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Knowledge Support in Learning Operative Organisations

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Laajalahti, Espoo,
December 27th 2002,
early morning hours.

Summary

The aim of this study is to understand the requirements, critical success factors and outcomes of knowledge support, particularly in learning operative organisations. Initially, the work focused on support of individual employees performing individual work tasks, but it soon became evident that the perspective was too limited. First, it was expanded to cover smaller work units, and later the scope was extended to organisations.

This study summarises many years of work, starting in the early 1990s and concluding on present day. It is based on five constructivist case studies, four of which address knowledge support of employees and teams performing light-weight end-assembly tasks, and one which addresses organisational learning and knowledge management in project organisations.

The key findings include:

– Knowledge support system design and development requires system perspective, understanding that the system is an integral part of the work system and the work system may have to be re-engineered to accommodate the support system.
– User-centered design is essential for a successful knowledge support system, and this approach must include not only reader-users of the system but all the various user groups, particularly the author-users creating and maintaining the support content of the system.
– Improved organisational flexibility is one of the key goals and observed results of knowledge support systems. But in order to facilitate organisational flexibility, support systems need to be adaptable and tailorable in order to be able to react to rapid changes in the products, markets and the environment.
– Implementation is a particularly difficult stage of knowledge support system development. In several cases implementation has fully failed or it has had severe side effects.
– A knowledge support system can act as the technological infrastructure of a learning organisation. But in order to do this, a support system has to capture new knowledge created in the organisation in addition to distributing existing knowledge.

While the results of a study consisting of case studies have limited generalisability, the results can be considered mostly valid in the domain of knowledge support of assembly work tasks. The assembly line cases studied had several similar key characteristics. But when it comes to findings concerning knowledge support in learning organisations, one should be more careful. Nevertheless, even those findings were most fascinating and indicate interesting possibilities for further research.

The original papers

This dissertation consists of an extended summary and four appended papers:

Eloranta E., Mankki J. & Kasvi J.J.J. (1995) Multimedia and Production Management Systems. Production Planning and Control, 6(1), 2-12.

Kasvi J.J.J., Vartiainen M., Pulkkis A. & Nieminen M. (1997) Information tools for the shop-floor. AI & Society, 10(1), 26-38.

Kasvi J.J.J., Vartiainen M., Pulkkis A. & Nieminen M. (2000) The Role of Information Support Systems in the Joint Optimisation of Work Systems. Human Factors and Ergonomics in Manufacturing, 10(2), 193-221.

Kasvi J.J.J., Vartiainen M. & Hailikari M. (2003) Managing Knowledge and Knowledge Competences in Projects and Project Organisations. International Journal of Project Management. Accepted for publication.

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1 Introduction

Highly competitive global markets and development of new technologies have brought about radical changes to work organisations. While changes in the environment create new demands, new technologies and organisational forms bring new opportunities.

This turbulent period is creating new tasks and professions, but even the traditional tasks like manufacturing of cars and mobile phones demand new tools, practices, skills and knowledge. This revolution of working life comprises rapid changes in competency requirements.

New customer focused production paradigms that stress quality and flexibility and new technologies are just some of the factors that have increased knowledge and competency requirements of different work tasks. 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 the line by themselves. Together, these factors may form an insurmountable proficiency overload. In such circumstances, training is not enough, and people cannot rely on their competences alone, but require efficient management of operative knowledge.

Corresponding situations can be observed in several other work settings, too. Work organisations need new knowledge and competency management practices and tools that facilitate these practices. Knowledge support or performance support, and corresponding computer systems offer one potential solution to these needs.

Figure 1. The revolution of work task requirements is well illustrated by the cockpit of a modern lumberjack with several computer and communication screens and control devices. Photos courtesy of Timberjack Group.

The traditional distinction between production work and knowledge work is becoming blurred. *Figure 1* shows a metaphoric image of this idea. The information and instructions we receive and act upon come more and more through machines rather than from observations of the real world. Now those machines are globally networked, and we have moved from the desktop into the world. We are witnessing an integration of media, people and communication. But people are not just passive recipients of information but actors, able to change and personalise the content of the information.

1.1 Background of the dissertation

Applications of information and communication technologies to support work task learning and performance with knowledge have been studied in the Helsinki University of Technology Laboratory of Work Psychology and Leadership since the early 1980s. The work started from development and study of computer based training systems and has evolved to support of learning work organisations (*table 1*). In the course of this work, three key developments have been observed.

Firstly, in the late 1980s, it became evident that the emerging information and communication technologies could be used for in task training. But until the early 1990s, the available multimedia technologies were so expensive and cumbersome that their practical training applications were limited. For example, the first mass-market digital cameras, high quality display drivers and sound cards became available during the first years of the 1990s.

Table 1. Research history behind this dissertation.

1970s	Critique of traditional work task training methods and practices.	e.g. Pöyhönen & al. 1982
Early 1980s	Development of task training and familiarisation methods. The Five Step Training method.	e.g. Vartiainen & al. 1989
Late 1980s	Development and study of a prototype *Computer Assisted Training System* (CATS)	Ollikainen & al.1991
Early 1990s	Development and study of another Computer Assisted Training System prototype (CATS!!)	Kasvi & al. 1993
Mid 1990s	Development and study of an operational support system for assembly-line work: *Interactive task support system* (ITSS) with ABB industry Oy.	Kasvi & al. 1994
Mid 1990s	Development and study of a Prototype information support system (ASIS) for marketing and maintenance.	Marttila 1995
Mid 1990s	Development and study of another operational support system for assembly line work: *Interaktiv Montagestøtte* (IMS) with Bang & Olufsen A/S.	Kasvi & al. 1996
Late 1990s	Study of implementation and use of a commercial information support system (Task Supporter).	Kasvi & al. 1997
Late 1990s	Study of *Information System for Assembly and Disassembly* (ISAD) A modular information system for assembly lines, including a support system for an assembly line work team.	Kasvi & al. 2000a
2001	Study of project organisation knowledge management and knowledge support needs.	Kasvi & al. 2003

Secondly, the 1980s and the 1990s marked a major shift in industrial paradigms. Or as one production line manager noted in the early 1990s when we tested our second Computer Assisted Training System prototype (CATS!!) on their assembly line: “A nice system, but we would have needed it five years ago. Today, we do not have time to train people anymore. We have to put them to productive work as soon as we hire them.” What was needed in addition to training was on-site support.

Finally, even as our first support systems (ITSS, IMS) were designed to support individual assembly-line work tasks (for example, end assembly of a DC drive), it soon became evident that the scope was too limited. The perspective had to be wider. First, we focused on assembly-line work teams, and lately on operative work organisations.

1.2 The many names of support

Over the years, the terminology we have used to describe knowledge support and systems providing it has changed many times. Originally, while our focus was on supporting execution of individual work tasks, the terms used were **Interactive Task Support** and **Interactive Task Support System (ITSS)**. The word interactive was used to stress the bi-directional nature of communication between the system and its user: in addition to delivering information, a support system should also collect it (Kasvi & al. 1996).

As our perspective expanded to cover work teams and organisations, the terms used were first **Information Support** and **Information Support System (ISS)** (Kasvi & al. 2000b). As the subject of knowledge management became better understood, these were soon changed to **Knowledge Support** and **Knowledge Support System** (Kasvi & al. 2003).

The most common term used in literature to describe corresponding systems is **Performance Support (PS)**, and systems providing this support are called **Performance Support Systems (PSS)**. If digital information and communication technologies are used to manage and deliver this support, the corresponding terms are **Electronic Performance Support (EPS)** and **Electronic Performance Support System (EPSS)**.

The reason why we have chosen not to adopt the EPSS terminology can be found in the definitions used for performance support systems in literature from the early and mid 1990s. These definitions often stressed minimisation of need for learning or human support (see, for example, Raybould 1995 and Rosenberg 1995). In our view, information and communication technology should be used to facilitate learning and social interaction, not to minimise them (Kasvi & Vartiainen 2000).

Other related terms include **Organisational Performance Support System (OPSS)** that focuses on supporting the organisation instead of an individual and focusing on collaborative learning, as suggested by Bill (1997). In a **Web-Based Performance Support System (WBPSS)** and a **Multimedia Performance Support System (MPSS)**, the technology used, the Internet or multimedia, is the main issue (see, for example, Brusilovsky and Cooper 1999, and Briggs 1996).

Interactive Electronic Technical Manual (IETM) is yet another, albeit more limited term. The term is most used in the U.S. military (see, for example, Kribs & al. 1996). Actually, an IETM can be used as a knowledge support system if it is accessible in a work context.

Job Performance Aid (JPA) and **Job Aid** are correspondingly wider terms, including all kinds of tools and systems that can be used to support work task execution (see Sleight 1994). If a Job Aid or a Job Performance Aid is computer-based, it is usually called an EPSS.

On-the-Job Training (OTJT) and **Just-in-Time Training (JITT)** are also often associated with knowledge support, particularly when information and communication technologies are used to deliver the training. While the idea of just-in-time training is to provide training when and where the competency in question is actually needed, on-the-job training is not necessarily bound by time but nevertheless takes place in an actual work environment. In literature, OTJT or JITT is often considered to form an integral part of a support system, and sometimes support systems are considered essential components of OTJT or JITT (see, for example, Cronjé & Baker 1999 and Collins & al. 1997).

1.3 The four studies

The four studies behind this dissertation have been published in peer-reviewed journals over the years. All of them have addressed issues related to knowledge management, particularly knowledge support in operative organisations. The organisations and settings have been different though, ranging from production management to assembly-line work to research and development projects.

The full texts of the studies can be found at the end of this dissertation, but short summaries have been included here for casual readers. Further discussion on these studies can be found in chapters 4 and 5.

1.3.1 Multimedia and production management systems

Eloranta E., Mankki J. & Kasvi J.J.J. (1995) Multimedia and Production Management Systems. Production Planning and Control, 6(1), 2-12.

While entertainment and educational applications of computer-mediated multimedia were already common in the early 1990s, industrial applications were still rare. Nevertheless, the opportunities for novel production management applications of emerging computing and communication technologies were already evident.

While emerging IC technologies provided the push for production management multimedia systems, the evolution of production management paradigms provided ‘’’the market pull required. During the previous few decades there had been three major waves in production planning control principles:
- MRP – Manufacturing resources planning
- JIT – Just-in-time

– LEAN – Lean (agile) production.

All three have been related to both the technology push of new data processing technologies and the amplifying market pull implied by new production management practices.

A lean factory is organised in teams. Communication is fast and continuous. The most important factor is to guide and support the decision making process. In such a team-organised environment, situations are examined, possible actions analysed and decisions made in a continuous process.

Lean information systems are needed for lean production management. Lean systems are decision support systems for professional users. Their information content is incomplete and even inconsistent in the traditional sense. The systems are planned around the decision-making processes of the teams. The detailed, bottom-up system concept with a preplanned solution to every situation gives way to the flexible, multimedia based communication and information environments, serving the principles of continuous improvement and learning organisation. The basic principle of lean ICT systems for lean production can be expressed as follows: “To apply human intelligence and interaction to simplify production management”.

The study concludes with two case examples of multimedia production planning related systems. (1) Plantool is a workstation application for creating and maintaining production schedules. The system offers an interactive graphical user interface that allows the user to tune planning schedules by clicking and moving the objects on the screen. (2) Interactive Task Support is multimedia based information support system that utilises text, still video graphics and speech to deliver information needed in a lightweight assembly task. This information includes data on tools and materials and critical quality factors and detailed work instructions. Each work site has a multimedia capable workstation connected to a common network file server. The system is used not only to deliver but to collect task related information. The end users can edit certain parts of the documentation and write inquiries into an embedded notebook. This way, authoring becomes a continuous process, enabling the organisation to learn.

1.3.2 Shop-floor information tools

Kasvi J.J.J., Vartiainen M., Pulkkis A. & Nieminen M. (1997) Information tools for the shop-floor. AI & Society, 10(1), 26-38.

The study discusses an information technological tool, Interactive Task Support System (ITSS). The purpose of the system was to both train inexperienced employees and to support experienced assemblers with all the task related information needed during the completion of a complex lightweight assembly task.

The system was 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. As the situation in the B&O case had been too turbulent to study in detail at that stage of the study, the conclusions were mostly based on the ABB case.

The usage of the ITSS changed when inexperienced trainees were turned into competent assemblers. The usage of the system diminished when an employee gained expertise, but it never ceased.

The users were heterogeneous in their media use. Some read all the texts some resorted to them only if everything else failed. Still video pictures were used as the most important information source. Actually, experiences with non-Finnish speaking test subjects indicated that even a major part of a complex assembly task can be completed without any textual information.

It was observed that the uniformity of the physical environment and the virtual environment within the support system is of paramount importance. Even minor differences like colour of a single component made some users think that they had made an error and prompted them to turn to other people for help.

The other observations included abolishment of paper documentation, increased flexibility of the work organisation, harmonisation of vocabulary and surprisingly low resistance to change.

A comprehensive performance support system can be regarded as the memory of the organisation. In fact, information management and support tools can be seen as the infrastructural basis for a learning organisation, as they enable individual and team learning processes: In addition to serving as an information source, a support system has to provide tools for reviewing existing knowledge and synthesising new knowledge.

Instead of just supplying information, a performance support system should provide a learning environment. It should provide interactions that enhance knowledge construction within the community of practice.

1.3.3 Information support and joint optimisation of work systems

Kasvi J.J.J., Vartiainen M., Pulkkis A. & Nieminen M. (2000) The Role of Information Support Systems in the Joint Optimisation of Work Systems. Human Factors and Ergonomics in Manufacturing, 10(2), 193-221.

Sociotechnical systems are adaptive and flexible if they have a certain amount of overcapacity, redundancy. The redundancy of a sociotechnical system is a function of its people (e.g. number, abilities and individual values), functions (e.g. goals and tasks), artifacts (e.g. parts and materials, information artifacts and tools), information and organisation (e.g. leadership, management, structure and organisational values).

Information supporting individual redundancy of functions can be extracted by interacting with four sources of information support:

1. One’s own memory consisting of declarative and procedural knowledge.
2. Social environment integrates cognitive, motivational, and emotional components with knowledge.
3. Physical environment consists of ordinary and computerised tools, parts and surroundings.

4. Information environment contains, for example, paper or computer based work instructions and manuals.

The definition of an information support system consists of four parts:
1. A source of information, supporting efficient, good quality, and safe completion of work activities.
2. Support is available on demand, in context with the task supported.
3. Information accessed spontaneously and the order of access in controlled by the end user of the information.
4. The system interactively supports the collection, creation, and synthesis of the experience-based knowledge of the members of the operative organisation.

The paper presents three examples of information support systems. All of them were designed to support complex light-weight end assembly tasks with hyperdocuments that contain text and still video pictures with optional CAD drawings, digitised speech and video sequences.

Two primary end-user groups were identified. Reader users used the information content to support their work and author users used the system to create this content. The roles were not completely separate, though, and reader users should be encouraged to input feedback and experiences into the system.

A successful introduction and implementation of shop-floor information support system requires three things:
1. A clear definition of the objectives
2. Solid cooperation between the developers and end-users
3. A change agent driving the project from conception to upkeep of the results.

1.3.4 Learning project organisation

Kasvi J.J.J., Vartiainen M. & Hailikari M. (2003) Managing Knowledge and Knowledge Competences in Projects and Project Organisations. International Journal of Project Management. Accepted for publication.

In addition to a product or service, projects produce technical, procedural and organisational knowledge. But while project organisations have become common, knowledge management of project organisations is underdeveloped. Nevertheless, project organisations require particularly systematic and effective knowledge management.

Table 2. A Project Memory System can be used to manage project knowledge. Its realisation and content depend on the knowledge management strategy adopted.

	Project Memory System	Project Memory
Codification strategy	Traditional and new information and communication technologies (e.g. documents, databases, email)	Explicit and declarative knowledge (e.g. specifications, instructions, definitions)
Personalisation strategy	Memory representations, personal interaction (e.g. mental models, dialogues workshops, seminars)	Tacit and procedural knowledge (e.g. competences, values, norms)

Two framework programmes and a review project were studied with interviews and questionnaires in order to understand:
– How do framework programmes manage knowledge?
– What knowledge management competences are required in framework programmes?

The observed codification strategy knowledge management practices were weak and unsystematic except for retrospective reporting. New knowledge was clearly created, but its accumulation and storage were unsystematic. Instead, the programmed relied on personalisation strategy. The greatest observed knowledge management competency needs were related to two knowledge management stages: knowledge distribution and dissemination, and knowledge utilisation and productisation.

Particularly systematic project knowledge management is needed, if results and lessons from one project are to be exploited in other projects. Some sort of a project knowledge repository and work practices that facilitate the use of this repository are being called for.

1.4 Structure of the dissertation

This dissertation consists of three main sections:
1. This introduction summarising and concluding the material presented in the four studies behind this presentation.
2. A supportive section consisting of an index and collected findings from the cases studied.
3. The four studies that form the basis of this dissertation.

Furthermore, this introduction consists of six chapters.
– Chapter 1 describes the structure and background of this dissertation.
– Chapter 2 discusses justification of this work and addresses the theoretical background influencing it.
– Chapter 3 identifies the research questions this dissertation aims to answer based on the material.
– Chapter 4 describes how this material has been collected and analysed.
– Chapter 5 reflects on the studies from the perspective of the research questions.
– Chapter 6 discusses the methodologies used and strives to place the results into a wider perspective.

2 Background

During the last few decades, business and society has become more and more turbulent. Both public and private work organisations have to become more flexible and agile, if they are to operate in this environment of continuous and unpredictable change (Goldman et al. 1995). One approach to flexibility improvement is organisational redundancy that can be attained either through redundancy of parts or redundancy of functions (Emery 1993 and Kasvi & al. 2000b).

This study focuses on redundancy of functions, particularly improving functional redundancy of the social element of the sociotechnical work system with knowledge support (*figure 2*). The discussion is rooted in a summary of 33 support system case studies found from literature.

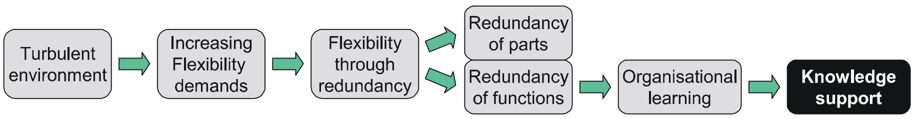

Figure 2. Flexiblity allows organisations to survive in a rapidly changing environment, and knowledge support is one way of improving that flexibility.

The chapter concludes with discussion on knowledge support system design and development.

2.1 Turbulent environment

Competency and knowledge requirements of the work place are increasing rapidly. Often this development is attributed to introduction of new product and production technologies (see *figure 3*), but technology is just one of the factors behind these developments. For example, new ways to organise work and people, and new business and production paradigms require employees to possess new competences. Principles like flexibility, agility and customer orientation have penetrated work organisations from strategic management to operative performance.

Marquardt (1996) lists four major areas, which have profoundly changed over the last years to influence work organisations:

1. Economic, social and scientific environment: Globalisation, economic and marketing competition, environmental end ecological pressures, new sciences of quantum physics and chaos theory (understanding of quantum physics means that one cannot predict with absolute certainty), knowledge era, societal turbulence.
2. Workplace environment: Information technology and the informated organisation, restructuring and resizing, total quality management movement, workforce diversity and mobility, boom in temporary help.

3. Customer expectations: cost, quality, time, service, innovation, and customisation.
4. Workers: Those who thrive will have problem identifier skills, problem solving skills and strategic broker skills. Corporations depend on the specialised knowledge of their employees. Knowledge workers do, in fact, own the means of production and they can take it out of the door with them at any moment.

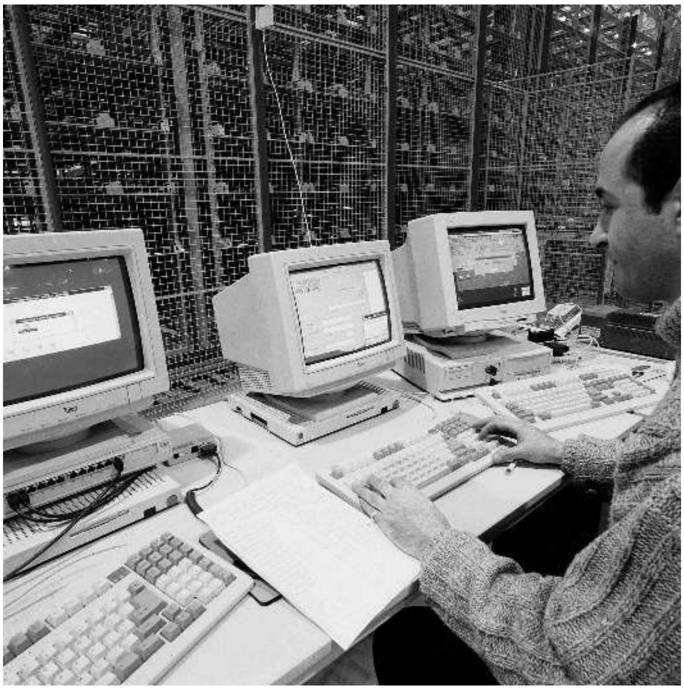

Figure 3. Work desk of a modern storeman with several computer systems. Picture courtesy of GWS Systems.

