti Vartiainen, PhD

Highly competitive global markets and the development of new technologies have brought about radical changes on the shop floor. While changes in the environment create new demands, new technologies and organizational forms bring new opportunities.

This period is creating new tasks and professions, but even the production of traditional products such as cars and mobile phones demands new tools, practices, skills, and knowledge. This revolution of working life comprises rapid changes in competency requirements. The traditional distinction between production work and knowledge work is becoming blurred; Figure 1 shows a metaphoric image of this idea.

New customer-focused production paradigms that stress quality, flexibility, and new technologies are just some of the factors that have increased competency requirements of shop floor work (Kasvi et al., 2000). Together, these factors often form an insurmountable proficiency overload. For example, in traditional line production people repeated frustratingly simple tasks over and over again, but on a high-tech assembly line it often happens that employees do not put together two similar products in a day. What is more, they often assemble the products from scratch and manage the operation of their portion of the line by themselves. In these circumstances, people working on the shop floor cannot rely on memory alone.

As a result, management of operative knowledge has become crucial. When logistic chains were studied in the early 1990s, researchers found severe problems in the coordination of production processes that span production organizations. The reasons behind these problems centered on deficiencies in knowledge and communication management (Luhtala et al., 1994).

Knowledge has become an essential part of products and services, which have in many ways become knowledge products. Nevertheless, knowledge is not usually regarded with the same professionalism as the physical parts of a product. The quality outlays of deficient information are frequently neglected. For example, does your organization know:

- how much disruptions caused by deficient information cost?
- how much production of operative knowledge costs?
- what the lead and phase times of the ”knowledge parts” of the products are?
- the reliability of the knowledge operations?

Figure 1. Operating the frame saw of a modern lumberjack requires more computing skills than an average desk job. Photo courtesy of Timberjack Group.

Multimedia on the Shop Floor

While studying computer-based training in the early 1990s researchers found that training was no longer sufficient (Kasvi et al., 1993). A new set of tools was acutely required to supplement training. Tools that would deliver task-related knowledge directly to the work context, to the right person at the right place, at the right time, preferably in an easily digestible format. We were not aware of the electronic performance support system (EPSS) discussion initiated by Gloria Gery (1991) at the time, but she would most likely have recognized the resulting shop floor EPSSs or interactive task support systems as we preferred to call them.

The four shop floor support systems discussed here are all based on the same technological concept: Assembly-line work sites are equipped with standard PC workstations that are connected to the infobase via a local area network (Figure 2). The workstations are used to deliver multimedia documents that consist of text, digitized pictures and speech, and occasionally video sequences and CAD drawings.

The multimedia documents are structured to reflect the hierarchical structure of assembly tasks supported. Tasks are divided into stages that are further divided into details. For example, the assembly of a grounded extension cord might have a stage called "plug assembly" that consists of details called "lead connecting," "pull remover fixing," and "plug closing." If the assembly were to be supported, each stage and detail would have a multimedia screen of its own. For an outside observer, a work task is a process that consists of the stage details, but to understand and to learn the task, the performer groups the details into higher level units and stages with a meaning.

Multimedia was as fashionable in the early 90s as the Internet is now. Many multimedia systems were developed just because the technology was available. The question is: How do different combinations of text, pictures, sound, and video affect performance? To find the answer, the Helsinki University of Technology conducted a laboratory experiment with a product that consisted of Mekano blocks (Figure 3). The setting was based on the theories that suggest that a human mind can process visual and auditory information in parallel. Thus cognitive processing of information presented with speech and pictures should be more efficient than processing of information that is presented with other media combinations.

The results were twofold (Repokari et al., 2000). People supported with speech and pictures completed the task faster than people who had text and pictures or only pictures. On the other hand, people that were supported with text and pictures made fewer errors than the others. Thus, media combination selection does seem to have an influence on the outcomes of the system.

Unfortunately, further studies conducted on the shop floor have not yet provided conclusive results as the shop floor environment presents too many restrictions and variables. Different media combinations have been observed to support assembly tasks adequately, but the differences have been lost to the noise. Nevertheless, observations indicate that

Figure 2. An interactive task support system supports the end assembly of a GSM base station in the Nokia Networks Oulu plant. Picture courtesy of Nokia Networks.