As a result of these developments, such a thing as purely physical work has become more and more rare. Instead, the nature of work is changing from mostly linear to mostly non-linear and from requiring mainly physical skills to requiring mainly mental activity. Knowledge workers will soon outnumber physical labourers as the fundamental working class of modern societies. Work tasks that have traditionally been considered physically oriented include more and more knowledge work characteristics (Fisher & Fisher 1998).

Many empowered manufacturing teams on today's shop floor make decisions that were previously reserved for middle-level management. Workers in these team-based operations set their own schedules, manage their own projects, rotate through multiple technical positions, hire their own team members, and participate in goal setting, peer evaluation, and daily management meetings. Even the most traditional factory work is rapidly shifting away from assembly-type linear work to non-linear physical work, or in many cases to knowledge work (*table 3*).

Table 3. Industrial trends affecting operations that traditionally have utilised physical work (Fisher & Fisher 1998, page 32).

Trend	Key implication
The automation of physical work	Remaining work is knowledge work
Work becoming increasingly complex	Workers need more technical knowledge
Unions more involved in decisions	Workers need more business knowledge
Increasing empowerment of workers	Workers spend more time on knowledge work rather than physical work

Traditionally organisations have answered to new competency requirements with task training and various job aids and documentation. But these traditional means are not always enough in the rapidly changing work environment, or as one production engineer commented: "It often happens that the assembly drawings arrive after the production of the product in question has ended."

Organisations do not always have the time or resources to train their people at the same tempo products, services and organisations are changing. For example, production managers regularly face and solve situations they may have never met before; Assembly-line workers may manufacture several different products with hundreds of potential variations on a daily basis; People called to participate in multi-disciplinary product design and development teams may not have training or experience in design and development, but their input and participation is nevertheless sorely needed. As a result, employees often start their work tasks before their learning curve reaches acceptable competency levels (*figure 4*).

The growing need for workplace learning has occurred because of the changes caused by technology and the tremendous increase in global competition. Or as for example Marquardt and Kearsley (1998) point out, corporate training has increased at 30 times the rate of college education in recent years. Employees will need to train themselves, and training will no longer take place in a fixed time and location with a group of people for just-in-case purposes; instead, it will be implemented on a just-what's needed, just-in-time, and just-where-it's-needed basis.

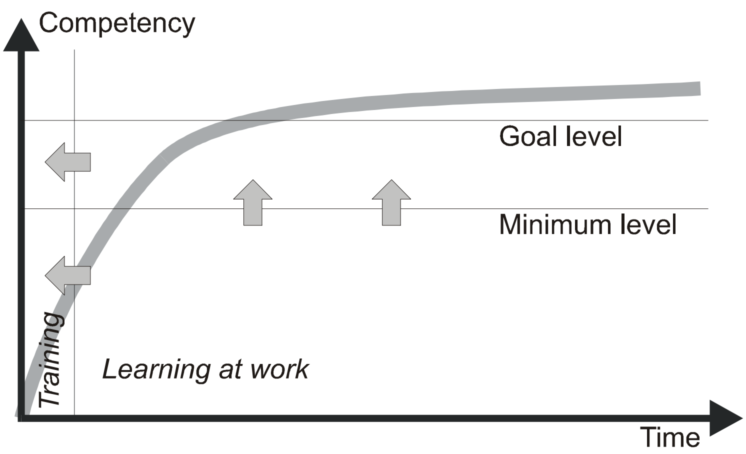

Figure 4. While time available for task training has diminished, competency requirements of many operative work tasks have increased. As a result, employees may have to execute tasks they are not yet fully competent in.

In order to thrive or even survive in such a turbulent activity environment, an organisation has to be very flexible. It has to be able to react rapidly to new threats and possibilities.

2.2 Four ways to flexibility

The key to organisational adaptability or flexibility is redundancy that according to the traditional sociotechnical approach can be improved either though increasing the number of parts or the number of functions of existing parts. But as work tasks have become more and more knowledge intensive, another perspective to flexibility becomes apparent: knowledge management.

2.2.1 Redundancy of parts and functions

A sociotechical system, for example, an organisation is a combination of a social and a technical subsystem, which are interconnected and interdependent (Emery and Trist 1960). In the traditional sociotechnical approach, organisations are viewed as adaptive and open systems (e.g. van Eijnatten 1993). Open systems interact with their environments moving from one technical and organisational structure and state to another (Mumford 1995, 1996).

A system is adaptive, if it has a certain amount of over-capacity, redundancy (e.g. Emery 1993). In the sociotechnical development approach, this redundancy can be attained either through redundancy of parts or redundancy of functions to the parts.

The redundancy of parts option considers human beings as unifunctional, replaceable parts: redundancy is achieved through technology and extra people. The number of employees changes if production volume changes. New competences are brought in as they are needed. In practice, work systems relying on redundancy of parts in order to be flexible, can often be characterised as lean.

The redundancy of functions option regards the parts, people as multifunctional resources capable of having many skills and roles: redundancy is achieved through extra competences, functions. Employees are shifted from one task to another in order to adapt the organisation to temporal changes in production volumes. People have extra competences in order to be able to work in many roles.

A good example of these two approaches can be found from Kari & al. (1999) and Kasvi & al. (1999), where two technically similar Finnish semi-automatic assembly lines producing corresponding products were analysed with several different methods. Both lines were in their first months of operation, included work steps from pre-assembly to packaging, and employed some ten people (*table 4*).

Table 4. Selection of flexibility approach can have a profound impact on production system characteristics (Kari & al. 1999, pages 50-51).

	Anthropocentric case	**Lean case**
Number of parts in main assembly	About 20	5 to 6
Phase time	Up to 20 minutes	4 to 8 minutes
Pre-assembly	By main assembly workers	Mostly by subcontractors
Repair of defects	By main assembly workers	By specialised technicians
Employment	Thru' extensive pre-training	Worker pool
Team leader	Yes	No
Buffering	Active buffer plus separate buffers for each workstation	Traditional buffer of one to three pallets
Flexible routing	Yes	Limited, workstations tied to the main material flow
Flexibility through	Redundancy of functions	Redundancy of parts

While the flexibility of one of the lines was based on redundancy of parts (lean case), the other was designed to utilise redundancy of functions (anthropocentric case). For example, in task design this meant that people in the lean case received only rudimentary training and performed relatively simple tasks that did not vary. Flexibility was attained through changing the number of people working on the line. In the anthropocentric case, employees received extensive training and performed complex tasks that varied a lot. Flexibility was attained through moving people from one task to another.

Another interesting difference was found from information sources used to support task execution in each line. For example, the printed materials used by the people working in the lean case assembly line were limited to laminated work method A4's, while in the anthropocentric case, corresponding materials included work method flap boards, work instruction folders, escort cards, test reports, and repair instruction folders. What is more, the anthropocentric case was about to receive an intranet based knowledge support system.

In spite of the fact that the sociotechnical approach preaches the affinity of the social and the technical organisation, it has divided organisations into definitely social and technical subsystems. Through technological developments this division has become more and more artificial. Or, as Banerji (1999) notes, work is done neither by people nor by computers but by human-computer systems. People and technologies interact and even merge to form new kinds of a work systems, whose "parts" are not mere people but entities consisting of people and their technical artefacts. These parts can have redundant functions, and the sociotechnical system can have functional redundancy, both through individual competences and information technological artefacts supporting these competences.

2.2.2 Two knowledge management strategies

Knowledge management (KM) has become one of the key activities of private and public organisations, as the basis of economy has shifted from utilisation of natural resources to application of knowledge assets. But while KM is widely discussed[1], it has no established definition, and some authors even refuse to use the term (see, for example, Barth 2000). This study adopts a process-oriented perspective on knowledge management, which is considered to consist of organisational practices, processes and technologies used to gather, develop, organise, distribute and utilise knowledge.

Organisations utilise two basic strategies for knowledge management (Hansen & al. 1999). **The codification strategy** is based on codifying the knowledge and storing it in artefacts and databases where it can be assessed and used over and over again. These technical repositories contain typically "hard" data, for example, database records, documents, and standard operating procedures.

In **the personalisation strategy**, the knowledge is closely tied to persons who developed it (people as repositories) and is shared by personal interaction. The content of these repositories are mainly "soft" items like stories, recollections, and details of a decision making process.

Davenport and Prusak (1998) offer a good example of the personalisation approach. While their organisational knowledge management model consists of the traditional three elements (Knowledge generation, knowledge codification and coordination, and knowledge transfer), they contain elements like personnel acquisition and informal communication.

As the main focus and investments in knowledge management are usually concentrated on ICT tools and explicit knowledge (codification strategy), the personalisation strategy often needs strengthening.

2.2.3 Combining redundancy and knowledge management

By combining the two approaches to organisational redundancy and the two knowledge management strategies, we can create a two-dimensional field for classification of different ways to improve organisational flexibility (*figure 5*). Selection of the most appropriate approach from this field is a highly sensitive selection that reflects both the situation and the values of the people involved.

[1] For example, the Google search engine found on August 29th 2002 935,000 web pages with the phrase "knowledge management".

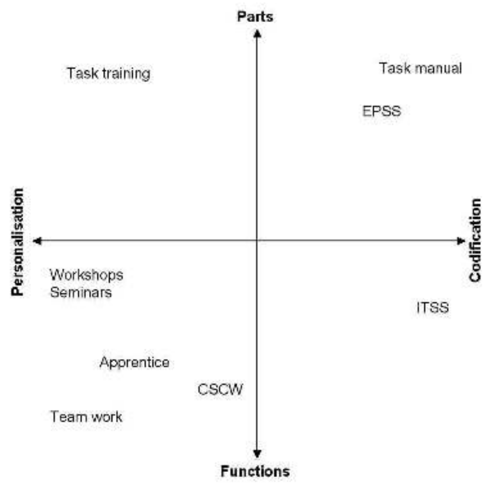

Figure 5. The four approaches to improve organisational flexibility through improved knowledge management.

2.3 Perspectives on learning

Managing knowledge is not enough. In order to be of use, knowledge has to be applied to practice by people. That is, they have to learn.

Learning has become a lifelong process. The traditional way of learning has been to bring students together for lectures that occurred in one's early years. Now learning is all-the-time, everywhere, yet just-in-time and customised just-for-you. We must now train ourselves, take the responsibility and develop the competences of self-directed learning. Learning has become the most important part of everyone's job.

2.3.1 Learning models

In order to discuss learning models, first we have to define learning. There are three fundamentally different ideas about the nature of learning, that is, how learning occurs, These three are behaviourism, cognitivism and constructivism. (see, for example, Ertmer & Newby 1993 and Andersson 1980)

Behaviourism is based on behavioural changes. The basic principle is to repeat and reinforce a new behavioural pattern until it becomes automatic. Behaviourism observes behaviour without referring to mental processes behind it. Learning is a passive process, where learner reacts to different stimuli (cues), for example, given knowledge.

Cognitivism focuses on the mental processes behind the behaviour. Human mind is seen as an information-processing system that commits abstract symbolic representations of given knowledge to memory, where they may be stored and processed.

Constructivism sees learning as an individual knowledge construction process. Knowledge cannot be given as such, but it will have to be (re)constructed by each learner. Therefore, learning results are based not only on given knowledge but on learners' prior experiences and schema. Furthermore, there are two main schools of constructivism. While cognitively oriented constructivists stress individual exploration and discovery as a basis of learning, socially oriented constructivists emphasise collaboration and interaction of learners.

Table 5. Characteristics of the three prevalent learning theories.

	Behaviourism	**Cognitivism**	**Constructivism**
Main contributors	Watson, Skinner and Bandura	Dewey, Piaget and Bruner	Vygotsky
Basis	Behavioural psychology	Gestalt psychology	Gestalt psychology and cognitivism
Knowledge	Given and absolute	Given and absolute	Relativistic and fallibilist
Focus	Observable behaviour	Mental processes	Personal or shared problem solving
Learning	Passive automatisation of repeated behaviour	Active mental processing of mental constructions	Individual or collaborative knowledge construction
Instruction	Repetition of stimulus and reward for desired reaction	Presentation of relevant information.	Preparation of the learner to construct the desired knowledge

2.3.2 Learning at work

Support of work task learning can be divided into three groups depending on the temporal relation between the work task and delivery of supportive knowledge: (1) training, (2) support, and (3) feedback. These groups correspond with the action regulation theory (Hacker 1973) that divides human actions to three phases: (1) orientation (design of action programs, decision making), (2) execution, and (3) control (supervisory activities, use of feedback) (*figure. 6*). So, in order to support work action from beginning to end, all three should be addressed.

Training happens before work task performance and may consist, for example, of lectures and exercises. In present turbulent work environment training is not always a sufficient solution as work tasks and competency requirements change too fast. What is more, the content has to be comprehensive, that is, answer to all the potential knowledge and competency requirements the trainee may face at work.

It should be noted that training is focused on the learner's present job, as stressed for example by Dubois (1993). This places training apart from **Education** that focuses on a future job of the learner and **Development** that is not focused on any particular work task (Dubois 1993).

Support takes place during task performance in task context. While trainer defines the content of training, it is the learner, an employee, that decides, what knowledge he or she needs in a given work situation. As support is available when needed, the employee does not have to remember everything by rote.

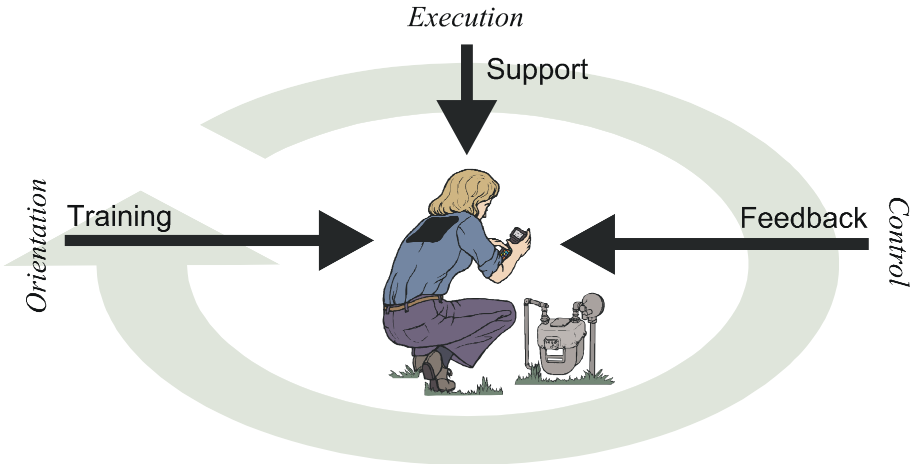

Figure 6. Methods and tools facilitating learning in work task context can be divided in to three groups depending on their temporal relation to work task performance. These three groups correspond with the three stages of human actions.

Feedback is provided after work task performance. This way it can respond to observed competency problems. The delay between the performance and the feedback should not be too long, though. Quality control systems are typical examples of feedback supporting learning.

It should be noted that according to many studies, most efficient learning happens when training is embedded in work processes (Raybould 1995, Huber 1998).

Table 6. While training, support and feedback may be provided by the same system, they have some fundamental differences. Adapted and expanded from Gery (1991) and Kasvi & al. (1997).

Training	Support	Feedback
Knowledge is delivered before the task.	Knowledge is during the task.	Knowledge is delivered after the task.
Either in or separate from task context.	Embedded into task context.	Either in or separate from task context.
Medium to long range goals.	Instant goals.	Short to long range goals.
Based on assumed information needs of the trainees.	Answers to employees' personal knowledge needs.	Answers to employees' observed competency deficiencies.
Trainer defines content.	Employee defines content, or the system observes the employee and deduces, what is needed.	Quality system defines content.
Trainees should not forget what they have learned.	Users can check on things if they are unsure.	People should not forget what they have learned.
Static environments and basic skills.	Dynamic environments and skill application details.	Skill performance feedback.

2.4 Learning organisation

Employees' individual learning is of course important, but it does not necessarily improve performance of the organisation they work in. If organisation itself does not learn, that is, integrate new knowledge learned by its members and change its ways of action accordingly, individuals working within the organisation may not be able to exploit the lessons they have learned.

Organisations that are able to learn faster will be able to adapt quicker and thereby achieve significant strategic advantages. This new species of organisations is called a learning organisation, and it possesses the capability to (Marquardt 1996, page 2):
- Anticipate and adapt more readily to environmental impacts
- Accelerate the development of new products, processes, and services
- Become more proficient at learning from competitors and collaborators
- Expedite the transfer of knowledge from one part of the organisation to another
- Learn more effectively from its mistakes
- Make greater organisational use of employees at all levels of the organisation
- Shorten the time required to implement strategic changes
- Stimulate continuous improvement in all areas of the organisation.

There have been many attempts to define a learning organisation, and as Virkkunen and Kuutti (2000) point out, the theory of learning organisation is still fragmented and lacks practival value. The most well known definition is that of Senge (1990, page 3), who defines a learning organisations as "Organizations where people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning to learn together." In addition, Senge lists "five disciplines" that are the keys to achieving this type of organization: personal mastery, mental models, shared vision, team learning, and most importantly, systems thinking.

Adoption of the learning organisation paradigm requires organisations to rethink their basic ideas (see *table 7*). While the need to acquire more knowledge will continue, but what people and organisations know takes second place to what and how quickly they can learn. Learning skills will be much more important than data. A learning organisation has the capacity to collect, store, and transfer knowledge and thereby continuously transform itself for success.

Table 7. The seven key paradigm shifts that make a learning organisation different from the traditional organisation (Marquardt & Kearsley 1998, page 29).

Traditional focus	Learning organisation focus
Productivity	Quality of performance
Workplace	Learning environment
Predictability	Systems and patterns
Training	Learning
Worker	Continuous learner
Supervisor/manager	Coach and learner
Engagement/activity	Learning opportunity

2.4.1 Perspectives to organisational learning

Organisational learning takes place when new routines and ways of action are conceived and adopted in an organisation through individual learning and group dialogue. These routines and ways of action are not dependent on the individuals and groups that have created them but survive even after the people involved have left the organisation.

According to Marquardt (1996), learning in organisations can occur at three levels. **Individual learning** is needed since individuals form the units of groups and organisations, or as Senge (1990, page 139) asserts "organisations learn only through individuals who learn". The factors that can contribute to individual learning in the organisation include:

- Individual and collective accountability for learning
- Locus and focus of individual learning (learning should have immediate application to the job.)
- Accelerated learning techniques.
- Personal development plan (people recognise that employers cannot guarantee them lifelong employment but that they can assist them in achieving lifelong employability. There should be a partnership between the organisation and the employee to assist in the long-term career development.)
- Abundant opportunities available for professional development
- Individual learning linked to organisational learning in an explicit and structured way.

Group/team learning means that work teams must be able to think and create and learn as an entity. They must learn how to better create and capture learning (learning to learn). A successful team learning system ensures that teams share their experiences with other groups in the organisation. Team learning will occur more fully if teams are rewarded for the learning they contribute to the organisation. Marquardt uses Watkins and Marsick's team learning model that shows the learning organisation as the union of individuals and organisation. The key is the overlap, which is where teams function.

Organisational learning (1) occur through the shared insights, knowledge, and mental models of members of the organisation, and (2) builds on past knowledge and experience which depends on institutional mechanisms (policies, strategies, explicit models...) used to retain knowledge. Though organisations learn through individuals and groups, the process of learning is influenced by a much broader set of variables (for example, the performance of a symphony is more than the sum of individuals' knowledge and skills but the result of the know-how embedded in the whole orchestra working in unison).

Another, problem focused perspective to organisational learning is offered by Argyris and Schon (1978), who identify three different levels of organisational learning.

- In **single loop learning** an organisation learns when it observes an error and corrects its, but does not change its policies, objectives or thinking models.
- In **double loop learning** an organisation learns by correcting observed errors in a way that involves the modification of organisational norms, policies and objectives.

– In **deutero learning**, members of an organistion reflect on and inquire into organisation's previous contexts and experiences for learning. Based on these reflections, the organisation and its members learn to learn, understand what facilitates or inhibits learning and invent new approaches for leaning.

The problem with Argyris' and Schon's (1978) levels of organisational learning is that that they are reactive. They require a stimulus, and learning is a response to that stimulus. In order to be proactive, a learning organisation should be able to create, acquire and transfer knowledge and change its behavior accordingly (for example, Sarala 1993)

But as Raybould (1995) points out, discussion on learning organisations has been weak on practicalities. What kind of practical mechanism would best support both individual and organisational learning? Raybould (1995, 2000) proposes an Organisational Performance/Learning Cycle (*figure 7*) as a basis for a conceptual framework for thinking about how people learn and perform in an organisation. This Cycle has five phases:

1. During **Performance-centered design** a knowledge base is structured and an interface created to present the knowledge to users.
2. **Performance** is achieved through the use of the system.
3. **Individual Learning** (of existing knowledge) happens as a result of performance supported with the system.
4. **Generation of new knowledge** happens in the course of performing work when the user develops new techniques, methods and procedures.
5. **Knowledge Capture** of the additional knowledge gained by individuals and teams in the course of performing their work is essential for organisational learning.

Organisational learning takes place when this loop is completed, and the knowledge captured in phase five is integrated into the knowledge base structured in phase one.

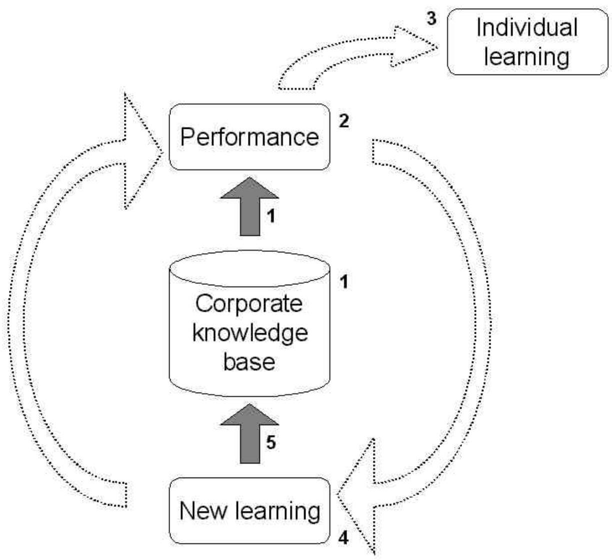

Figure 7. Raybould's (1995, 2000, page 4) Organisational Performance/Learning Cycle.

While Raybould's Cycle is limited to encoded knowledge and codification based knowledge management strategy (see subsection 2.2.2), it can act as a technological basis for a system that facilitates organisational learning.

2.4.2 Remembering organisational knowledge

Operative organisations have several potential outputs, not all of which are intentional or intentionally managed:

- A product or a service provided and delivered for an internal or external customer.
- Different kinds of knowledge related to the product or service or the organisation:
  - Technical knowledge concerning the product and its production and use.
  - Procedural knowledge concerning the procedures to produce and to use the product.
  - Organisational knowledge concerning the organisation itself.

Organisational knowledge is particularly important for organisational learning. If the organisation fails to systematically capture it (see *figure 7*) it risks repeating its errors over and over again and losing any learning possibly taking place. Organisational knowledge is based on the good and bad experiences of organisation members, team leaders and managers when they have successfully or unsuccessfully solved problems at hand and completed their tasks. But the negative experiences are easily forgotten, and people don't usually have enough time to handle and reflect on the positive experiences.

Organisational memory is used to define (1) the organisational knowledge and (2) the processes by which this knowledge is managed. This duality can be underlined by two outwardly similar but fundamentally different definitions of organisational memory: While Walsh and Ungson (1991) define organisational memory as stored information from an organisation's history that can be brought to bear on present decision, Stein and Zwass (1995) define organisational memory as the means by which knowledge from the past is brought to bear on present activities. The difference lies in the focus of the definitions: Walsh and Ungson concentrate on the memory content and Stein and Zwass on the memory system.

Organisational memory is distributed throughout the entire organisation in individuals' knowledge representations and competences and the Organisational Memory System may store it in various forms, for example, as databases, writings, stories, learning histories and as memories in people's minds.

The technologies and methods people use to realise an Organisational Memory System may be very simple like a shared paper folder or they may apply state-of-the-art information and communication technologies depending on the needs and facilities of a particular organisation. Electronic document management systems, electronic performance support systems and knowledge support systems, the subjects of this study, are typical examples of such technologies. But in order to form a core of an Organisational Memory, these systems have to accommodate all the levels (e.g. individual, group and organisation) and stages of organisational learning (for example performance, individual learning, creation of new knowledge, knowledge capture) discussed above (see *figure 8* for an example).

Actually, an Organisational Memory System, or EPSS, or whatever, should be able to handle two distinctively different kinds of knowledge. It should cover both substance and lessons learned, what was done and how it was done. It is not enough that an organisation collects, stores and distributes technical and procedural knowledge according to traditional knowledge management principles. The way this knowledge was obtained should be stored as well. There are practices that work and things that do not work in a particular situation. The organisations involved should be able to utilise these experiences, this organisational knowledge in their future projects. If these lessons are not stored for future use, the organisations cannot understand what actually happened and why. They effectively forget what they have learned and cannot become learning organisations.

But if the experiences are captured only as documents and other knowledge artifacts, the contexts and the processes behind the documents is lost (Conklin 1993). Both codification and personalisation knowledge management strategies (see subsection 2.2.2) are needed in order to comprehensively manage different kinds of knowledge in operative organisations.

In spite of the fact that knowledge support and knowledge management is much more than technology, technology is an integral part of it. Technology's most valuable role is extending the reach and enhancing the speed of knowledge transfer (Davenport & Prusak 1998). Technology also helps in the codification and even in generation of knowledge.

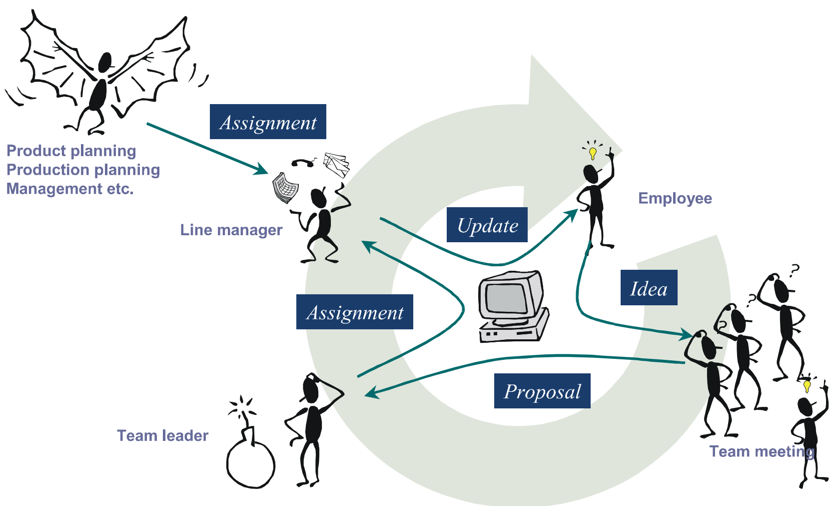

Figure 8. An example of a social system facilitating organisational learning within a work team. At the center of the system is a technological system supporting the social system, for example, a computer supported cooperative work system or a knowledge support system acting as an organisational memory system.

Davenport and Prusak (1998) point out that since it is the value added by people, context, experience, and interpretation, that transforms data and information into knowledge, it is the ability to capture and manage those human additions that make information technologies particularly suited to dealing with knowledge. Knowledge technologies are more likely to be employed in an interactive and iterative manner than, say, data management technologies. Therefore, the roles of people in knowledge technologies are integral to their success.

But supporting an individual or even a group to execute a work task with technology is still simple when compared to extending the concept of knowledge support to cover the whole organisation: “In order to support organisational learning, you have to address the whole operative organisation. As informative support has traditionally been targeted to individual people or groups, in a learning organisation we have to face the whole organisation in context” Kasvi & al. (1999, page 201).

2.5 Knowledge support

Davenport and Prusak (1998) conclude that what makes a company a learning organisation is 1) its capacity to have its people learn faster and better and 2) its ability to effectively manage knowledge. Technology is absolutely necessary to accomplish each of these functions. Or as Marquardt and Kearsley (1998) propose, knowledge support, or EPSS, as they prefer to call it, can provide a valuable info-structure for building a learning organisation. Raybould (1995) agrees, seeing an EPSS as the enabler of a learning organisation.

In order to thrive, that is, to learn and to adapt in these conditions, work organisations require knowledge tools that complement the requirements and abilities of their operative personnel. In addition to distributing knowledge to the work context, these tools should support knowledge creation, collection and development, if they are to facilitate organisational learning (*figure 9*). Developing such operative knowledge management tools is a challenging task that requires a combination of different kinds of competences. The designers of such tools have to take into account the requirements and limitations set by the people using them, the knowledge managed with them and the work tasks supported with the knowledge.

The knowledge managed with these tools is required elsewhere in the organisation, too. For example, an assembly line produces lots of valuable information on manufacturability and costing that could and should be utilised elsewhere in the organisation.

Fortunately computer and communication technologies have evolved during recent years so that they can be used to address this challenge. There are already several examples of very useful information systems that gather, manage and deliver required pieces of knowledge directly to the work situation. Unfortunately not all such operative information systems have been successes. There are also several such information systems that actually hamper work task performance.

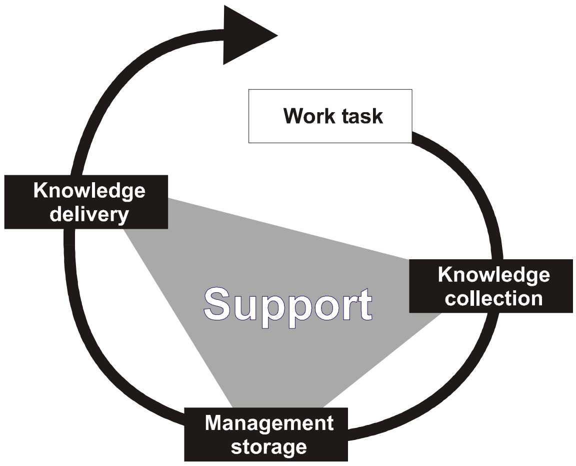

Figure 9. It is not enough to deliver the needed piece of knowledge to the work task performer.

Gloria Gery, an acknowledged authority in the field of computer based training, noticed in the late 1980s that training given prior to a task was not any more able to satisfy the various competency requirements of present day work environments. At the same time, computer technologies had developed rapidly and in the late 1980s possibilities like multimedia and local area networking emerged to widespread use. Putting these pulls and pushes together, Gery devised a totally new paradigm she called electronic performance support systems or EPSS for short (Gery 1991).

While the concept of EPSS was born in the United States a decade ago, and there are many successful case histories in North America, in Europe there have been only a few implementations of EPSS and the whole approach is almost unknown (Ceroni 2001). Ceroni identifies two main reasons behind Europeans' lukewarm reception of performance support: Different industry requirements and different cultural and social environment. In Europe there is a cultural (and often even legal) aversion to measuring or tracking individual performance. This dilemma is discussed in more detail in subsection 6.4.3.

Development and utilisation of support tools and methods has been closely tied with development of information and communication technologies:

– 1970s and before: Separate, non-computerised support, for example, paper documents, job aids, model dummies, task training, phone support (help-desk) and programmed learning.
– 1980s: Linked, computer-based support, for example, on-line-help, on-line-documentation, computer-based training and expert systems.
– 1990s: Embedded computer-based support, for example, electronic performance support systems (EPSS), product data management, wizard-functionalities and context-sensitive help
– 2000s: Transparent, interactive support, for example embedded, transparent support, mobile support and interaction with other people instead of a computer (teamware).

Table 8. Both users' and tasks' characteristics influence potential utility of a support system (adapted from Banerji 1995).

User characteristics	Task characteristics
– Staff turnover is high – Employees need to achieve high levels of proficiency very rapidly – High cognitive load – Wide range of user capability (knowledge level and task responsibility)	– Infrequently performed tasks – Tasks involving large amounts of information – Tasks involving multiple steps and parts – Applications or procedures that involve extensive functionality – Tasks requiring diverse knowledge

The potential utility of an EPSS depends upon the characteristics of both the people supported and the tasks supported. Banerji (1995) lists several, mostly knowledge intensive work situations where an EPSS may be an attractive solution (*table 8*). It should be underlined that not all support systems are computer based or even electronic. Too often, discussion focuses on technologies used and the knowledge managed with these technologies and the organisational implications are forgotten. Or as Harmon (1999) stresses, the word "system" is more important in electronic performance support systems than the word "electronic".

A comprehensive support system brings together different kinds of support from informal human support to well-defined electronic documentation (Sherry & Wilson 1996). One size does not fit all, that is, all forms of support have their strengths and weaknesses, and over-reliance on one type of support may leave the whole lacking in some respects.

Table 9. Key resources for comprehensive performance support (Sherry & Wilson 1996, page 31).

Support	Examples	Strengths	Limitations
Designed messages and experience	– Documentation – Training and instruction – Simulations – Web pages	– Conveys information well – Good peer review – Quality control	– Expensive to produce – Difficult to keep updated – May require specialised hardware/software
Information tools and resources	– Information databases – Procedural aids – Online help – Quick references – Search tools	– Flexible user control – Easy to construct and maintain – Specific and detailed – High-level expertise – Timely – Easy to keep up-to-date	– Information overload – May not be presented well – Variable quality – May not match user's needs
Informal human support	– Primary workgroup (office, team. cohorts, family, etc.) – Specialised support groups (online support groups, self-help groups, users' groups, SIGs, clubs, etc.)	– One-on-one mentoring – Backup support, helping where other supports fail – Local expertise – Motivational support – Group identity – Quick response time	– Resource intensive – Variable quality – Limited presentation capabilities – Lack of access

While the overall context for development of a knowledge support system is to improve job performance, the use of such systems tends to actually redefine the nature of work activities. Once people realise that a support system can allow people to accomplish a lot more, they start to develop/request more sophisticated on-line capabilities. Job responsibilities and roles change because a given individual is likely to be able to carry out a more diverse range of tasks, with more competency. Support system designers should know what changes in job performance they wish to achieve.

2.5.1 Definition

Early definitions of knowledge support or performance support reflected traditional organisational paradigms. Support was provided for a single recipient at a time, and the information content of the system was static and authored by someone organisationally separated from the recipients of the support. For example, Reynolds and Araya (1995) see performance support systems simply as electronic job aids, and the performance support pioneer Barry Raybould (1990) defines an EPSS as “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”.

But as organisations and their environment changed, the limitations of these early definitions became soon apparent. For example, Raybould (1995, page 11) has revised his definition to reflect systems thinking, essential to organisational learning: "An EPSS is the electronic infrastructure that captures, stores, and distributes individual and corporate knowledge assets throughout an organisation, to enable individuals to achieve required levels of performance in the fastest possible time and with a minimum of support from other people".

Another revision, introducing on organisational perspective, is offered by Bill (1997, page 6): Organisational performance support system, OPSS, is “an electronic infrastructure that captures, stores, organizes and distributes individual and corporate knowledge assets throughout an organization and enhances communication to enable an individual and the organization, to transform existing behaviour in order to achieve performance objectives in the fastest possible time.”

Yet another important extension is offered by Laffey (1995, page 31), who extends the idea of an EPSS with the concept of dynamism: "Dynamic support systems are characterised by the ability to change with experience, the ability to be updated and adjusted by the performer, and by augmenting other supports found in the performer's community".

Finally, as if to summarise all the definitions presented above, Raybould (1995, page 21) concludes by proposing a new definition of EPSS as “the electronic infrastructure that enables the learning organisation”.

While illuminating, Raybould’s (1995) conclusion is too unspecific and wide for our purposes. A more detailed definition of a system providing comprehensive knowledge support consists of four parts (Kasvi & al. 2000c, page 29):

- A source of information, supporting efficient, good quality and safe completion of work activities.
- Support is available on demand, in context with the task supported (*figure 10*).
- Information is accessed spontaneously and the recipient of the information controls the order of access.
- In addition to providing information, the system interactively supports the collection, creation and synthesis of the experience based knowledge of the members of the operative organisation.

Figure 10. This knowledge support system used in the Nokia base station plant in Oulu illustrates, how support is brought directly into work context. Picture courtesy of Nokia Networks.

2.5.2 Different kinds of knowledge support

The actual form and functionality of a knowledge support system depends on the work and people supported. For example, a simple memory aid may suffice for a simple and stable assembly task but complex tasks like maintenance of the assembly equipment may require detailed work method descriptions and a base of real life maintenance cases augmented with communication tools that allow consultations with human experts. In use, the system tells less-experienced users the best solution to a problem. Experienced users may question the system's recommendations.

A support system may be active or passive. While an **active support** system monitors the employee's progress and the production process and provides information that the system deduces to be needed, a **passive support** system, waits for employee's requests for information (*table 10*).

Table 10. An active support system can monitor both employee's progress and the work process (Kasvi & al. 2000c, page 41).

		Monitors actively employee's progress	
		No	**Yes**
Monitors actively work process	**No**	Printed manual of a computer program	Task trainer
	Yes	Escort card	Experienced colleague

Banerji (1995) categorises support systems according to the nature of the task supported:
1. Systems intended for software support.
2. Systems designed to support computer-based tasks.
3. Systems intended to support non-computer-based jobs.

Another important distinction can be made based on the level of integration of the support system with the task supported. Gery (1995) distinguishes between three basic types of support:
- **Intrinsic support** (or embedded) is so integrated with the underlying application that from the end user's point of view it can be regarded as part of the application itself. For example, a wizard (there may also be extrinsic wizards that the user has to invoke as stated by Gery 1995).
- **Extrinsic support** (or linked) is also integrated into the application but the user must break task execution in order to access support. For example, Windows Help.
- **External support** (or separated) is not integrated with the application and requires a user to break the work context and access something that is clearly separate from the target application. For example, a printed user manual or help desk.

The recommended design principle is to make support as intrinsic as possible. Or as Bezanson (2002) notes, support can often be implemented by building into products various performance-enabling features. Those aspects that cannot be built in, can be taken care of with a specific support system. Of course, if the tasks supported are not conducted with a computer, only external support is possible.

Capabilities provided by a support system depend on its realisation and application area. For example, a wizard may be very useful for tasks involving computer applications, but has no application on a system supporting maintenance tasks. Examples of typical support system capabilities include (see, for example, Reynolds & Araya 1995, Ockerman & al. 1996, Leighton 1996 and Gery 1995, classification follows principles suggested by Miller 1996):
- Source of information the employee needs to perform a task. The repository of this information is often called an information base.
  - Reference information, for example, case histories that the users may occasionally need.
  - Work method instructions, for example, a list of subtasks or a simulation of the work task.
  - Cue cards provide hints and tips on important task details.
  - On-line help is a reactive advisor that aids users of a computer system over problems.

  - Task-specific, just-in-time training, for example, tutorials and simulations allow users to study and learn. The learning experience occurs while the work is being done, not in a separate context.
  - Tracking and feedback tracks task execution in order to provide feedback.
- Simplification of the task.
  - Tools that support execution of actual work tasks, for example, by automating routine calculations.
  - Wizards and templates guide users through tasks summarising choices and conditions and suggesting recommended procedures.
  - A coach is a proactive advisor, providing guidance in goal setting and task monitoring.
- Decision support that enables the employee to identify appropriate action in a particular situation.
  - Advisors and decision support systems guide users when they analyse and evaluate a situation and help them to make decisions.
  - Expert systems provide specific advice for specific needs.
- Other.
  - Self-assessment of performance.
  - Knowledge collection and development tools are used to accumulate and manage knowledge content for the support system. Such tools may be used, for example, to gather case histories describing, how the users have approached and possibly solved problems.
  - Communication tools support communication needed at work and delivery of new knowledge created.

When CBT Solutions magazine in 1996 made an inquiry into types of EPSS used in the United States, 639 of 10,000 questionnaires were returned. While the sample used in the survey is small and far from representative, the results illustrate the great diversity of the approaches support system developers use (*table 11*).

Table 11. Support systems may apply very different methods. The CBT Solutions magazine survey in 1996 indicates that eight types of support were used in 100 or more of the 639 organisations that had completed and returned the questionnaire (Benson 1997).

Support method	Number of organisations using the method
Reference information with search functions	216
Explanations	200
Context dependent help	186
Demonstrations	140
Interactive instructions	136
Tool hints	135
Context independent help	136
Work method instructions, wizards, coaches	117
Application presentations	77
Cue cards	77
Screen tours	68
Other	25

2.5.3 Reader and author users

Knowledge support systems have two primary user groups, each of which should be taken into account in support system design. In many knowledge support systems there are two separate user interfaces for these two groups.

Reader users or end users, as they are also called, use the system to support their work performance. They are typically operative personnel, for example, repairmen or bank clerks. In many cases they do not possess previous experience in computer system use, and may have negative bias to computers. Introduction of new computer systems should therefore be planned carefully in order to avoid negative first impressions.

Author users create and maintain the information content of the support system. They are typically trainers, foremen, or production planners. They should have a very good understanding of the people and tasks supported and the environments where they are performed. In many cases, authoring does not take place in connection with the tasks supported, and the author users are not familiar with the everyday problems encountered.

These two roles are not always clearly divided, as people using a knowledge support system to support their work may also contribute to its information content. Actually, such mixing of roles is essential for continuous improvement of the system and the support it provides.

2.5.4 Related information systems

Knowledge support is just one of many new applications of technology that influence work performance and learning. Often the actual computer systems introduced to operative organisations combine characteristics and functionalities of various different systems, and it may be difficult to say, where knowledge support ends and for example knowledge management or computer-based training begins.

Sherry and Wilson (1996) list several information systems and disciplines that are closely aligned with performance support, including computer-supported collaborative work (CSCW), technical communication (TC) of just-in-time just-in-place information, and electronic publishing. According to them, all of these systems actually provide performance support and have two shared concerns even if emphasis may vary:

- Instruction and learning: Creating environments, products, and processes to support new learning
- Information conveyance: People can perform well when they have the information they need in a timely and understandable manner.

Computer-supported collaborative/cooperative work (CSCW) systems and groupware systems facilitate synchronous and asynchronous cooperation regardless of collaborators’ physical location. Tools used may include videoconferencing, chat systems, and realtime shared applications, such as collaborative writing or drawing (synchronous) and email, newsgroups and shared databases (asynchronous). While

CSCW may form an integral part of a knowledge support system, all knowledge support systems do not necessarily support cooperation.