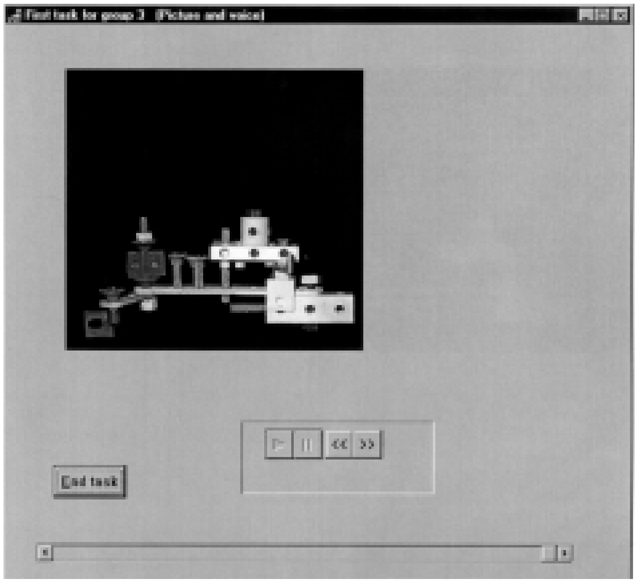


Figure 3. An example of a multimedia document used in the laboratory experiment to study influences of different media combinations (Repokari et al., 2000).

different people use the media in different ways. While most seem to prefer digitized pictures as their primary medium, some are more text oriented. If a support system is to serve all its users, both groups should be taken into consideration.

The Four Cases

In all the cases discussed here, the tasks supported were complex complete build end assembly tasks. Lead times varied from 20 to 45 minutes. In all cases the number of orders varied rapidly, and people were often transferred from one task to another. What is more, products and manufacturing methods were revised often, sometimes daily.

In addition, management of paper-based support materials had in many cases proven cumbersome and impractical. As the number of product variations grew, the paper become harder to manage. In one case the actual paper was the problem, as the static electricity produced by paper damaged sensitive electronic components.

In the Direct Current (DC) drive case, the support system completely replaced paper documentation on the shop floor. Not even the assembly drawings that had been the most important source of information were needed.

In the DC drive case and the Information Support System case the need for support was underlined by a high number of product models and variants. For example, the theoretical number of ABB DC drive variants exceeds 1 million! In the other two cases, the products were so complex that even without a large number of variants, the tasks justifiably required support.

End Assembly of DC Drives

Our first realized support system was a prototype built in cooperation with the ABB Industry Ltd. Pitäjänmäki Power Electronics plant in 1994, and it has since been used to support end assembly of DC drives. The support system was used for three purposes: to orient new employees to their tasks, to support training by doing and to support actual work task performance.

Initially the system was used extensively as people learned their tasks, but as people grew more proficient, the system was used less often. The use did not end though, and even the most experienced employees used it regularly to check details of their tasks. The usage of the system changed correspondingly. While new employees followed the multimedia documents with discipline from one stage detail to the next, the old hands used the contents page of the documents as jump points to reach the details they needed.

As a result, the flexibility of production and the whole organization improved. It became possible to transfer people from one task to another in a moment's notice. Furthermore, a couple of years later the support system eased moving the whole line *and* the work practices to Germany. An influence on quality was observed when the system was down due to technical problems: The automatic testing system rejected more defective drives than when the system was up and running.

The problems focused on the maintenance of the information content. As the work methods were revised so often, the support documents did not always stay up to date. If, for example, the color of a part on the screen was different than the part at hand, people often thought that *they* had made a mistake and halted the work.

End Assembly of an Audio System

Our second case, the IMS support system (Interaktiv Montagestøtte) was created to support the end assembly of the Bang & Olufsen A/S CD player with a built-in tuner and amplifier, BeoSound 9000 (Figure 4). There were no product variations to speak of, but the product was extremely complex. As a result of the design oriented product philosophy of Bang & Olufsen, BeoSound 9000 includes a total of 23 circuit boards. No compromises have been made to facilitate manufacturability. In addition, new materials, methods and tools were required.