Computer-based training (CBT) is an old discipline dating back to 1960s, when IBM trained users of its mainframe computers with Coursewriter (Hawkridge 1988). This history is reflected by the multitude of terms used over the years to define the variety of computer systems used to facilitate learning (*table 12*). These terms have reflected not only development of technology (from computer to multimedia to web) but also development of learning paradigms (from teaching and instruction to learning). The main difference with knowledge support is that that training takes place before actual task execution, and often not in task context.

Table 12. The multitude of terms and associated acronyms that have been associated with learning applications of information technology. Adapted from Kasvi (1991).

(Interactive) (Intelligent)	Computer Multimedia Hypermedia Internet Web WWW	Based Assisted Aided Mediated Managed Enhanced Interactive	(Self) (Collaborative)	Training Learning Instruction Education Teaching Development Study Studying Coaching Tutoring Testing

The infobase containing the knowledge content of a support system is often actually a knowledge management (KM) system or an enterprise data management system (EDM or EDMS) or it may contain a product data management (PDM) system (*figure 11*). The role of the knowledge support system may be to act as an interface to these higher level systems, identifying relevant information and presenting it in a format that is applicable in work task context.

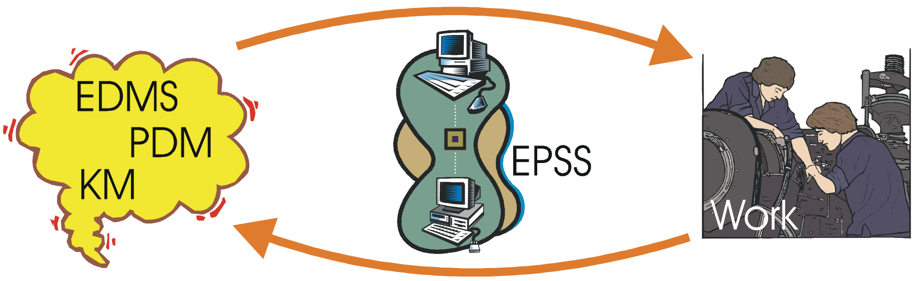

Figure 11. Knowledge support may act as a bridge between work task performance and higher level information systems.

2.5.5 Knowledge support cases

Good examples, especially studies of actual support systems and their influences are rare in literature[2]. What is more, the systems described are often addressed only from the technological point of view, and the organisational and social issues are neglected.

This subsection collects findings from 33 case studies conducted on different knowledge support systems. The list is a result of an extensive search through literature. This search would have been impossible without access to several web-based article databases provided by the library of the Helsinki University of Technology.

Several case studies found have been omitted from this list, as the papers discussed only requirements and design issues of a support system to be developed, or documented a system to be implemented. Or as O´Gorman (2001) notes in the summary of his case study of the SAS Maintenance Support System: "It would also be interesting to collect some real data on the performance of the SAS maintenance organisation before and after the system was introduced to try and quantify the benefit in some way". An American Society for Training and Development (ASTD) study on the use of electronic performance support systems in companies found out that only 31 percent of companies with at least one EPSS in use had evaluated the system for effectiveness, and only 10 percent of the systems had been evaluated for improved job performance and only five percent for return-on-investment (Benson 1997).

The *table 13* below is divided into four columns. The first describes shortly the system studied and its context, the second identifies the goal of the study, the third describes the data and methods used in the study, if available, and the last column presents the findings and outcomes of the study. In some of the cases, one or even two of these issues has not been addressed in detail. As a result, even some of the summaries in the table below, are somewhat terse.

While the table below summarises findings of tens of studies in a compact format, an even more compressed perusal was needed in order to find the common and the distinctive factors of these studies. This summary has been appended to this study as Enclosure 1: Key features of the case studies analysed.

Table 13. Knowledge support case studies identified from literature, their goals, data and methods, and findings and outcomes.

[2] There exists a good source of descriptions of commercial performance support systems and tools in the Internet. The EPSS Central presents several systems that have won the annual Performance Centered Design Competition awards in: http://www.pcd-innovations.com/infosite/design_awards.htm

Case description	Study goal	Data and Methods	Findings and outcomes
ADAPTS Adaptive Diagnostics and Personalised Technical Support is an intelligent, adaptive hypermedia EPSS for maintenance technicians maintaining complex equipment. ADAPTS integrates adaptive guidance from diagnostics systems with adaptive access to technical information. The system adjusts the diagnostic strategy to who the technician is and what the technician is doing. (Brusilovsky & Cooper 1999, 2002)	To proof the concept of adaptive EPSS and experiment with the user model using operational technical manual from a U.S. Navy H-60 helicopter	Not described.	It can be concluded form continuation of the development and research work that the concept of adaptive EPSS was proofed. For example, a usability study has been initiated.
AmEx EPSS An American Express Financial Advisors (AmEx) EPSS supports handling of the death of an AmEx client, that is, 'Title Transfer'. A Title Transfer task may involve several financial products and the task performers have to understand more than 30 ownership types, five to seven estate settlement types, 50 state estate settlement reporting requirements and so on. The system is actually an automated letter-writing system that links to AmEx mainframe, from which it gets information about customers and their financial products. (Paul 1999)	To describe developers' experiences.	Not described.	Observations presented include: – The system saves users about 29 minutes per letter while people working with title transfers produce an average of 1000 letters every month. – Half of the people working on title transfers quit before the application was fully deployed. – Some employees feared that they would be supplanted by a machine. – Political issues are involved in any EPSS project.
APPLE A Adaptive Planning and Process Learning Environment for Assembly is used to produce assembly plans. The system is based on proprietary web-browser technology in an intranet and determines operators' requirements from three factors: skill or training, experience with a company or job, and familiarity with a particular product, assembly plan or operation.	To determine what benefits the system would provide to manual assembly planning: – Make comparisons with the existing systems, particularly in terms of cost and quality. – Identify interface and functionality problems.	6 subjects, 2 from each of the 3 UK aerospace manufacturing firms were all experienced planners, and received 1,5 hours of training in APPLE A use. Performance measures like time taken to produce a plan and preference measures like clarity of terminology were collected through video analysis (60 hours), background	Not all the material had yet been analysed in the papers. Presented conclusions include: – Participants found the system easy to use. – All participants initially found the tree structure confusing; they tend to think bottom-up, creating the assembly documentation in sequential order. – Inputting data was considered to be relatively easy. – Some of the participants found some of the

Case description	Study goal	Data and Methods	Findings and outcomes
Operators' skills matrix is compared with skills required by the assembly plan, and support that fits both the task and the performer is provided. The system has been developed in cooperation with three U.K. aerospace and avionics companies. (Rea & al. 1998, 2000)	– Prove the system in a working environment with current and meaningful assemblies.	Questionnaire and audio recordings.	standardised terminology confusing. – Bill of materials window was considered to be the most useful aspect of the system.
ASSIST ASSIST stores and utilises the collective memory of astrophysicists about data analysis and is used world-wide by them to support their work. In addition to providing support to astrophysicists and collecting for example their "data analysis recipes", the system communicates with different analysis systems and different documentation mechanisms. The system is an X Window System application built upon the Answer Garden Substrate (AGS). (Ackerman & Mandel 1999)	To assess usability and usefulness of the ASSIST system.	6 self-identified ASSIST users were interviewed with a semi-structured interview and 20 users were given a questionnaire.	– Usability of the ASSIST was acceptable. The two problems identified were the number and management of windows, and the terseness of the lists of analysis components presented. – The system reduced the amount of complexity in astrophysical data analysis.
BOPS The Back Office Performance Support system developed in the INSEAD Business School Centre for Advanced Learning Technologies is actually a learning and knowledge management system that supports employees, trainers and managers to provide the right training and knowledge to the right people at the right time. (Ceroni 2001)	– To assess the impact of the system, focusing on benefits – To identify external and internal barriers to the adoption – To identify potential organisational changes, – To evaluate resistance to change, and effectiveness of change management plans.	Three pilot organisations, Caritas Luxembourg, a Catholic charitable organisation, Siemens Information and Communication Networks SpA, a telecommunication equipment manufacturer, and The Chamber of Commerce and Industry of Paris. Questionnaires, interviews and log file analysis were used, but no details of the methods or data were given.	The findings of the pilot cases were mixed: While the concept and technical implementation were found to be valid, the results imply the existence of other success conditions. Three key success factors were identified: 1) Corporate IT culture: A large diffusion of PC usage and familiarity with networked communication eases the adoption of a new IT system. 2) Users motivation and involvement: Special attention to change management and end user involvement in system design reduces organisational resistance and avoids unnecessary design errors. 3) Responsibility and organisational framework:

Case description	Study goal	Data and Methods	Findings and outcomes
			Those in charge of deploying the system must have proportionate control over the target organisation and its active collaboration. Roles and responsibilities must be clear.
CLASS CLASS is a distributed performance support system (DPSS) developed to support teaching, learning and administration activities within the School of Business and Management at the University of Teesside. In practice, CLASS could also be called a comprehensive learning and teaching platform. (Barker & Beacham 1999)	To assess learning results and both staff's and students' attitudes.	The situations considered were: 1) Minimal support; a CAL package was used to teach the topic; no lectures were given and tutorials were organised in an ad-hoc basis, as and when they were needed. 2) Conventional support with 'add-on' CAL; A conventional teaching situation (with scheduled lectures and tutorials) with students using the CAL package as an 'add on' extra. 3) Conventional support with 'ownership' of CAL; Similar to (2) but involved re-organising the way in which the CAL package was used; The CAL program was used (by the lecturer) as a central resource (for demonstration and illustration purposes within lectures, tutorials and workshops) and by students (for the support of self-study activities). 4) DPSS. The same as case (3) but with the addition of a purpose-built DPSS facility (CLASS) to augment the course Z (in general) and the teaching of the module Y and topic X (in particular). Questionnaires were used in order	– Cases 3 and 4 were superior over cases 1 and 2. – The topic knowledge transferred by CAL techniques using Case 3 was less than that which takes place in Cases 1 and 2. – The only approach which scores positively in all the six attributes studied (knowledge of topic after using CBL package, like using the CBL package, factors limiting use (difficulty with package), CBL package easy to use, environment contains features that are helpful, the range of sources available for practice) was Case 4.

Case description	Study goal	Data and Methods	Findings and outcomes
		to obtain the opinions of staff and students with respect to pedagogic, technical, logistic, organisational and resource-based issues.	
Ericsson hypermedia MI A hypermedia system designed to support manual end assembly of mobile phones in the Ericsson factory at Carlton-in-Lindrick (UK). The system used a mixture of text, movies, lists of parts and drawings of parts. The system plays three roles: 1) An operator memory aid on the shop floor 2) A quality document that provides a standard way of assembling the phone 3) A Training aid for new recruits. (Fakun 2000, Greenough & al. 2000b)	– To evaluate usability of the system. – To explore the application of hypermedia documentation to the manual assembly of mobile phones.	Feedback was gathered in two stages: 1) During a set of presentations with informal discussions. 2) Through formal usability study with 20 assemblers, two at a time, who filled a background questionnaire before using the PDF version of the application in a series of test scenarios.	During the feedback session, users felt that – The system was easy to use – Better than the paper equivalent – Good introduction to the assembly process – They might get lost in the system – The movies were too fast – There was not enough information on use of physical job aids. In the usability study: – Computer anxiety had a significant negative effect on perceived ease of use. – User participation (user-IS relationship) did not have a significant effect on perceived ease-of-use. – User participation did not have a significant effect on perceived usefulness. – Perceived ease-of-use had a significant positive effect on perceived usefulness. – Perceived ease-of-use did not have an effect on intentions to use the system. – Perceived usefulness had a significant postivie effect on intentions to use the system.
Ford Digital Manual A hypermedia system providing maintenance information to teams of multi-skilled workers. The main goal was to enable rapid identification of components that needed replacing and to help users to find the relevant stores reference number. A pilot system has been developed to support the piston/connecting rod assembly machine in	To evaluate the impact and usability of the system upon maintenance in an automotive engine plant.	In the Bridgend plant 18 users participated in usability trials after the system had been in use for eight months. 15 of the subjects had not used the system before but were from another area of the factory. In the Ford Dagenham engine plant, 12 operators participated in corresponding trials but with an	– The first responses from users were positive, but system usage was disappointing due to the existence of informal sources of information, developed by employees over several years. After a new assembly machine was installed, the informal sources became obsolete. – Computer anxiety did have a significant effect on perceived ease-of-use in one site but not in the other, indicating other influential factors.

Case description	Study goal	Data and Methods	Findings and outcomes
the Ford Bridgend Engine Plant. (Greenough & Fakun 1998a, Greenough & al. 2000a, Greenough & al. 2001, Fakun 2000)		improved version of the application. Improvements were based on the Bridgend trials. The trials were based on the Technology Acceptance Model and consisted of several small tests in which users were asked for information, which they had to find with the system. During the tests the subjects were observed. After the trials the subjects were asked to evaluate their use of the system. The tests were conducted off the actual work site due to noise.	– User participation (user-IS relationship) did not have a significant effect on perceived ease-of-use. – User participation had a positive effect on perceived usefulness. – Perceived ease-of-use had a significant effect on perceived usefulness in one site but not in the other, indicating other influential factors. – Perceived ease-of-use did not have a significant positive effect on intentions to use the system. – Perceived usefulness had a significant positive effect on intentions to use the system in one site but not on the other, indicating other influential factors. – Estimated annual savings if the pilot system were extended to the entire line, would be at least $190,000.
Hymatic hypertext A hypertext support system with a web browser as a user-interface is used to support assembly and testing of a product. The system contains process documentation for assembly and testing for a wide variety of complex products. The documentation for a job consists of process layout, test specification, process specification, test card, drawing request, test set-up and technical library. (Fakun 2000)	To confirm that operators experienced a reduction in frustration in retrieving the required information.	A questionnaire was distributed to all operators. 30 completed questionnaires were obtained, equivalent to 75% of the population.	– The operators saved about 30 minutes per job using the system as opposed to printing corresponding instructions. – Computer anxiety had a significant negative effect on perceived ease-of-use. – Ease of use had a significant positive effect on perceived usefulness. – Ease-of-use did not have a significant effect on use. – Usefulness did not have a significant effect on use. – User training did not have an effect on ease-of-use. – User training did not have an effect on usefulness. – Subjective norms did not have a significant effect on use. – Image did not have an effect on use.

Case description	Study goal	Data and Methods	Findings and outcomes
			– Usefulness had a significant positive effect on reduction in frustration. – Reduction in frustration had a significant positive effect on use.
IMMS The Intelligent Maintenance Management System of the U.S. Air National Guard McEntire training base provides information and decision-making assistance to maintenance officers in scheduling helicopters for maintenance at the base. IMMS generates, on demand, reports that show which helicopters are nearing phase inspections or other special inspections, specifying components requiring maintenance soon, and the priority flying schedules. (Byrd & al. 1991)	To evaluate the system.	Five test cases using real data from past situations were used to compare how well a human scheduler and IMMS prepared priority flying schedules. Two statistical tests were used to compare management data from the 12-month period before IMMS implementation with the first 12 months of implementation. User interface usability was tested by comparing the number of errors made by nonusers (n=4) with five minute long instruction to using the system (15 tasks with 30 minutes of time) of the system with those made by experienced users (n=3). In order to evaluate the system, a questionnaire consisting of 78 items was given to maintenance schedulers after the system had been in use for a year. The questionnaire addressed nine categories: Data amount and arrangement, data availability, data presentation, structured framework, decisions and advice, efficiency, data integrity, interface design, and overall reactions.	– Two helicopter types (of three) moved significantly closer to the maintenance goal of flying all helicopters of a particular type equal numbers of hours. – The number of the fully mission capable aircraft was increased. – The schedules produced by a human scheduler and IMMS were identical in all the five test cases. – There was only a small difference between the number of errors conducted by nonusers and experienced users. – Over 90 percent of the responses to the questionnaire were positive.
Insurance agent EPSS An EPSS, developed for a large Dutch insurance company is used by its widespread network of insurance agents.	To compare working and learning effectiveness of EPSS in comparison to traditional classroom	Three groups: one working and learning in a traditional way, one working and learning with an EPSS and one acting as a control group that	– Traditional paper based presentation was preferred, because it was quicker to look things up from a manual than from a computer. – The computer did not support the agents better

Case description	Study goal	Data and Methods	Findings and outcomes
The system provides information, advice and learning about the insurance products. (Bastiaens & al. 1997)	based training.	received no training and worked in a traditional way (n=36 in total). Qualitative data was extracted from structured interviews (four from each group), observations of a practical case situation (the same subjects) and a discussion. In addition, managers were interviewed (n=8). Quantitative data was collected by individual sales results and questionnaires.	or worse than paper. – In training, classroom instruction was preferred over CBT because trainees liked the contact with colleagues. – Trainees enjoying learning together preferred classroom instruction and trainees preferring learning alone preferred CBT. So an EPSS is not a solution for everyone. – CBT was not appreciated as the most effective form of learning. – The difference between classroom training and CBT learning results was not significant. – There were no significant differences in the selling results of the three group. – Training did not have any contribution to the productivity. – EPSS is cheaper than traditional training. In order to fully benefit from EPSS, the organisation has to restructure its tasks and organisation. During the study, employees tried to do their job the old way, with an EPSS.
Interactive Volleyball Interactive Volleyball is an EPSS supporting volleyball coaches to plan their daily practices. The system includes over 400 video drills, the ability to modify the drills, 250 educational practice notes, a glossary with 130 volleyball terms, and a customisable practice planning tool. (Kilb & al. 2001)	To explore the impact of an EPSS on coaches	24 volleyball coaches and physical education teachers were trained (a two-hour workshop) to use the program and asked to use it in planning their daily practices. Pretest questionnaire evaluated coaches' experiences and attitudes towards using computers. After the workshop, the they filled in a questionnaire about their attitude toward the usefulness of the software and whether they would consider using it in the next volleyball season.	All of the coaches agreed that there is a role for technology in coaching.

Case description	Study goal	Data and Methods	Findings and outcomes
Internet Kiosk An information kiosk presenting information to factory workers via a web browser. The content was related to the maintenance and setting up of machine tools. In a pilot study, the kiosk was used to support operation and maintenance of a complex machine tool. In the main study, the kiosk was used to support people working on a machining center machining profiles on aircraft engine combustion casings. (Greenough & Butcher 2002)	To evaluate the use of an information kiosk in a factory.	In the pilot study, a simple usability questionnaire was used, but the number or nature of subjects is not discussed. The main study is still going, and only initial field notes have been used.	The pilot study was spoiled by slow speed of the system, caused by a glitch in the software environment. No inappropriate use of the Kiosk was observed during the pilot. In the main study, the system is popular with operators and is seen by them to have some advantages over existing methods. For example, information access is faster.
Johnston Boiler Project A demonstration EPSS developed by the U.S. Coast Guard to support technicians using the Way-Wolff Boiler #2 used on Coast Guard Cutters. The boilers were failing every two to three years instead of expected 20 to 30 years. The system is actually an Interactive Electronic Technical Manual, containing all the material used before in an accessible electronic format. (Arnold 1999)	To assess how individuals use the EPSS in operating environment.	The Coast Guard evaluated 20% of the cutters of the fleet that had the boiler system, tested individuals on mock-up demonstrations and tested on-shore based maintenance teams.	– On a 13 question test, the scores of individuals using EPSS and the paper manual were 12.9 and 3, respectively. – The time to complete tasks was 50% lower for those trained using EPSS than for those trained with the paper-based manual.
KERMIT EPSS Two prototype support systems to support use of a simple file transfer software called KERMIT in a laboratory experiment. One system provided text-based task information and step-by-step prompting while the other had the added feature of step-by-step audio prompting. (Banerji 1995)	To evaluate potential utility of on-line support.	18 male and 18 female subjects were organised into six groups consisting of three males and three females: 1) Control group was made up of expert KERMIT users 2) Control group of novices, who performed the task with online-help. 3) A novice group that had online-help and a printed document 4) A novice group that had online-help and an expert providing advice and guidance	– Task performance times were affected by various levels of support provided. – Performance time with the text-based EPSS was comparable with that of an expert user. – With the multimedia EPSS, 64% memory retention was achieved, which was 24% than that achieved using the text-based EPSS

Case description	Study goal	Data and Methods	Findings and outcomes
		5) A novice group that had online-help and the text-based EPSS 6) A novice group that had online-help and the multimedia EPSS. Performance times of two tasks consisting of 12 steps were measured. A post-test was given to all subjects to assess how many commands were remembered ater a lapse of 30 minutes.	
KWS Knowledge Worker System, developed by the U.S. Army Construction Engineering Research Laboratories is a computer based, integrated performance support environment, groupware, designed to document, coordinate, and execute the business processes assigned to workgroups. It allows workgroups to define the tasks, information resources, institutional knowledge, and computer applications required to perform their business processes. (Thomas & al. 1995, Kappes & al 1995)	To identify appropriate methods to evaluate the feasibility of a performance support environment for knowledge workers.	A literature study of various feasibility study methods from the perspective of the KWS.	No single tool can effectively measure and evaluate an activity as complex and intangible as knowledge work or performance. A set of five techniques, each applicable to specific workgroup setting is suggested for assessment of feasibility and usefulness of a performance support environment: – Work profile analysis can indicate how knowledge workers typically spend their time. By calculating the number of hours worked and the total cost of each type of work, the total cost can be figured. – Direct to indirect ratio shows, how much time is spent on direct vs. indirect work. – Time saved times salary technique multiplies gains in efficiency by labour cost. – Activity based costing attempts to allocate the actual cost of providing a service or producing a product. – Quality assessment should minimally collect customer and supervisory feedback and provide opportunities for self-assessment.
LPS The Lesson Planning System is designed to	To investigate the value of performance support for	Four students, novice lesson planners were studied for patterns of LPS	– Subjects were able to perform a complex task and develop expertise.

Case description	Study goal	Data and Methods	Findings and outcomes
support lesson planning tasks. The system had two sets of functions: Instructional support focusing on learning (e.g. lesson structure, preparation, planning methods and reflection) and performance support focusing on task performance (e.g. verb database, work pad and example processes). (Wild 1998)	novices undertaking a complex cognitive task.	usage over a two-week period, when they planned a minimum of six lessons. Data was collected by video tape recordings in order to count interactions with the LPS. Individual interviews were conducted at the completion of the period. Further, each of the lesson plans produced was evaluated by an expert and compared to a lesson plan produced by each subject by pen and paper.	– Afterwards, they were able to continue planning lessons even without the use of the LPS. – Subjects found considerable cognitive support in the LPS, when support was most needed.
Manufacturing on-line help A large Dutch manufacturing firm with 2700 employees introduced an on-line help system for 300 employees at the departments Production, Planning & Engineering and Inventory. Together with the new system, new working procedures and new computer software were introduced. (Bastiaens & al. 1999)	To evaluate the effect of on-line help systems on the performance and learning of the employees.	Three jobs (planning engineer, coordinator and warehouse employee) were selected. The researchers monitored the implementation phase for six months and looked at the usability and effectiveness. A summative evaluation was conducted three months after the implementation and after a refresher training course. Employees (n=30) were asked to solve problems in the their own field of expertise and in three related fields. They had 20 minutes to solve each case. From this group an additional 11 employees took part in an observation. In the pretest, the subjects were requested to answer 8 open questions (declarative and procedural) derived at random from a set of 16 questions. They had to respond to the questions without the support of the on-line help	– Scores on the cases were extremely low, although the employees all had a specific refresher training course. No group could give a solution to a case within the 20 minutes time limit. – The value of the on-line help system was not evident – The employees scored higher on the learner test after implementation of the help system.

Case description	Study goal	Data and Methods	Findings and outcomes
		system. After the implementation of the system the subjects had to answer 6 questions. This time they were allowed to use the help system. To evaluate the surplus value of the on-line help system, the group of employees was randomly split into two conditions: 15 employees were allowed to use the help system, and the rest were not allowed to use it.	
Multimodal support A laboratory test information support system designed to support simple assembly tasks with different combinations of media. (Repokari & al. 1999, 2000a)	To identify the optimal composition of different media in lightweight assembly knowledge support.	Four groups (37 university students in total) were given different instructions (plain text, text and picture, picture and voice, printed CAD-picture) on how to assemble two objects from Mecano blocks. All subjects answered a questionnaire that covered experience in using computers, age, and educational background.	In the laboratory test, it was found out that media selection has an effect to assembly time and quality: – The assembly was fastest in the group that got the instructions with voice and picture. – The group that got the instructions with pictures only, made the greatest number of errors. – The group that got the instructions with text and picture made significantly less errors than other users.
NECST The New Engineering Contract Support and Training system is an EPSS developed to support mid-level managers of a large South African, semi-state owned utility provider to learn a new system of contracting. The system is built around a hypertext document, containing the New Engineering Contract in its entirety, with hyperlinks to comments on relevant clauses. The advisory system consists of a contract generator, where the user specifies options or completes dialogues leading to the generation of a final clean copy of the contract. Drawing from the infobase, is a collection	to assess the appropriateness particularly acceptance of the users of EPSS in providing on-the-job assistance and training in the construction industry	The system was installed to the computers of 21 randomly selected potential users, 12 of which used the system and participated in the study. Methods included Observation, usability testing, expert reviews, an implementation log, interviews with users and a questionnaire distributed to the users.	Findings supported continued use of electronic systems to support the performance of mid-level management. EPSS is a valuable alternative in a society where all the skills may not be in place to have a specific job done. Involving the subject matter experts in the beta test worked well. Recommendations were: – Subject matter experts should believe in their subject matter. – Subject matter experts should be familiarised with the concept of performance support.

Case description	Study goal	Data and Methods	Findings and outcomes
of interactive training sequences. There are two assessment systems. The first is a self test which can be done as a conventional test or coupled to a game of "Black Jack". The second is a formal computer-based examination. (Cronjé and Baker 1999).			
NNAble NNAable supports Apple Technical Coordinators in their tasks that include troubleshooting computer and communication systems used by Apple employees. The system consists of a case library (that the user can extend), collaboration tools, reference source and training practices. On top of these is an agent finder shielding the users from the complexities of finding the resources needed in each situation. (Laffey 1995)	To support Apple Technical Coordinators and to study how they acquired, utilized and transmitted problem-solving knowledge within their job context.	Research methods or data used was not presented.	Three key areas essential to successful skill development and work were identified: personal experience, tools and artifacts, and community membership. The author recommends that a performance support system is to augment and integrate the sets of resources relevant to the workers in the field. The key principles required from EPSS developers are: – Appreciation that their work will be a part of the work system – Focusing their design on the users' interaction with the work – Recognising the power of the situation to shape meaning and understanding – Drawing upon organisational memory – Fitting technology to the performer rather than vice versa.
PHelpS PHelpS is an AI-based system developed for the Correctional Services of Canada Prairie Regional Psychiatric Centre. PHelpS supports employees who use the Offender Management System that keeps track of information about the inmates in Canada's prison system. The system consists of two modules: The Personal Assistant provides context-specific performance support, case-abased help and peer help during task	To evaluate usability of the system.	Usability study consisting of two sessions, both lasting for 75 minutes. The first one was used to introduce the system. The four trainees were in the training room and the helpers were on duty performing their day-to-day activities. The experiment was recorded using audio, video, trickle files (of the keystrokes) and observation notes. In addition, initial usability	– The users used task hierarchy checklists but most of them checkmarked task steps only when they required peer assistance. – Five out of seven help requests were successful. The failures were attributed to failure to communicate the context of the help requests. – All trainee workers preferred to choose "a knowledgeable peer", even though they were sometimes strangers. In addition, the trainees ignored the job hierarchy as long as the helpers

Case description	Study goal	Data and Methods	Findings and outcomes
execution and the Knowledge Update module permits users (peer helpers and helpees) to inspect and update the system's models. (McCalla & al. 1997, Greer & al. 1998)		experiments and formative evaluations have been conducted with the system.	were willing to collaborate. – In the initial usability experiments and formative evaluations the learners using PHelpS were more focused on learning the procedural skills to complete a task, had a reduced cognitive load and thus, were more able to focus on the kinds of judgements required.
Retail banking Support System An intranet-based system has been designed to support the advisory and sales process in retail banking. The systems contains information about the customers, products, and competitors from internal data sources and external information like news, stock quotes, market surveys, and so on. (Schmid & Bach 2000)	To identify and solve specific business process problems.	Action research was used in order to identify and solve specific business process problems. The methodology used to design an intranet to support a business process with knowledge consisted of four steps followed by implementation: 1) Process analysis, especially required knowledge inputs and generated knowledge outputs. 2) Knowledge analysis in order to match knowledge sources with knowledge requirements. Includes data records, documents and expertise. 3) Knowledge organisation, with particular attention to implicit knowledge. Knowledge can be organised to facilitate process oriented or subject oriented navigation. 4) Content management processes for creating, distributing, maintaining and removing contents of knowledge sources.	In addition to the prototype system and the methodology used, authors document some lessons learned: – Structured access to relevant information eased finding the information needed. – The users expect the quality of the consultations to be improved due to process-oriented navigation structure. – Facilitated access to experts will help the advisers. – To ensure the usefulness of the system, its contents must always be up-to-date.
Software configuration management An UNIX based pilot EPSS has been developed for Bell-Northern Research Ltd in	To draw recommendations for support system	Developer's personal experiences.	Based on his experiences, the author provides the following recommendations: – Users may need to be coached into a new

Case description	Study goal	Data and Methods	Findings and outcomes
order to support use of a software configuration management tool. The system includes some 20 CBT modules, some 30 help modules, and eight reference documents. (Bezanson 1996)	developers.		paradigm. – PSS development should be of an iterative prototyping nature. – PSS development is complex and needs project management. – A PSS team should be multidisciplinary. – Research current PSS development tools. – You may need to start by convincing your organisation to invest in PS. – Design your information modules to be small, single purpose, and quick to refer to. – You should be careful not to assume that you know better to teach than the user knows how to learn. – Work very closely with customers and users.
STAR-ASI System for Training Aviation Regulations, is an on-the-job training aid for Aviation Safety Inspectors. The system is based on a computer-based training system for Aviation Maintenance Technicians, STAR-AMT. (Chandler 2000)	To descibe the development process.	The case traces the process of repurposing a computer-based training system into an on-the-job training aid. Data or methods are not discussed in the paper..	Based on the experience, the author draws four conclusions: – It is much easier to build a resource that incorporates training than to build a trainer that metamorphoses into a job aid. – The system needs to be highly modular. – Applying a browser approach to interface design increases the options for how the system can be used. – Keeping training programs current will continue to be a challenge, even if electronic publishing may offer some solutions.
TA A prototyped Task Advisor has been developed to support Microsoft Access users. TA can provide task-oriented information in a proactive manner while people are working on their tasks. (Brown & Mao 1999)	To assess effectiveness of EPSS relative to classroom training.	92 novice users of Microsoft Access were provided with either classroom training, or orientation with the Task Advisor in addition to Access' built-in online help. Following the session, they completed a variety of tests to determine the types and completeness of their mental models,	– EPSS supported subjects outperformed classroom trainees on conceptual tasks while there was no significant performance difference in procedural tasks. – EPSS supported subjects were far more likely to develop conceptual mental models, but these models tended to be less complete. There was very little difference in the completeness of

Case description	Study goal	Data and Methods	Findings and outcomes
		and their ability to perform both procedural and conceptual tasks.	mental models when they were procedural.
Testing of face shovel hydraulics An EPSS providing graphic, textual and animated information has been developed to support the operation and testing of the hydraulic circuits on a Hitachi EX3500 face shovel. The system assists a tradesperson in performing testing and adjustment procedures to manufacturers specifications. (Briggs 1996).	To describe the development process.	Documentation of the EPSS development process.	Conclusions include: – Whilst collecting the content was not particularly difficult it was found that obtaining the necessary detail was more difficult than anticipated. In many cases the service literature did not supply such detail and it was necessary to actually perform many of the tasks to ensure that procedures were correct. – Instructional design has proven to be the most difficult to construct. – According to end-user feedback, the system has fulfilled the need for which it was designed and become the first point of reference for supervisors and tradespersons. The system has been accepted as an integral part of the toolkit.
THEO EPSS THEO is a customer service application used by one of the world's largest utility companies to support customer service representatives when they receive calls from customers and perform tasks such as creating customer accounts or providing explanations about the customers' electricity bills. The prototype EPSS studied focused on supporting representatives explaining the Equal Payment Plan that allows customers to pay equal monthly amounts instead of amounts based on the previous month's electricity consumption. The prototype utilised two different support techniques, both potentially providing the same information. Number inspection technique allowed the user to click numbers on the	– To evaluate the benefits and return on investment of the THEO-EPSS – To develop a methodology for EPSS ROI evaluation.	31 pre-recorded phone calls were analysed and 15 tasks were derived. Three experimental conditions were defined: 1) 15 tasks to three novices and two experts who were asked to find the information from the THEO-EPSS. 2) One novice and three experts were asked to use THEO without access to the EPSS. 3) Two subjects were asked to complete 15 tasks at three different times during the same day. The experimenter tracked the number of tasks correctly completed and the overall time it took to go through all tasks. A questionnaire on perceived	The main results were: – The support system allowed two of the three novice users to perform the task without errors. – Users learned rapidly to use the system efficiently. – In the questionnaire, all the subjects gave positive comments on the EPSS. – The number inspection technique was preferred over hierarchical decomposition. – The cost-benefit break-even point can range from 1 to 18 years and is likely to occur after about 4 years. Recommendations included: – A member from the training department should be included in the user interface design team. – EPSS should be an integral part of the initial training. – Novice users should be the first targeted users

Case description	Study goal	Data and Methods	Findings and outcomes
screen to see how they have been computed. Hierarchical menu technique is based on classification of all potential customer questions into a hierarchical decision tree. (Desmarais & al. 1997)		usefulness of the EPSS was given to all subjects at the end of the session. Cost-benefit analysis focusing on training benefits was conducted on three scenarios: best-case, expected, and worst case.	of the EPSS. – Standard software tools should be used whenever possible.
TSS and PSS A hypertext Task Support System and a hypermedia Performance Support System have been used by a major US telecommunications company that manufactures base transceiver stations. As each transceiver is built to customer specifications the configuration of the components varies resulting in complex testing procedures and repeated changeovers. The systems have been used for supporting checking and monitoring of the reliability of the equipment used for testing of the products. (Tjahjono & al. 2001, Tjahjono & Greenough 2002, Greenough & Tjahjono 2002)	– To evaluate the Task-Technology Fit (TFF) of the TSS. – To evaluate development and use of the PSS	In the first study, 19 shop floor operators and technicians from two work-shifts were studied. TTF data was collected with a questionnaire focusing on five of the three TTF dimensions: Accessibility, currency, ease of use, meaning, and system reliability. The second study focused on developing and documenting a collaborative approach to creation and management of the hypermedia PSS. 16 users were questioned.	Findings of the TFF study were mixed. The users of the TSS felt that the system was not up-to-date. Moreover, their perception of the system's reliability was close to neutral. The PSS system has been well received by managers because of simplicity, ease of use, usefulness and maintainability. Also the questioned users' perceptions of the system were very positive. Other observed benefits of the PSS were – Users' improved comprehension through use of the system – Decreased effort required to train new operators, allowing supervisors to spend more time elsewhere. – More consistent knowledge transfer – Greater information currency – Less system maintenance effort – Simpler translation into other languages. The benefits of the collaborative development approach used in PSS development were: – Availability when and where needed. – Improved comprehension. Novice operators prefer to use the system because they better understand their tasks through pictures and/or video than text alone. – Reduced training effort: – More consistent knowledge transfer through use

Case description	Study goal	Data and Methods	Findings and outcomes
			of digital video clips. – Information currency. – Less maintenance effort of the hypermedia PSS knowledge content. – Multilanguage capability to those organisations that operate in a number of countries due to replacement of much of the text with pictures and video clips.
U.S. Navy DSS A U.S. Navy Decision Support System applies monitored distribution approach to deliver lessons learned in the field of Non-combatant evacuation operations plan authoring (NEO). The system combines an Active Lesson Delivery System (ALDS) with a plan authoring tool (HICAP) that helps users to construct hierarchical plans. (Weber & Aha 2002)	To test whether monitored distribution can positively impact the performance measures of plans authored with HICAP.	100 plans were generated with and 100 plans were generated without lessons delivered by the system. The systems were authored by a simulated user instead of real military planners. All the plans were executed with a non-deterministic NEO plan executor to estimate their average performance measures (total duration, duration until medical assistance becomes available and casualty rates for evacuees, friendly forces, and enemies) and their standard deviations.	Using lessons substantially improved plan quality, particularly execution time and casualty rates.
Wearable origami support A simple wearable support system has been designed to support Origami making and to test the concept of wearable support. The user enters and receives information from the computer using a microphone, an earphone, and a head-mounted visual display. The wearable computer shows drawings, audio, and video, which demonstrate how to fold a jumping frog. The system also provides basic origami information (e.g., common origami folds and information on origami paper). The user	To compare a computer-based performance support system with a book for learning and performing a simple task.	Performance (speed and accuracy) was compared on three simple tasks while using either a wearable computer performance support system or a book. Both groups consisted of 10 subjects. A background questionnaire was used to determine subjects' level of experience with origami. An end questionnaire was used to gather participants' ratings of the support system they had used.	The difference between using the two support systems was minimal, probably due to the fact that the tasks performed were so simple. The wearable system did not hinder performance of the user.

Case description	Study goal	Data and Methods	Findings and outcomes
controls the navigation and pace of the instruction with voice commands. (Ockerman & al. 1997a, 1997b 1998)			
Wearable QALive and WaRP QALive and WaRP (in some of the sources both are called Factory Automation Support Technology systems, FAST) are support systems based on a wearable, voice-activated computer that allows users to operate systems while keeping their hands free to perform their tasks. QALive is used to support poultry plant quality assurance inspectors to enter data directly into a plant's main computer system, and WaRP supports the environmental engineer of the plant to reduce water usage. Using a microphone/earphone headset, the system accepts voice commands and provides audio information while protecting workers' hearing. A head-mounted display with a tiny computer screen, that does not block the worker's vision, allows the worker to continue working while looking at text, drawings, and videos. A tiny video camera mounted on the head-set allows someone at a remote site to see what workers are doing and provide input into how a particular job is being performed. A wireless LAN allows the worker to send data to and receive data from a central computer in the poultry plant and allows the plant manager to see the quality assurance data as it is collected. The system provides reference information, just-in-time task-specific training, expert advice on how to complete the tasks,	To explore the issues associate wit an EPSS for a mobile industrial workforce.	The goal of the FAST project is Three generations of wearable computers have been built, each lighter, smaller, and more powerful than its predecessor. In this study, the concept of wearable support was tested in poultry industry. In the QALive field test, the quality assurance worker (n=1) took about 10 minutes training the system to recognise his voice commands and then spent 30 minutes collecting meat sample temperatures on the plant floor and sending them over a wireless network.	In the QALive field test, the technology worked flawlessly in the actual noisy (above 90dB) work environment, and the subject also enjoyed using the system. Lessons learned from the field test and development of the system include: – Use light, small, and highly adjustable wearable computer components and position them out of the wearer's way. – Use phrases that sound very different from each other to maximise voice recognition accuracy. – Let the computer automatically perform tasks to minimise the number of voice inputs. – The typical graphical user interface does not work with voice input. The older, command-based or function key-based user interface is much more effective. – Develop the training information using a variety of media to accommodate user preferences. – Design, prototype, and evaluate wearable systems iteratively with users and managers.

Case description	Study goal	Data and Methods	Findings and outcomes
and automated calculation tools. (Ockerman & al. 1996, 1999, Najjar & al. 1997a, 1997b 1999)			
WRCC Web Resource Collaboration Center supports learning communities in building their own web-based learning and performance support systems to support lifelong learning and professional development. The system consists of a Discussion Forum for learners, a Link Manager where learners can access and add links to learning resources and a Resource Construction System where learners work together to build new resources for inclusion to the Link Manager. (Dunlap 2002)	– Can facilitated use of the WRCC lead to improved use of the Web for learning and professional development activities? – Can use of the WECC for lifelong learning and professional development lead to the development of some transferable lifelong learning skills? – Can facilitated use of the WECC lead to continued use of the WECC after the facilitation ends.	The system was used and facilitated in three learning communities (work based: n=11, school based: n=14 and a hybrid: n=19) for a four-month period. The study was conducted using pre and post questionnaires and log-in information.	– There was a positive impact on continued, non-facilitated non-WRCC structured use of the web to support learning and professional development activities. – Only one group reported improvement on their strategies when using non-web resources. – The school based and hybrid learning communities did not use the Link Manager or Discussion Forum after facilitation ended. – Some 500 people not originally involved in the original development of the system participated in the two “open to the public” cases.

There is great variety in the characteristics of the knowledge support systems and their environments described in the cases above. Generalisations based on these cases can only be tentative at best.

The tasks the systems studies were used to support were very different ranging from aircraft maintenance to astrophysics data analysis. The common denominator seems to be the complexity of the tasks supported. In many of the studies, the authors particularly stressed, how complex and demanding the seemingly simple task in question was. Only the laboratory test tasks, Mecano block assembly, origami making, and use of the KERMIT program can be considered simple.

Also the variety of computer based technologies applied to provide support is surprisingly large, ranging from on-line help to wearable computers and adaptive hypermedia. Some common trends can nevertheless be observed:

- **Adaptivity** corresponds with active support as discussed in subsection 2.5.2. These systems follow both the user and the work situation in order to determine, what kind of support the user needs.
- **Interactive systems** include functions that allow the users to submit their own contributions into the system.
- **Tools** were included in many support systems. Sometimes they practically automated some complex tasks, in some cases they just helped users to put support into action.

Most of the studies can be grouped into three categories:

- Studies focusing on **impacts** reported mostly positive outcomes, but there are a few conflicting results too.
- **Feasibility** studies mostly find knowledge support systems (or EPSSs') worth developing. It would have been interesting to see studies where the actual outcomes would have been compared to these studies.
- Several studies presented a number of different **design and implementation** guidelines ranging from development philosophies to competences needed in the development team. Unfortunately the methods and data used in these studies were not usually described at all.

Reliability of the studies presented above is in some cases weak due to the small number of subjects involved. Furthermore, characteristics or handling of the subjects is often not discussed at all, which makes it difficult to estimate reliability of the results. Of the 33 case studies included, 20 discussed the number of subjects, ranging from one to 92, with the average 25.

Seven of the 33 case studies did not identify research methods used. These mainly focused on documenting the support system in question and its development process. These seven were nevertheless included into this study, as they reported some findings, and the systems discussed were interesting as such.