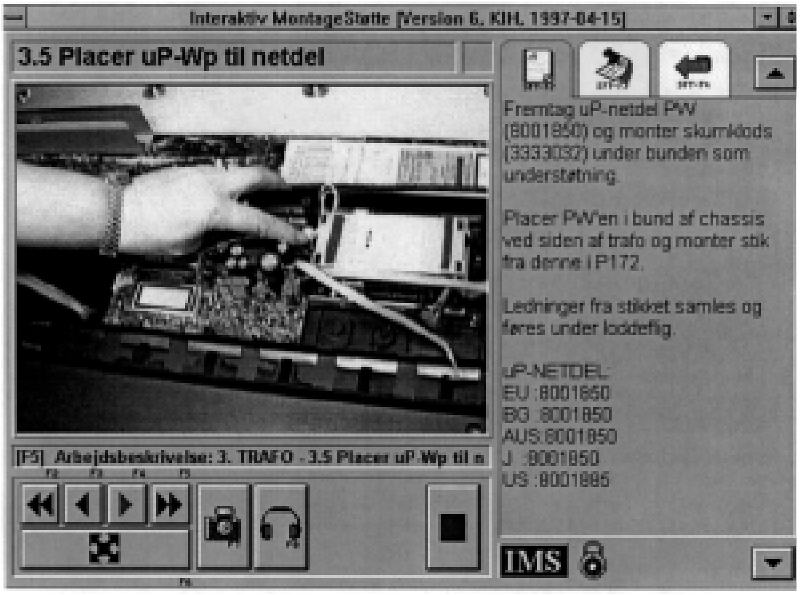


Figure 4. The IMS system was designed to be language independent as the programmer of the system knew no Danish and the users of the system had no idea of Finnish. This English version of the user interface was used to translate the interface terminology.

What is more, as most of the products are made to order, employees are often transferred from one line to another. Need for support is aggravated by the seasonal nature of highest end audio sales. Products like BeoSound 9000 sell much better in spring than in autumn. In addition to autumn holidays and longer work days in spring, the number of people in production grows from 350 to 480 in the spring season.

In addition to supporting task performance, the IMS system was designed to be used as a training tool and to support documentation of production methods. The idea was to create the information content during production method design. When applied in practice, this was found to be too cumbersome, as the methods change too fast during the planning phase. Instead, production testing was found to be the best time to author the first version of the support materials.

While the IMS system was tested in production, the employees working on the line started actively editing and commenting upon the information content of the system. Originally, editing the material was supposed to be restricted, but in the testing phase the lock had been left open. The people responsible for the work method design considered the material most useful. As a result, a liberal work method documentation scheme was adopted. After all, the people working on the line are the most experienced experts on their work methods.

According to a Bang & Olufsen study conducted in 1997, the IMS system was well suited for training new employees, who were able to practice without stress or embarrassment. Time needed for traditional training was reduced to one quarter, while the rest was replaced with learning by doing. This freed sorely needed planning resources as training of new tasks has traditionally been taken care of by product and task designers.

The IMS system was used for task support especially when assembly methods changed or people were uncertain of correct procedures. About half the shop floor employees kept the IMS system on while they were working. While the inexperienced employees followed the multimedia documents rigorously from stage detail to stage detail, the more experienced employees scanned the documents from stage to stage only occasionally navigating to details in search of more detailed information. Even more experienced assemblers used the IMS system, but only when they were uncertain of something. The system was also used as a notepad: People kept one “page” on the screen to remind them of a detail they had had trouble with. In addition, the system was used to solve an obstinate quality problem. For a while, all the employees were required to use the system all the time and to go through every task stage detail.

Locating correct information from the system was considered easy and fast, but the quality of the still video pictures was considered poor. In addition, maintaining the information content was considered easier than before as it was easy to do little revisions on the files in the server instead of copying and distributing paper file revisions to work sites.

System users missed a function that would have correlated users and revisions and told the user which pieces of documentation had changed since the last time he or she had used the system. Another shortcoming was lack of connections to other software systems. Production managers would have liked to transfer information to and from the IMS system.

Task Supporter

While the systems used in the two previous cases had integrated authoring and reading functions into a single system, Task Supporter of Brainware Oy consisted of three subsystems for authoring, reading, and managing information content.

The most important improvement of the system was reusability of the material: Parts of existing multimedia documents could be copied to new documents. For example, a picture could be used in several Task Supporter documents.

If the picture was edited, the author was able to decide if the change was specific to one document or if the picture should be changed in all the documents that use it.

The use of Task Supporter was studied in one company that had successfully implemented it. The complexity of the task supported was illustrated by the fact that the mere presence of the observer making questions caused the employees to make several critical mistakes.

Early 90's	Mid 90's (digital camera)	1999 (ISS)
Taking the photographs	Taking the pictures with a digital camera	Taking the pictures with a digital camera
Writing and printing the new instructions and developing photographs.	Writing the new instructions and combining the digital photographs with PC editing tools.	Writing the new instructions and embedding the digital photographs with PC editing tools.
Clipping and gluing the printed instructions and photographs to the final format.		
Copying new instructions with a color copier.	Printing the new instructions.	
Distributing the new instructions to the assembly stations.	Distributing the new instructions to the assembly stations' paper booklets.	Putting the new instructions to the server.

Figure 5. Maintaining support material has become more efficient with the introduction of new technologies (Koskinen et al., 2000).

In addition to the Task Supporter system, three other sources of support were present:

- The product construction and the work environment had been designed to support assembly.
- Trainers' offices were next to the line and the employees were supposed to consult them when needed.
- The old paper documentation system was still operating.

This diversity caused problems as the information provided was not always in the same phase. While the trainers and supervisors usually informed the employees immediately of new revisions, it took several days before the paper documentation was updated and even more time before the multimedia documents were up to date. As a result, people did not always trust the Task Supporter system. Even the trainers were sometimes outdated. A training session was observed where the trainer, an engineer who had helped design the product, was several times corrected by the line workers. He had not been informed of the latest revisions.

Nevertheless, people were satisfied with the shop floor information environment. They noted, "Information works really well here. We are immediately told when there are changes coming. We can also go and tell, if we have new ideas to suggest. Things work better on our line than on the other lines."

Information Support System

The Information Support System (ISS) developed by Arrow Engineering Oy differs from the previously introduced systems in two ways. First, it does not organize task descriptions into task stages and stage details. Only stage details are addressed and given "pages" of their own. Second, ISS is designed to communicate with other shop floor software systems. So ISS knows which model is coming to the worksite next.

The introduction of an ISS was studied on a Finnish production line (Hailikari et al., 2000). The new line was the answer to the rapidly increasing demand for the products. New people were introduced to production all the time, and personnel turnover was almost nonexistent.

The employees interviewed considered ISS better and easier to use than the old paper documentation system. Instructions provided in the paper documents were considered badly organized and it was difficult to locate the information needed. In addition, the paper files were often in the way and not always where they were supposed to be.

On the other hand, some of the end users felt that they could have used more training. Some of the employees did not even know how to turn the computer on! Meanwhile, some of the end users felt that training would be a waste of time. This difference disturbed introduction of the system as some of the people who would have benefitted from further training were too shy to come forth and ask questions. In addition, not all of the employees trusted computers. This distrust was enhanced by the fact that ISS was often down during the implementation phase. Different fears were also associated with the system. People were afraid that the support system would automate task performance too much or reduce employees' ability to remember important things by themselves.

The author users of the system considered the multimedia documents easier and faster to update and maintain than paper-based documents. In the early 1990s, updating the support material took an average of 235 minutes. In the mid 1990s the introduction of a digital camera reduced the average time to 125 minutes, and in 1999 the introduction of the support system cut the time further to 91 minutes (Figure 5) (Koskinen et al., 2000).

Lessons Learned

The implementation and efficient application of shop floor support has proven to be surprisingly challenging. For example, only about a quarter of the companies that had purchased the production license of Task Supporter actually used the system. One company even removed the system from production. The implementation problems were partly due to a turbulent economy: In several cases the plant in question had been sold and bought and the introduction of a new piece of software had been forgotten.

Once the support has been successfully implemented, there is surprisingly little resistance to change in spite of the fact that most of the end users have had very little experience in computer use. Mouse and keyboard are cumbersome, and in one case they were replaced with a bar code reader that the users were familiar with. In another case a foot pedal or a set of extra function keys was considered. The end users have almost unanimously considered computer-delivered support better than paper-based support arrangements.