Observations, questionnaires and interviews have been used in several studies, but only rarely the choice of data gathering techniques is justified or their details described. In many cases, triangulation of the findings with another method might have provided more conclusive results. What is more, only few studies systematically evaluated actual performance outcomes of the performance support systems studied.

Findings of the studies are as diverse as the systems studied. They tell more of the particular system and the context studied than of knowledge support in general. Most of the impact and feasibility studies have provided positive outcomes, but there are a few exceptions. For example, the American Express title transfer EPSS saves some 60 days worth of work every month, and the time to complete U.S. Coast Guard cutter boiler maintenance tasks were reduced by 50%. But half of the people processing American Express title trasfers quit before the application was fully deployed, and a support system had no significant influence on selling results of the insurance agents for the Dutch insurance company.

The authors' reflections and recommendations for developers and implementers of support systems may be the most interesting category of results of these cases: Most of them can be grouped into four classes:

- **Policy issues:**
  - You may need to start by convincing your organisation to invest in performance support.
  - Prepare for resistance for change. Users may need to be coached into a new paradigm.
  - Special attention to change management and end user involvement in system design reduces organisational resistance and avoids unnecessary design errors.
  - In order to fully benefit from EPSS, the organisation has to restructure its tasks and organisation.
  - Those in charge of deploying the system must have proportionate control over the target organisation and its active collaboration.
  - Roles and responsibilities must be clear.
- **Development issues:**
  - Developers should appreciate that their work will be a part of the work system, focusing their design on the users' interaction with the work, recognising the power of the situation to shape meaning and understanding.
  - The system should draw upon organisational memory.
  - Technology should be fit to the performer rather than vice versa.
  - Support system development is complex and needs project management. The process should be iterative, and based on prototyping.
  - A support system needs to be highly modular.
  - Standard software tools should be used whenever possible.
- **Content issues:**
  - Design your information modules to be small, single purpose, and quick to refer to.
  - Develop the training material using a variety of media to accommodate user preferences.
  - Paper based support material does not necessarily supply information in such detail that is necessary to actually perform many of the tasks supported.
  - Structured access to relevant information eases finding the information needed.
  - To ensure the usefulness of the system, its contents must always be up-to-date.
- **Development team:**
  - A PSS team should be multidisciplinary.

- A member from the training department should be included in the user interface design team.
- Work closely with customers and users (findings from the Ford and Ericsson cases may challenge this recommendation).
- Subject matter experts should believe in their subject matter and be familiar with the concept of performance support.

2.5.6 Benefits and disadvantages

While empirical analysis of the advantages and disadvantages of knowledge or performance support is rare, many authors have discussed potential outcomes of such systems. This summary (*table14*) is based on an extensive search through literature. The diversity of the suggested characteristics presented in the table below is surprising, and the authors of the cited studies share on only a few common points.

In addition, reported benefits and disadvantages of the case studies presented in *table 14* have been collected into their own column. It should be noted that in many issues the results were contradictory, particularly concerning the impact on efficiency and quality of the tasks supported.

One should also keep in mind that in the *table 14,* several related benefits or disadvantages have been grouped together even if the original wordings were not similar. In addition, different types of (dis)advantages have been grouped together and those shared by several authors emphasised with boldface.

Table 14. Potential advantages and disadvantages literature associates with electronic performance support systems.

		Gery 1991	Bastiaens & al. 1999, 1997	Reynolds & Araya 1995	Cote 1996	Finley 2001	Desmarais 1997	Sleight 1992	Bezanson 1996	Lawton 1999	**Cases**
Advantages											
Knowledge management	**Can capture and capitalise knowledge**					**X**	**X**		**X**	**X**	
	Access to the latest information				**X**	**X**			**X**		**X**
	Advice is available at the point of need				**X**	**X**			**X**	**X**	
	Knowledge is managed systematically	**X**				**X**					**X**
	Right information is easy to find.							X			
Training and learning	**Reduced training costs, especially with dispersed trainees**	**X**		**X**	**X**		**X**		**X**		**X**
	Improved learning	**X**							**X**	**X**	**X**
	May accommodate to different learning styles							X			
	Can be used for training					X					
	Learning not needed – avoids long, difficult training			X							
	No delay between training and application				X						
	People learn what they need to know	X									
	Production time preservation due to shorter training time									X	
	Unified work-learning station may be used			X							
Work and support	**Directly supports job performance (quality and / or productivity)**	**X**		**X**			**X**		**X**		**X**
	Uniforms work practices, consistent content						X			X	
	Increased employee autonomy and empowerment						X		X		
	Sustaining support								X		
	Improved organisational flexibility	X									
	Broader span of management control	X									
	Reduced task complexity										X
Other support	Reduced use of non-electronic support paper, hot-line etc.	X							X		
	Experts not needed to support less-expert staff	X									

		Gery 1991	Bastiaens & al. 1999, 1997	Reynolds & Araya 1995	Cote 1996	Finley 2001	Desmarais 1997	Sleight 1992	Bezanson 1996	Lawton 1999	**Cases**
Other	May allow people to work collaboratively							X			
	May automate low level tasks and give the opportunity to concentrate on higher level tasks		X								
	Lighter cognitive load									X	
	Easy to use					X					
	Easier to program than most computer languages			X							
	Additional utilisation of ICT investmeents	X									
Disadvantages and challenges											
Learning	It does not teach or instruct – not tied to learning objectives			X							
	Learner control is not as effective as instructional control		X								
	Employees may fail to build a unified picture of their job		X								
	Small information parts will create a fragmented knowledge base		X								
	May de-skill the workers		X								
Development	Development calls for skills that may not be available			X							
	Development of high-quality systems calls for extensive effort			X							
	Becomes easily partly outdated								X		
Social, Psychological	**Users may resist the system**		**X**						**X**		**X**
	May isolate employees, reduce human contact							X			X
	Can create work behaviour problems		X								
	Use depends on the user's motivation			X							
Other	Changes the whole corporate culture								X		
	Slower than paper										X
	Does not influence work performance										X
	Health problems from prolonged computer use							X			

The table above lists many more potential benefits than disadvantages or challenges. And indeed, many of the authors cited did not discuss potential problems associated with support systems at all. This is possibly due to the consultant driven nature of the performance support industry. Many of the books and articles used to make the table are actually trying to promote the concept of electronic performance support systems, not to mention services of the authors. Critical analysis of the potential problems does not serve these ends. Therefore, the list above should be taken with at least a little pinch of salt.

While none of the advantages is shared by all the authors cited in the list above, there are some, several of them agree upon:
- Capture and capitalisation of knowledge created in the organisation
- Constant access to the latest information at the point of need.
- Systematic knowledge management
- Reduced training costs and improved learning outcomes
- Improved job performance, including quality and productivity.

When it comes to potential problems, only two issues are mentioned more than once:
- Implementation of a support system may initiate severe resistance to change.
- A support system may isolate people from each other.

2.5.7 Development and implementation

Software development is often described with structured, linear stage models. The tasks involved may be assigned, for example, to six stages (Rauterberg & al. 1995):
- Analysis of the work system to be optimised.
- Conception
- Specification of the interfaces
- Programming
- Testing
- Implementation.

While general guidelines of good software development apply to knowledge support system development as well, there are some principles that are particularly important. As the goal of a support system is to empower the user to perform, the main philosophy associated with effective design is user-centered design (Stevens & Stevens 1995). The design is meant for users, not designers, or users' superiors. If support system design and implementation is carried out by teams who have little contact with end-users in the field, there is a risk that the system is designed to meet the requirements of management rather than those of the ordinary users (Sherry & Wilson 1996).

More extensive lists of guidelines and critical factors can naturally be found from literature (for example Gery 1991, Laffey 1995, Bezanson 1996, Stevens & Stevens 1995, and Raybould 2000, see *table 15*) and from the case studies discussed in subsection 2.5.5. The key guidelines in these lists include, among others:
- The design should be user- and performance-centered.
    - Task and user analysis is the foundation for the development.

  - Design should focus on the users' interaction with their work.
  - Technology should be fit to the user rather than vice versa.
  - Results should be evaluated with an eye toward business impact and improved performance.
- The system should draw upon organisational memory.
  - Users' information requirements and information sources should be identified and organised.
- The system should be designed as a part of the sociotechnical work system.
- The development process should be iterative, and based on prototyping.

Another key issue in addition to the user-centered approach is the variety of expertise needed in knowledge support system development. Literature abounds with lists of various roles and competences needed from project managers to knowledge engineers to multimedia pedagogical designers. But the main issue is not the exact definition of the roles involved but ensuring that this heterogeneous group, the support system development team, can communicate and cooperate effectively in spite of the fact that their educational and professional backgrounds are different. Whatever software development model is used, it should facilitate inter-group communication and cooperation.

Table 15. Banerji's (adapted from 1995) ten key principles for developers of a performance support system.

Identify performance problem and the approach to solve it.	Specify and prioritise the critical areas of under-performance within the application domain and then identify appropriate strategies to improve performance.
	Attempt to design mechanisation aids and automation tools to facilitate increases in personal and organisational performance with respect to task-oriented skills.
	Identify relevant generic and application-oriented tools and processes which will provide on-the-job support and improve task performance.
Identify appropriate methods.	Attempt to identify and, if possible, eliminate all unnecessary information blockages and constrictions within an organisation or a work environment.
	Identify an appropriate combination of media, multimedia, hypermedia and telecommunications in order to optimise information flow and inter-personal communications.
	Where a user or employee has an identified skill deficiency, attempt to rectify the situation using just-in-time (JIT) training and learning techniques.
Individual user perspective	Whenever it is feasible, a performance support system should accommodate individual learning styles and thus attempt to maximise its utility for as wide a range of users and task performance situations as is possible.
Accommodate group work and communication	Identify appropriate groups of people who have the expertise needed to solve demanding problems and provide the infra-structure necessary to facilitate group working.
	Whenever it is feasible, attempt to use intelligent agents within an EPSS facility in order to – identify the skills needed for a given task – locate sources of organisational expertise relevant to these tasks – enhance software components.
Accommodate organisational learning	Attempt to provide facilities to create a corporate pool of knowledge and skill assets that can be used to maintain and enhance performance levels.

Table 16. Generic (Rauterberg & al. 1995) software development stage model and two EPSS development stage models.

Rauterberg & al. 1995, pages 394-397	**Gery 1991, page 232**	**Reynolds & Araya 1995, page 51**	**Proposed knowledge support development stage model**
Analysis of the work system to be optimised	Needs analysis	Define the process or performance problem	1) Analysis of the work system (users, tasks, context, information needs and sources)
Conception	High-level design, including prototyping		2) High-level design of the system concept.
		Develop a prototype	3) Proof-of-concept prototyping (Raybould 2000)
Specification	Detailed design, including detailed prototyping		4) Detailed design of system specifications
			5) Detailed prototyping
Programming	Development	Develop the final system	6) Development of the final system
Testing	Testing	Evaluate the system	7) Evaluation and testing
	Revision		8) Revision
Implementation.	Implementation	Implement the system	9) Implementation
	Post-implementation evaluation		10) Post-implementation evaluation of the impact
		Maintain the system	11) Using and maintaining the system.

The two support system specific software development stage models identified from literature have the same basic structure as the generic model discussed above (*table 16*). By combining these models and the guidelines discussed above, a more comprehensive stage model for knowledge support system can be devised. In addition, the concept of Proof-of-concept prototyping has been imported from Raybould (2000).

While the proposed eleven stages reflect the guidelines discussed above, it does not guarantee a user-centered approach or efficient group communication. In addition, stage models are one-way-streets that do not encourage continuous development of the system after its implementation. Besides, according to Rauterberg & al. (1995), the traditional stage based software development model is exposed to three problems that may undermine user-orientation:

– **The specification problem** is caused by the fact that client organisations are not always able to provide software developers pertinent and adequate information on all requirements for an interactive software system.
– **The communication problem** between client organisations, end-users and developers of the system results from incompatibility of the technical languages used for communication. The application-oriented jargon of the user flounders on the technical jargon of the developers.
– **The optimisation problem** involves the non-technical context of the application environment. While software developers are adept in technical optimisation, optimisation of economical, technical and social processes require different methods and techniques.

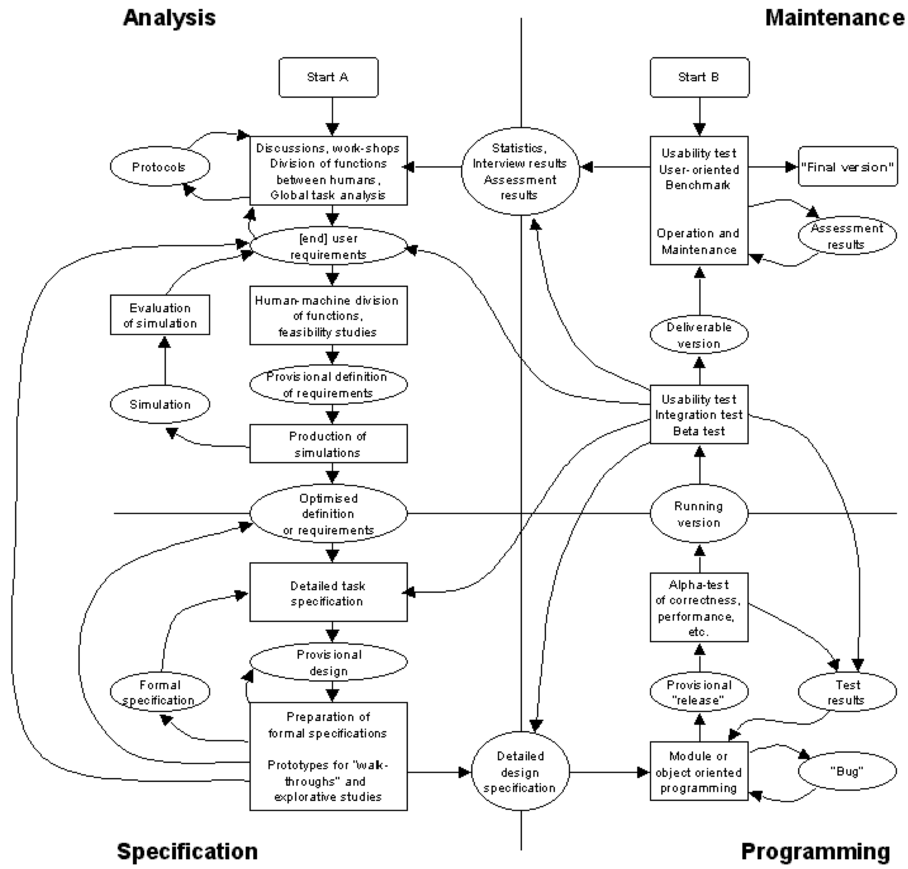

Figure 12. The participatory cyclic software development model by Rauterberg & al. (1995, page 401).

In order to address these three problems, Rauterberg & al (1995) propose a participatory cyclic software development model that divides software development into four main phases, quadrants, that follow each other in a cyclic manner (*figure 12*). A corresponding cyclic model is proposed for knowledge support system design, too (*figure13*). The proposed model is based on both the cyclic participatory model and the 11 stages presented above. What is more, the model has been simplified a bit in order to make it easier to grasp and adapt to particular situations. For example, fixing of "bugs" has been considered to be such an integral part of programming that a separate box is not needed for it. In addition, criticism on traditional "heavyweight" software development, has been taken into account by introducing some elements from one of the new, so called "lightweight" software methodologies, Extreme Programming (see Wells 2002 and Beck 1999).

The "lightweight software movement" is a reaction to traditional software development methodologies that have become so cumbersome and slow that developers follow them only in letter but are forced to break the rules in order to meet delivery deadlines and budgetary restrictions. What is more, one of the key features of Extreme Programming is that a customer participates in software development from beginning to end.

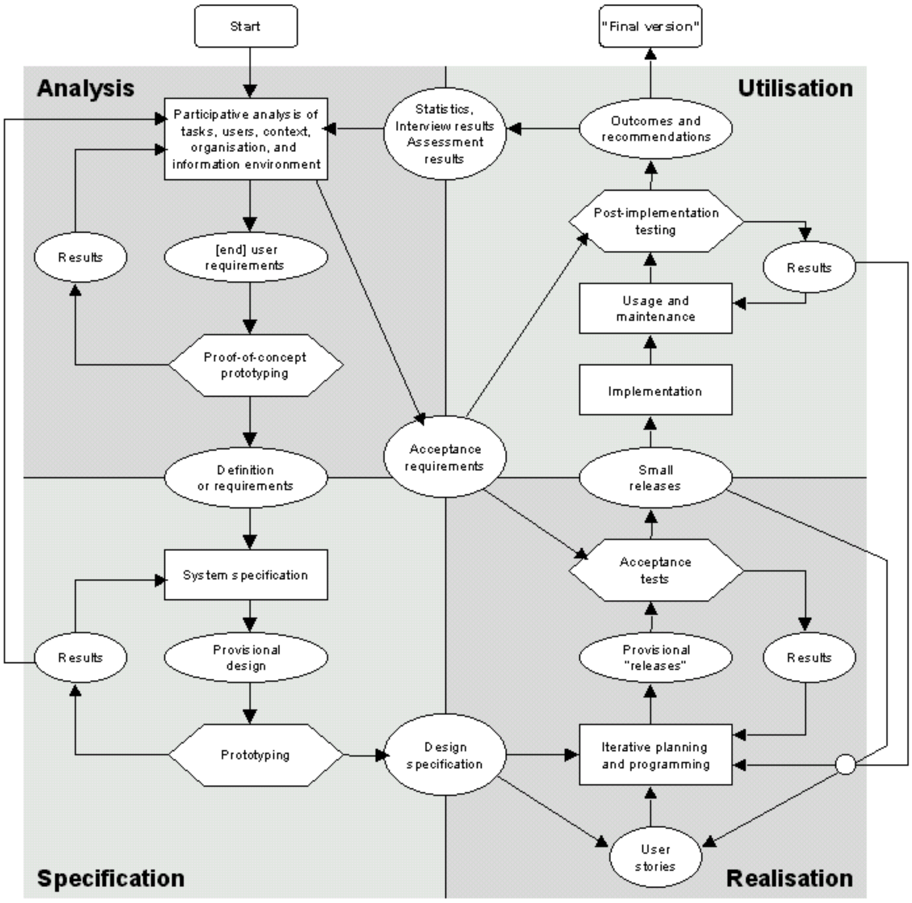

Figure 13. A proposed cyclic knowledge support system development model based on Rauterberg & al. (1995), Gery (1991), and Raybould (1995).

The four main phases of the proposed knowledge support system development cycle depicted in *figure 13* are: Analysis, Specification, Realisation and Utilisation. In addition to being cyclic as a whole, the model incorporates cyclic development loops in all the four quadrants. What is more, if the definition of requirements is found to be inadequate during Specification, the process can go back to Analysis, and if software errors are found from the implemented system, they can be fixed by returning back to Realisation.

Marquardt and Kearsley (1998) stress that underlying any successful EPSS is careful **analysis** of users, job functions, work contexts, and user needs. Or as Stevens & Stevens (1995, page 36) put it: "Analysis is not only essential, it is everything". A lot of interviews and observation are needed to identify the specific information that employees need to do their jobs.

The problem often encountered in analysis is that that in addition to a knowledge support system, the users actually need a whole new work system that they are not always able to define themself. Knowledge support system developers have to assume the role of consultants in addition to software developers, and the analysis methods used should address organisational and social issues in addition to the actual application domain. This system approach makes it difficult to straightforwardly adopt granular software development methods that blend analysis and programming like for example Extreme Programming discussed above does.

The key issue in task analysis is an examination of why people fail to do their jobs well and where the major performance problems exist. The purpose of the analysis if to identify those knowledge and competency demands the support system is to solve for individuals, groups and organisation:

1. What stages are critical for productivity and quality (product and work life quality)?
2. Where in the boundary between work tasks and employees, available knowledge and competences do not correspond with the demands of the tasks?

Analysis proceeds in three stages. First, the whole work context and process is defined, and finally knowledge and competency demands of the work tasks are analysed (*figure 14*).

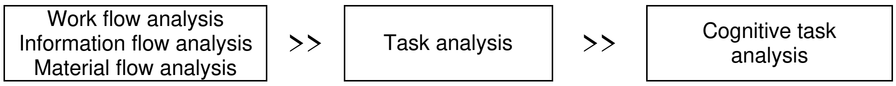

Figure 14. The three stages of analysis needed for end user requirements (Kasvi & al. 2000g, page 154).

The analysis should give particular attention to identifying end-users' requirements, as satisfying them will determine whether the system developed will succeed or fail. The point is to bring in real users to describe in their own terminology the things that the system could and should do for them. Requirements should not address specifics of technology to be used.

The analysis results in [end] user requirements, and acceptance requirements. **User requirements** specify, what identified user groups need from the system. User requirements and the concept for the system is checked out with simple **proof-of-concept prototypes** that may consist of nothing more than pieces or cardboard or a set of web pages without any functionality. These proof-of-concept prototypes are evaluated with different user groups in order to see, how well the identified user requirements actually correspond with reality. **The acceptance requirements** are deviced together with user requirements in cooperation with end-users. They specify scenarios to test when user requirements have been implemented.