According to our experiences, at least the following points have to be taken into consideration when shop floor support systems are designed:

- The goals of the system have to be well defined to have something to compare the results to. In addition, clear goals improve users' motivation to actually use the system.
- Interaction between developers and users of the system has to be intensive. Resistance to change and fears associated with new technologies have to be taken into account.
- Usability is paramount. For example, the novice users of the support system used in the DC drive production case required only 30 minutes of training (Nieminen et al., 1995).
- Authoring and managing the information content of the system has to be easy.

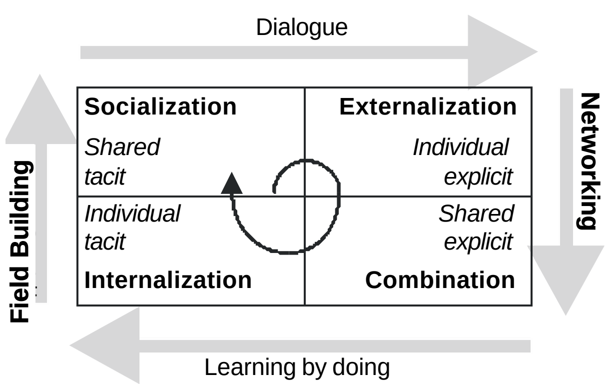


Figure 6. Designers of support systems should take Nonaka's and Takeuchi's (1995) spiral of new knowledge development into consideration. To foster individual and organizational learning, a support system is to support all the four transformations of tacit and explicit knowledge.

- The author and reader users of a shop floor support system require training.
- The authors of the content material have to know the tasks supported and their activity environment.
- The responsibilities have to be defined explicitly. In one case the person responsible for Task Supporter did not know about his responsibility for a year!
- A change agent is essential: In every successful case an agent dedicated to the support system was identified.
- The system has to be easy to tailor. As one production manager noted, "What do we do with a support system that takes half a year to tailor when we have to tailor our products and production on a daily basis?"
- The system must not be forgotten after implementation—but the system and its contents have to be maintained.

Discussion

In addition to delivering information, a shop floor support system should be used to support organizational learning. Actually a support system can be seen as the memory of a learning organization. To live up to the image, the system should support conceptualization and collection of the hands-on experiences of the employees. Unfortunately, mere technologies do not help if the organizational culture does not permit their application.

According to Nonaka's and Takeuchi's (1995) spiral of new knowledge development, individual and organizational learning are connected. To support this spiral, a support system has to address all the four transformations of tacit and explicit knowledge. (Figure 6). Different tools are needed to support different transformations, and care should be taken to ensure that the tools applied on one part of the cycle do not disturb some other parts.

Until recently, the EPSS discussion has been based on definitions written in the early 1990s. There is a risk that if applied rigidly, these may lead to systems that disrupt the spiral of knowledge development (italics added by authors):

"An EPSS is the electronic infrastructure that captures, stores, and distributes individual and corporate knowledge assets throughout an organization to enable an individual to achieve a required level of performance in the fastest possible time and *with the minimum of support from other people*" (Raybould, 1995).

"Those who have been able to see potential in EPS have also embraced its basic premise, that it is possible, and often desirable, *to enhance performance without necessarily pro-*

moting learning, to create expertise without necessarily creating an expert" (Rosenberg, 1995).

If social interaction is minimized with EPSS, as Raybould suggests, dialogue required for externalization of tacit knowledge may be diminished. If learning is minimized, as Rosenberg suggests, internalization of new knowledge may be influenced, as learning by doing does not happen. In our opinion, communication and information technologies are by name to be used to promote social interaction and learning, not to minimize them.

In addition, there are other, less-tangible questions that should be taken into consideration:

- How does support affect mental workload of the end users? A system that is difficult to use may actually increase competency requirements of the task supported. In addition, a support system can be used to track and to time tasks, which may have counterproductive influences.
- How does support affect the work community? Knowledge is power even on the shop floor and a support system will certainly have an influence on those structures. Does support make knowledge more democratic, or does it actually impose new restrictions?
- How does support affect competency and creativity? A major part of our self-esteem is based on our craftsmanship in our respective fields. An interactive support system may be used to collect individual tricks of trade and socialize them for the whole organization. But where does that leave our self-esteem?

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