System **specification** is based on the requirements provided by the analysis and moulds them into an implementable form. The resulting specification of the system should be so detailed and unambiguous that the actual knowledge support system can be based on it. The programmers should not have to guess what is required from them. Rauterberg & al. (1995) suggest that at least four different kinds of specifications are needed in order to achieve this:

– Specification of the organisational interface (or system interface as I would prefer to call it) determines if and where it makes sense to employ knowledge support. The point is to understand the work system as a whole and see how it

changes with the introduction of the support system, and what measures this change may require.
– Specification of the tool interface decides the intended division of work between human and machine. This is particularly important when performance support tools are developed (see subsection 2.5.2)
– Specification of the input/output interface defines the screen layouts. Interaction with end-users or heuristic usability checklists may be used.
– Specification of the dialogue interface determines how the system and the users communicate with each other.

Critical parts of the specification can be checked out with prototyping, focusing for example on the user interface usability. Real end users should be used as test subjects.

Rauterberg & al. (1995) stress that in the **Realisation** phase, all care must be taken to ensure that the technical subsystem of the knowledge support system developed exhibits properties defined during specification as precisely as possible. But despite careful analysis and specification, new requirements often emerge at this stage of development. This is particularly true for knowledge support system development that can be considered both a software development and a re-engineering effort. Both the support system and the work system are under construction.

When the first provisional versions of the actual system are put to test in actual organisational and technical context, users see for the first time in practice, what the system is all about. If developers are not able to capture and utilise these reactions, the resulting knowledge support system may answer to wrong needs.

The concept of User stories from Extreme Programming (see Wells 2002) is suggested to alleviate this problem. User Stories are written by the various users of the system. In a few sentences, the User Stories describe individual things that the system needs to do for the users. If a story cannot be realised in two or three weeks, it should be divided into two separate stories.

What is more, the system is released iteratively in several smaller units in order to get feedback from the users. This way feedback can have an immedite impact on the system's development. Defining and planning releases that make sense is essential, or otherwise users may not be motivated to use them and feedback is not acquired.

Utilisation phase consists of implementation, use and maintenance of the finalised system. In addition, the system, including the work system the support system is a part of, is evaluated and tested in practice in order to
1. Identify potential improvements or requirements for additional knowledge support systems.
2. Improve utility of the system by improved usage and maintenance.

Implementation is a critical spep, or as Marquardt and Kearsley (1998) point out, it does not matter how wonderful an innovation is, it is worthless unless it is used. And knowledge support seems to be a particularly difficult innovation to implement. For example, when an online technical support system was developed for newly trained teachers, the majority of whom had requested it, only three percent of the teachers actually used it regularly. 31 % used the system less than five times, and 66% did not use it all. (Sherry & Wilson 1996).

2.5.8 Authoring

Development of a knowledge support system involves not only creating the system but also the authoring of the content to be provided by the system. This can be challenging since the information may come from a variety of sources within or outside the organisation. In many cases, much of the information needed may never have been made explicit before. Furthermore, determining how to present the information so it is immediately useful to users takes a lot of work.

Content authoring can roughly be divided into five steps (Kasvi & al. 2000a) that are repeated iteratively:

1. **Task analysis:** Exiting documentation is collected and the task to be supported is analysed. Analysis includes the structure of the task, its context and environment and what knowledge is needed and created in the course of task execution.
2. **Design:** Decision on the knowledge to include, how it is to be organised and how different media are to be utilised.
3. **Material creation:** New materials needed are created, for example, photographs taken and texts written.
4. **Composition:** The existing and new materials are composed according to the Design.
5. **Distribution:** Finished material is distributed to the work sites, for example, by changing pages in the paper folders or by updating the files in the file server.

It should be noted that a support document is never ready, but develops as feedback is gained from the users and new work methods are developed. In order to facilitate this development, an organisation's culture should allow and encourage feedback and ideas to flow freely from reader-users to author-users.

3 Research aim and questions

As discussed above, knowledge support systems may offer a good way to facilitate individual and organisational learning and further, to improve organisational flexibility.

The aim of this study is to understand the requirements, critical factors and outcomes of knowledge support, particularly in learning operative organisations. Initially, the work focused on support of individual employees performing individual work tasks (the case studies focused on assembly line work tasks), but it soon became evident that the perspective was too limited. First, it was expanded to cover smaller work units like assembly line work teams, and later the scope was extended to even bigger organisations consisting of several smaller units (in our case, project organisations).

As discussed in subsection 2.5.7, the key to developing an effective knowledge support system for people working on manufacturing is to understand the job functions and user needs involved: what kinds of tasks and who are supported? Consequently, the purpose of Research Question One is to identify potential general requirements, manufacturing work task sets to knowledge support and the technological systems providing it:

> **RQ1: What are the requirements for knowledge support in manufacturing work?**

While many of the case studies discussed in subsection 2.5.5 presented positive outcomes, some of the findings were contradictory, indicating presence of some unidentified factors influencing the outcomes of the knowledge support systems studied. Research Question Two aims to identify critical factors of implementation and use that could influence the outcomes of such systems in operative manufacturing organisations:

> **RQ2: What are the critical factors of implementation and use of knowledge support systems in operative manufacturing organisations?**

While different knowledge support systems have been around for a decade, their actual outcomes have only rarely been properly analysed. The goal of Research Question Three is to identify these outcomes, particularly in the context of operative manufacturing organisations:

> **RQ3: What are the outcomes of knowledge support systems in operative manufacturing organisations.**

As discussed in subsection 2.4.2, a knowledge support environment can act as the technological infrastructure of organisational learning, collecting, conceptualising, storing and distributing knowledge and lessons learned. The purpose of Research Question Four is to understand, how this can be achieved in practice:

> **RQ4: How Knowledge support can be used to facilitate continuous improvement in learning organisations?**

4 Data and methods

This chapter describes, how research material has been collected and analysed.

The data used comes from five case studies, four of which have been presented in the four peer reviewed journal papers. The fourth case (ISS) has been added as it is directly associated with the other cases, particularly ABB, B&O and Task Supporter. The findings from this case have not been published in a peer-reviewed journal, but in professional journals (Kasvi & Vartiainen 2000), conference papers (Koskinen & al. 2000a and 2000b, Hailikari & al. 2000, Repokari & al. 2000a and 2000b and Kari & al. 1999) and books (Kasvi & al. 2000a). In addition, some previously unpublished material from this case has been used.

The ISS case was an important intermediate phase in my work. As the early cases (ABB and B&O) focused on providing knowledge support for individual employees, in the ISS case, the system was designed to support a whole work group. What is more, it became evident, that the scope should be expanded even further, to address the whole organisation, as was done in the MET case.

Table 17. The cases included to this dissertation, their aims, scopes and research approaches.

Research questions and data		Question 1			
			Question 2		
			Question 3		
	Question 4				Question 4
Study	**1**	**2**	**3**		**4**
Cases	**(ABB)**	**ABB, (B&O)**	**ABB, B&O, Task Supporter**	**ISS**	**MET**
Mode of explanation	Explorative	Descriptive and Explorative	Descriptive and Explorative	Descriptive	Descriptive and Explorative
Research aims	Understanding the role of multimedia in lean production management	Guidelines and requirements for shop-floor knowledge support	Expanding redundancy of shop-floor groups through knowledge support		Understanding knowledge management and support requirements of project organisations.
Main scope	Organisation	Individual	Individual and group	Group	Organisation
Research approach	Case study	Case study	Case study	Case study	Case study

4.1 Data: cases and subjects

While the first of the published studies introduced in section 1.3 did not address a particular case but discussed multimedia and production management on a general level, all the other three studies are based on case studies. Papers two and three handle operative knowledge support on a shop-floor setting and were based on three case studies (ABB, B&O and Task Supporter).

Paper number four, on the other hand, explores operative knowledge management and operative KM tools from a project organisation perspective. This paper is based on a case study that addressed two framework programmes and one review project (MET).

4.1.1 The ABB case

Our first realised support system, Interactive Task Support System[3] (ITSS) was a multimedia knowledge support system prototype built in 1994 in cooperation with the ABB Industry Ltd., and it has since been used to support end assembly of DC drives. The support system has been used for three purposes: (1) to orient new employees to their tasks, (2) to support training by doing and (3) to support actual work task performance.

The DC drive product and production line were brand new. There were four main models of the product and practically thousands of potential variations in production. The batch size was small, even one. What is more, the product specifications and the production methods varied constantly changing during the study. The complete-build assembly work task was very complex, and the phase time varied from 30 to 60 minutes.

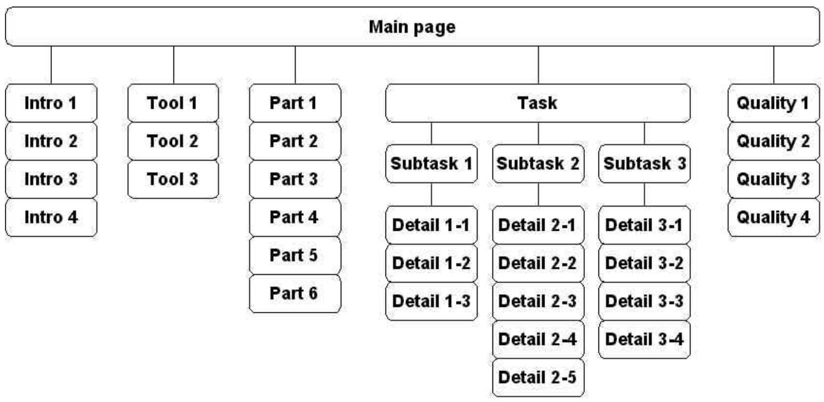

Figure 15. In the ABB case, the Interactive Task Support System organised support documents material into five chapters that consisted of pages with text, still-video pictures and an option for digitised speech.

[3] In some publications, the system has also been called HIPS on-the-job Training System (HOTS), as it was developed in the Human Integrated Production System (HIPS) project.

Figure 16. The support system was brought directly into assembly line work sites. The system was controlled by a bar code reader that the employees were more familiar with than the mouse. Picture courtesy of ABB Industry Ltd.

The knowledge was organised into hypermedia documents consisting of text, digitised speech and still-video pictures. The material was organised into pages, each of which contained at least some text and a picture. These pages were grouped into five chapters (*figure 15*).

- **Introduction** containing basic information about the product and production.
- **Tools** describing the tools needed and their safe use and maintenance.
- **Parts and materials** describing the parts and materials needed.
- **Task description** that was divided into two levels. The first level described subtasks of the task supported, while the second gave details of each stage.
- **Quality factors** stressed critical quality issues.

The system was programmed with ToolBook and the same application was used to both author and access the support documents.

The users of the systems consisted of all the four employees working regularly on the assembly line, Finnish and foreign trainees and two technicians maintaining the information content of the system. While the assembly line workers were a heterogeneous group with some competent computer users and some novices, the technicians were expert computer users but had no experience in the tasks supported. In addition to ordinary users, a group of Chinese trainees were observed using the system. Instead of writing the texts in Chinese, they were spoken aloud.

The system was used and studied in the ABB Industry Ltd. Pitäjänmäki Power Electronics plant, DC drive end-assembly cell consisting of the assembly line and a small administrative unit situated in a cabin next to the line on the shop-floor. There were six work stations on the line, four of which were used for assembly and equipped with a multimedia workstation connected to a local area network.

ABB is a global group of companies producing power and automation technologies. The ABB Group operates in more than 100 countries and employs around 150,000 people.

4.1.2 The B&O case

Our second case, the IMS support system (Interaktiv Montagestøtte) was created to support the end assembly of the new Bang & Olufsen A/S CD player with a built in tuner and amplifier, BeoSound 9000. The planned application areas of the system were (1) support of work task performance, (2) task training and (3) assembly task design documentation.

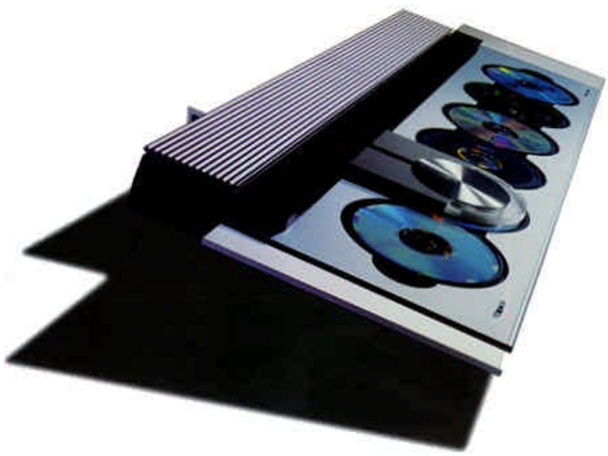

Figure 17. BeoSound 9000 is a good example of the design oriented product philosophy of Bang & Olufsen A/S.

There were no product variations to speak of, but the product itself was extremely complex. As a result of the design oriented product philosophy of Bang & Olufsen, BeoSound 9000 includes a total of 23 circuit boards. As Bang & Olufsen considers its product designs artworks, no compromises can be made to facilitate manufacturability. In addition, new materials, methods and tools were required, and a new production control system implemented.

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

The system was based on the same basic idea as the one developed in the ABB case, but it contained only the task description. Introduction, tools, parts and materials, and quality factors had been omitted as they had not been used in the ABB case. Menus had also been removed from the user interface and replaced with buttons, as using menus had caused problems to novice computer users. What is more, the system allowed use of live video and still picture sequences in addition to text, sound and still pictures.

The system was used and studied in the A2 audio equipment production line of the Bang & Olufsen Struer plant, manufacturing only the BeoSound 9000 CD player. At the time of the study the line had only four employees, who were not experienced computer users. Author users maintaining the contents of the system were production planners.

Bang & Olufsen a/s is a Danish company with headquarters in Struer. The company manufactures and markets high end consumer electronics, particularly audio and video equipment. B&O employs some 2800 people and has sales representatives in 26 countries with over 3000 dealers selling its equipment worldwide. Production is carried out in four factories with headquarters in Struer, Denmark.

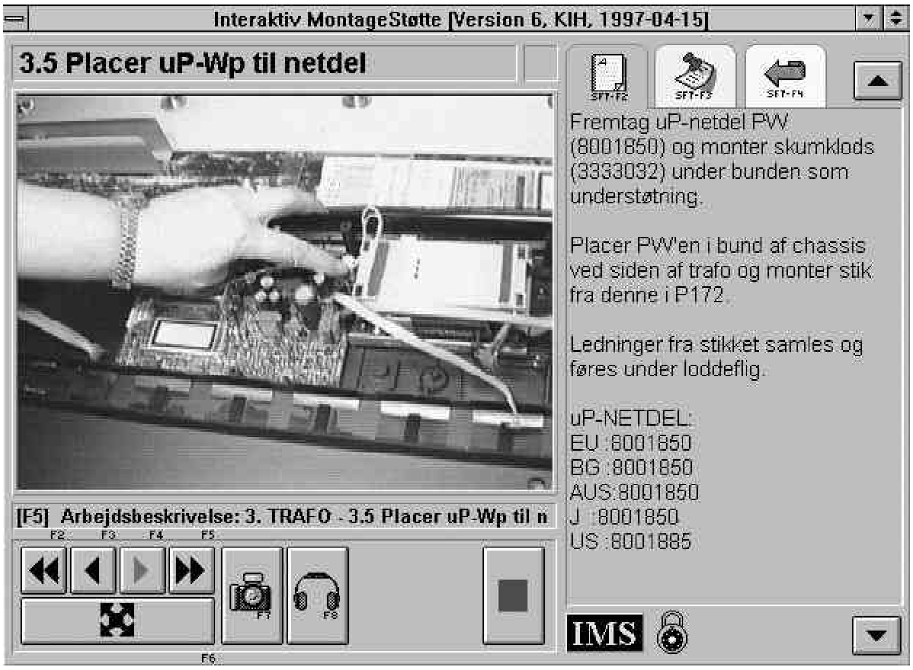

Figure 18. A screenshot of the IMS support system illustrates an interesting language problem. The author of the software and this dissertation did not know any Danish and the users of the system did not know any Finnish, so an easy to use mechanism for writing new language versions of the user interface had to be created.

4.1.3 The Task Supporter case

While the systems used in the two previous cases were prototypes designed and programmed with ToolBook by the author of this dissertation, Task Supporter was a commercial support tool developed by a small Finnish software company Brainware Oy. On the other hand, the system was based on the experiences of the previous two cases and the HUT research team was interacting closely with the developers.

While the two prototypes used in the previous cases had integrated authoring and reading functions into a single system, Task Supporter consisted of three subsystems for authoring, reading and managing information content of the system. In addition to text, still pictures and digitised sound, the system was able to present assembly drawings imported from a CAD (computer assisted design) system.

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.

Originally, the research plan called for analysis in all the companies that had implemented the software, but the most startling finding was that in most cases implementation had totally failed. Thus, research focus was expanded in order to find out, what had gone wrong in those companies. Why had so many companies not succeeded in introducing this piece of software into production? All 11 of the companies that had purchased the system were called and the person in charge of the system interviewed by phone.

Almost all the companies that had purchased a testing license for the system were large or very large international companies, whose production consisted mainly of assembly. In one of the companies, production was more process oriented, and one of the clients was a training and consulting company. A third of companies that had purchased a testing license actually purchased a full production licence. All these companies were all major international companies with tens of thousands of employees world-wide.

The use of Task Supporter was studied in detail in one company that had successfully implemented it. Unfortunately we are not free to divulge the identity of the target company. The plant the system was used on was producing industrial equipment products, and the tasks supported consisted of complex lightweight assembly. In this company, the system was installed on twelve work site computers, one server computer and two author users' computers. Four of the five end-users of the system were middle-aged women with only basic education. They had one to two years of experience using computers, mainly in work context. The two author users, managing the contents of the system, were production engineers. In addition, three trainers, a line manager, a member of plan management and a representative of information system management were interviewed and questioned.

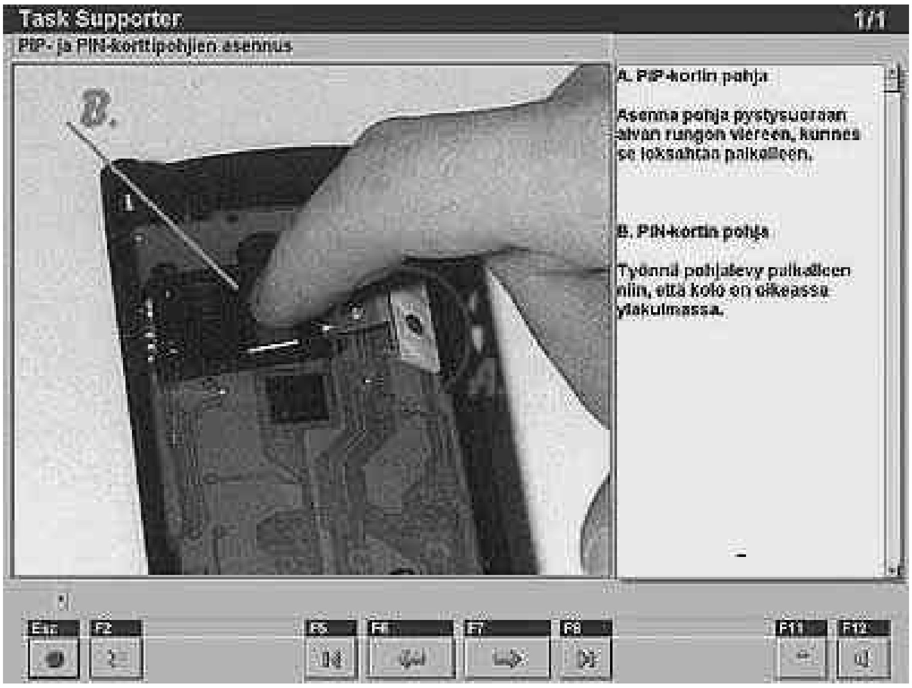

Figure 19. The end-user interface of the Task Supporter system was very simple, focusing only on the essentials. Picture courtesy of Brainware Oy.

4.1.4 The ISS case

The Information Support System (ISS) developed by Arrow Engineering Oy differs from the previously introduced systems in two ways. Firstly, it does not organise task descriptions into subtasks and stage details. Only stage details are addressed and given “pages” of their own. Secondly, ISS is designed to communicate with other shop floor software systems. So ISS knows, for example, which model is next coming to the working site.

The introduction of an ISS was studied on a Finnish end-assembly line that was replacing a cell-based assembly system (see Hailikari & al. 2000 for details). The new line was the answer to the rapidly increasing demand of the products. There were eight work stations on the line, each equipped with a computer running the support system software. The tasks were complex lightweight complete build assembly tasks, with a phase time between 20 to 30 minutes, ten major subtasks and some 50 subtask details. The 14 people working on the line were also responsible for some support functions like repairs of defective products returned by clients. New people were introduced to production all the time, and personnel turnover was almost nonexistent. New employees were recruited through an intensive training program conducted in cooperation with a local vocational education centre. Training the basic skills required took several months, and trainees that passed the training period were hired.

The aim of the study was manyfold and the results have been published in several conference papers. The main goals included:

- How employees felt about the support system and what kind of support or training they would have needed during implementation? (Hailikari & al. 2000)
- How introduction of a computer-based support system influences information support management? (Koskinen & al. 2000a)
- How does a computer-based support system influence employees' mental workload? (Koskinen & al. 2000b)
- How is the multi-modal information provided by a support system processed on the shop-floor? (Repokari & al. 1999, 2000a)
- How could the usability of the system be improved (Repokari & al. 2000b)

The company where the system was used and studied is a rapidly growing medium-to-large company with a few hundred employees, manufacturing complex investment products. Unfortunately we are not free to divulge the identity of the company.

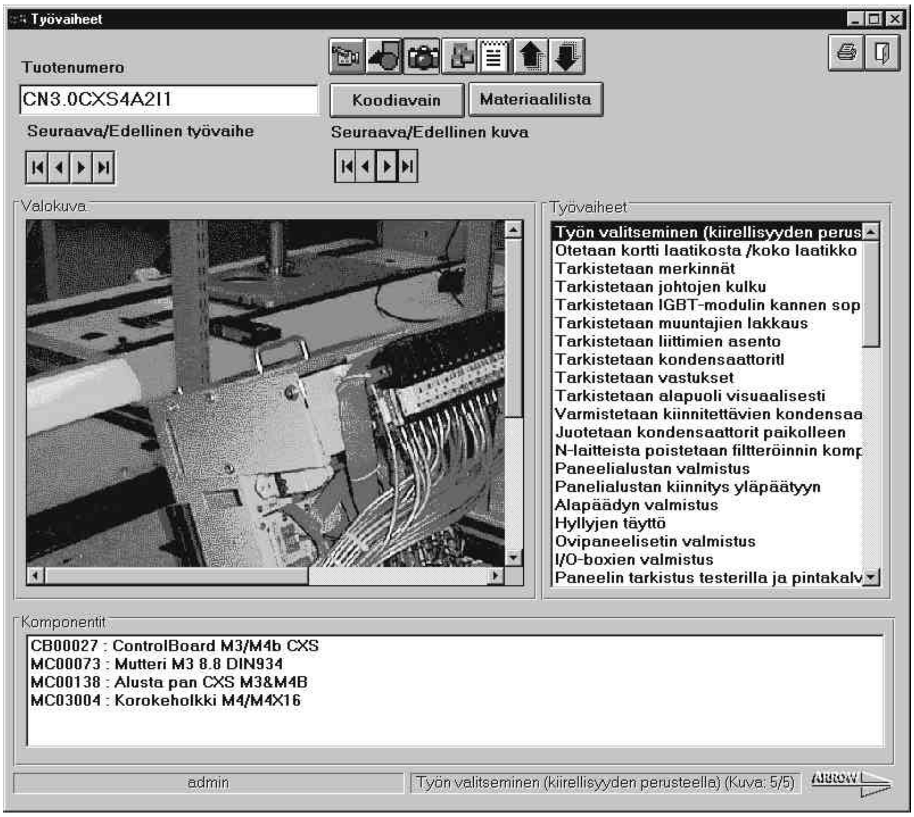

Figure 20. The Information Support System (ISS) does not organise task descriptions hierarchically into subtasks and subtask details. As there are several different product versions and variations in production, product and part identification codes are brought to the main screen. Picture courtesy of Arrow Engineering Oy.

4.1.5 The MET case

The case covers two national framework programmes and one small review project managed by the Federation of Finnish Metal Engineering and Electrotechnical Industries (MET) and funded by the National Technology Agency, Tekes, and the participating companies. Both of the programmes involved several public and private organisations, and had a duration of three years.

One of the programmes was intended to secure technological competitiveness of Finnish shipbuilding and shipping industry with a total volume of EUR 2.5 million. The other programme headed for increasing the efficiency of medium and heavy assembly with a total volume of EUR 17.6 million. The programmes involved several public and private organisations including international companies, small and medium sized enterprises, universities and research institutions. The review project aimed at mapping the preconditions to establish a new and larger framework programme in the field of product information in networked businesses. The project involved a single research institute that collected information from a large number of companies. Its total budget was about EUR 130,000.

The aim of the study was to understand how project organisations, particularly framework programmes manage knowledge, what knowledge management competences are needed, and how knowledge management processes of project organisations could be supported.

The Federation of Finnish Metal Engineering and Electrotechnical Industries is a prestigious national organization and has a decades long experience in organizing research and development programmes and projects (*figure 21*) It has some 1,100 member companies that account for 90% of the Finnish metals and electrotechnical industry´s turnover.

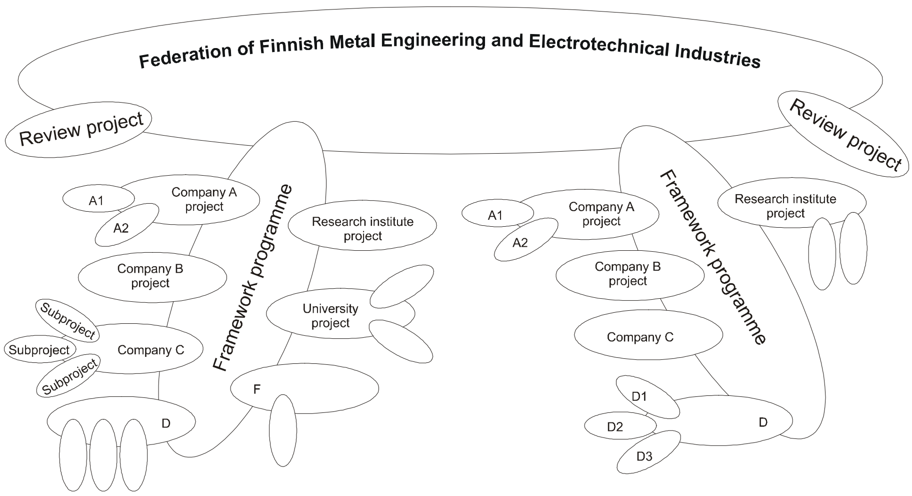

Figure 21. MET manages both complex framework programmes and relatively simple review projects that often look for fields suitable for future framework programmes.

For the purposes of the study, 24 representatives were selected from different organisations participating in the programmes. In addition, all 11 MET project managers were questioned with a web-based questionnaire and the MET project development manager interviewed with an open interview.

4.2 Research approach and methods

4.2.1 Approach

As this dissertation consists of several studies, several different research methods have been used, depending on the specific research settings and also lessons learned from the previous studies. Nevertheless, all the research designs have been based on qualitative research approach (see, for example, Bryman 1989), emphasizing subjects' views and interpretations and the particular social and organisational context.

Data has been collected through several case studies. What is more, all of the case studies involved had characteristics of action research, as described by Bryman (1989): The author and his fellow researchers collaborated with the case organisations, particularly people working on the operative level of the organisations, in order to develop a diagnosis and a solution for a problem involving knowledge support and organisational learning. In the Task Supporter case, focus was on the implementation and evaluation stages of the action research cycle (*figure 22*), as the solution implemented was based on the two previous cases, and in the MET case, evaluation of the outcomes is still missing.

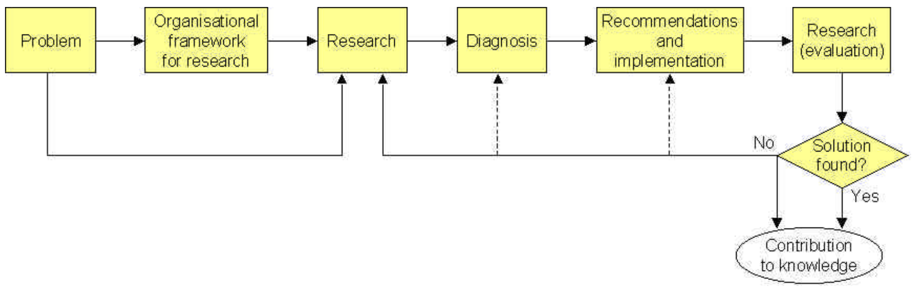

Figure 22. Stages in action research. Adapted from Bryman (1989).

4.2.2 Methods

The research methods used reflect qualitative research approach, consisting mainly of different kinds of interviews and observations. In order to gain more valid insights these methods have been complemented with more quantitative methods like questionnaires and log-file analysis.

In addition to qualitative, the adopted research approach can be considered constructive (see, for example, Kasanen & al. 1993). The purpose of the constructive research approach is to produce innovative constructions (for example a thinking model or a concrete technological artefact) that solve real world problems and make a contribution to the theory of the discipline in question. In this study, the real world problem consists of the expanding demands for organisational flexibility and the competency requirements these demands set to employees. The knowledge support systems (cases ABB, B&O, Task Supporter and ISS) and the model of a learning project organisation (the MET case) are the constructs.

Table 18. The methods and data used in the five case studies.

Case:	ABB	B&O	Task Supporter	ISS	MET
User observation	Usability: 4 Usage: All	4	X	14	
Participative observation	X	X	X	X	
Video analysis	Usability: 4			14	
Task documentation analysis		X	X	X	X
Open interviews			3		1
Semi-structured interviews	Usability: 4, QUIS based Usage: 10 Retrospective: 1	9	13	14+1	24
Stimulated recall					X
Group interviews		4			
Phone interviews			11		
Questionnaire	Usability: 4, QUIS based		X		25
Web questionnaire					11 (100%)
Log-file analysis	7 months	1 month			
Interview based communication network analysis	30 interviews				X
Internal company review		X			
Workshop					X

As the methods used have been numerous, it is not practical to address them all in detail here. Some clarifications and justifications may nevertheless be in order.

The approach to **participative observation** has developed from the author's own experiences and personality. As the tasks supported in these cases have been very complex and involved a lot of tacit knowledge that even the employees were not always aware of, it soon became evident that in order to fully understand the tasks in question, the observer would have to perform them himself or herself. As there was no possibility for the author to be fully trained, he performed the tasks with an experienced employee supervising and commenting his performance. These experiences and discussions with the supervising employees have provided invaluable insights. What is more, this approach has allowed a more intimate relationship with the employees studied. For example, in the ABB case, it took considerable effort to reach the full trust of the assembly line workers. It took weeks before it became evident that they had to use unofficial, hand written documentation not sanctioned by the quality system used by the company.

Figure 23. Observation and recording of video material for the purposes of usability analysis in the ABB case.

RQ1, the requirements for knowledge support in manufacturing work, was addressed by participative observation of the work tasks to be supported and open and semi-structured interviews with employees to be supported and their immediate superiors. Group interviews were used in the B&O case, as the time available to interviews was limited, and an interpreter had to be used, as the interviewer did not know any Danish and the assembly line workers were not fluent in English.

It would have been useful to analyse task documentation in the ABB and B&O cases in order to understand the requirements of these tasks in terms of knowledge support, but as the products and production methods were still under development, no task documents were available as such. In the B&O case, documentation of a corresponding task was studied, but it soon became apparent that the work methods had actually been developed further by the assembly line employees without anybody putting these changes on paper. As a result, the tasks to be supported were analysed through interviews and observations.

RQ2, the critical factors of implementation and use of knowledge support systems in operative manufacturing organisations, were addressed by observation and even video analysis of people working with the support systems. What is more, users and their immediate superiors and relevant support staff (for example information system managers) were interviewed with a semi-structured interview and triangulated with questionnaires. (Phone) interviews with people who had purchased a knowledge support system but failed to introduce it into production were also extremely useful. Finally, usability analysis and analysis of the log-files generated by the prototype support system, provided useful data.

For example, in the Task Supporter case, the semi-structured interview of the end-users contained questions like:
– Does the structure of the support documentation correspond with your own mental image of your work task?
– Does the support documentation proceed logically with your work tasks?

And the information system managers were asked questions like:
– How are decisions concerning purchases of new IT systems made?
– What kinds of computers are used for content authoring?

The corresponding managers' questionnaire contained questions like:

Has the knowledge support system in your opinion increased or decreased need for personnel?
Decreased Increased
1 2 3 4 5 6 7 8 9 Don't know

Competences and performance (mark all the applicable claims)
✍ Turnover is high in our company (or unit) and task content changes often.
✍ There are great differences in staff competences and quality of performance.
✍ Our most competent employees are willing and able to transfer their own expertise into the knowledge support system.
✍ Both staff and management feel that work performance is not satisfactory.

RQ3, the outcomes of knowledge support systems in operative manufacturing organisations, was addressed partly with the same tools as research question two. The semi-structured interviews and questionnaires used included questions covering both issues. Observation of end-users provided outcomes in addition to critical factors.

This data was complemented with analysis of the communication network after the implementation of the support system in the ABB case. Unfortunately, it was not possible to analyse the communication network before the introduction of the system as the assembly line in question and the products produced were brand new.

Finally, in the B&O case, the company conducted an extensive internal review in order to evaluate the benefits and problems of the knowledge support system introduced to one of their production lines. This review provided a lot of useful information on the outcomes of the system from the company point of view.

For example, the end user questionnaire used in the Task Supporter case contained questions like

Has the need for paper documentation
Increased Diminished
1 2 3 4 5 6 7 8 9 Don't know

Has interaction ***not relevant*** to work
Diminished Increased
1 2 3 4 5 6 7 8 9 Don't know

RQ4, how Knowledge support can be used to facilitate continuous improvement in learning organisations, is less straightforward than the other three. Requirements for such a support system have been collected through semi-structured interviews and paper and web-based questionnaires. As the concepts involved in organisational learning proved difficult for some interviewees to grasp, stimulated recall was used to point out relevant issues. This, of course, does not correspond with the tradition of qualitative research as pointed out by Bryman (1989). What is more, in order to understand, what kind of communication support would be needed, a communication network analysis was conducted.

The guidelines of the semi-structured interview covered issues from interviewee's and project's background to interviewee's tasks, knowledge management and delivery in interviewee's project, interaction and communication, and suggestions for improvement. The interview contained questions like

– What external factors promoted or hindered your project's progress?
– How has the new knowledge created in the project been utilised in your organisation?

Paper based questionnaires were given to interviewees in order to complement the interviews. These questionnaires focused on project management competences of various groups involved in the projects studied. The goal was to identify those interest groups and competences that require support in project organisations. There were seven different classes for competences and five groups to evaluate:

The web-based questionnaire was addressed for the project managers. In the questionnaire the project managers evaluated their present and goal project management competency levels.

4.2.3 Procedure

This study summarises a decade of work, consisting of several research projects with diverse goals and funding. As a result of the long time-span, the technologies used to deliver knowledge support, organisational paradigms of the companies using the support, and even research methods and competences of the author have evolved considerably.

Initially, in the mid 1990s, that is cases ABB and B&O, our work focused on support of individual work tasks (the case studies focused on assembly line work tasks). But it soon became evident, that the perspective was too limited. First, in the late 1990s, in the Task Supporter case and particularly in the IIS case, the focus was expanded to cover smaller work units like assembly line work teams. Later, right after the change of the century, the scope was extended to even bigger organisations consisting of several smaller units, in our MET case, project organisations.

The organisations involved in the case studies were not chosen for any particular virtue but their willingness to provide access for the researchers. What is more, the funding arrangements of the research projects this study consist of, in most cases defined the organisation to be studied:

– In the ABB case, the case company was contacted by the research group and they agreed to participate in the development of a prototype knowledge support

system and to allow access to the new assembly line that started using it. This research was funded by the Support Fund of the Helsinki University of Technology, The Finnish Work Environment Fund and ABB Industry Ltd.
- In the B&O case, the case company contacted the research group and asked them to develop a knowledge support system for a new assembly line. This work was funded by Bang & Olufsen A/S.
- In the Task Supporter case, the knowledge support system was developed by Brainware Oy in cooperation with the research group that was being paid revenues for the sales of the system. Brainware Oy provided the research group with contact information of all their clients, all of whom were contacted. One of the client companies allowed researchers access to their production in exchange for an in-depth analysis of the usage of the system in their production. Work was funded by The Academy of Finland.
- In the ISS case, the knowledge support system was developed in a research and development project involving several companies in addition to the research group. The system was only one part of a comprehensible assembly system information system. The first client to implement the information system provided access to their production in exchange for analysis of their new production line and consequent development suggestions. The work was funded by Tekes and the companies participating in the R&D project.
- In the MET case, The Federation of Finnish Metal Engineering and Electrotechnical Industries contacted the research group and asked their help to improve learning and knowledge management in the national framework programmes they were managing. This work was funded by The Federation of Finnish Metal Engineering and Electrotechnical Industries.

The basic research approach in each of the assembly line cases was similar. Firstly, the author and his colleagues familiarised themselves with the assembly lines to be studied. As printed documentation was in many cases sparse or non-existent, this familiarisation took place with a line manager or a corresponding person. Then the researchers were introduced to the people working on the line and the purpose and the methods to be used were presented. Intensity of the actual research depended on the distance to the assembly line in question. For example, in the ABB case, the author visited the plant almost daily, but in the B&O case, the visits were months apart, lasting for a few days in each time. But in each case, the researchers identified themselves with the end-users of the support system, spending most of their time by the assembly line. Finally, the results of the analysis were compiled into an end-report, delivered to the target company and funder of the project. These end-reports were also used as a basis for various publications like conference papers. In some cases, Task Supporter and ISS, not all of the material included in the end-reports could be used, as the target companies were to stay anonymous. The material collected in all these cases formed the basis of a book “Organisaation muisti – Tieto työn tukena, Organisational memory – Supporting work with knowledge”.

In the MET case, the approach was somewhat different, as the organisation studied was so different, and the subjects were distributed around Finland. Firstly, the organisation of The Federation of Finnish Metal Engineering and Electrotechnical Industries and the framework programmes it manages were studied from organisational documents. Then two programmes and a project was chosen for study. The main factor influencing the choice was timing as the programmes and the project were ending or about to end. Thus, a programme-long perspective was achieved. Again, an end-report was written and delivered to the target. What is more, the end-report forms the basis for a book that the research group is writing about organisational learning in project organisations and project organisation knowledge management.

5 Results

This chapter reflects on the included papers and the five case studies from the perspective of the research questions. Not all the relevant observations have been included, as their number grew rather big, and the main issues became buried under the multitude of details. The full lists of observations relevant to RQ1, RQ2 and RQ3 can be found from the enclosures:

– Enclosure 2: Requirements in the cases studied
– Enclosure 3: Critical factors in the cases studied
– Enclosure 4: Outcomes of the cases studied.

5.1 Requirements (RQ1)

In all, a variety of different **requirements for knowledge support in assembly line work** can be extracted from the cases included in this particular study. As some of the issues discussed in the earlier cases were not readdressed in the later ones, and some issues were added, repetition of the issues cannot unfortunately be used as an indication of prevalence.

While a complete list of all the observations made and the requirements deduced from them can be found from Enclosure 2, there were several issues that came up repeatedly during the cases. These shared observations made in these cases suggest common requirements that apply for knowledge support in assembly-line work.

In all the cases, the tasks supported were complex end-assembly tasks with long phase times. What is more, in

– two of the cases, the work methods were changing repeatedly, even on a daily basis.
– all but one of the four assembly line cases the production line and the product itself was brand new.
– two of the cases there was a large number of product versions and variations in production.

As a result, the employees had the learn new things constantly, and the required competency level was very high. Even experienced employees were observed using the support systems.

In all of the cases the number of orders was fluctuating, and flexibility demands were high. Employees had to be moved from one task to another, which would have been impossible without availability of support.

The reader users using the knowledge support system were mostly inexperienced computer users, but there were a number of exceptions. On the other hand, the author users were not always familiar with the tasks to be supported.

In addition to the knowledge support system, information was obtained from a variety of other sources in all of the cases, but different disruptions and delays in communication were observed in three of the cases. What is more, unofficial, hand-made documentation used to complement official documentation was observed in two of the cases.

Static electricity and/or dust caused by paper documentation was identified to be a problem in two of the cases. As sensitive electronics are an integral part of many present assembly products, this problem is probably shared by many companies.

The systems were used for on-the-job training and orientation in addition to supporting task execution.

The computers used to deliver support were multimedia-capable PCs that were connected to a local area network. Other pieces of software were running in the systems, too.

In addition to requirements shared by the cases it is worth noting that in each and every case there were requirements specific to that individual case.

The key requirements identified from the cases can be summarised as follows:

- The system should be able to support complex, extensive tasks that change often.
- The system should allow for a large number of different product versions and variations.
- The system should provide appropriate support both different kinds of employees: inexperienced and experienced in the task supported and in computer use, and temporary and permanent employees.
- The system should include learning functionalities, too.
- Author users of the system should be versed not only in computers but in the tasks supported as well.
- Knowledge environment of the work site should be addressed from a system perspective as a whole.
- The system should allow complete removal of paper from production.
- The computers and the network used should be capable of handling all the applications running in the system without lagging.
- The system should be easily tailorable.

5.2 Critical factors (RQ2)

Several **critical factors of implementation and use of knowledge support systems in operative manufacturing organisations** can be identified from the cases.

As with the requirements, the cases studied provide a number of different critical factors concerning successful implementation and use of knowledge support systems in operative manufacturing organisations, that is, assembly lines. The most important and interesting observations have been collected here, and the full list of the critical factors observed and consequent recommendations can be found from Enclosure 3.

The most profound requirement is the need for comprehensive system perspective in knowledge support system design, covering the whole information environment, including support gained through interaction and communication with other people. In several of the cases studied, it became evident that the information needs of the people and tasks supported had not been properly identified and included into the system. As a result, people had to resort to other, even self-made sources of information in addition to the support system.

Maybe the most frequent problem observed was the fact that the information provided by the support systems was often out-of-date. Content authoring and maintenance tools and processes were not streamlined enough, and appropriate personnel resources were not always available for timely upkeep of the content. As a result, users did not always trust that the information they received was accurate and timely. What is more, the systems studied did not necessarily indicate, when the document had changed, and what parts of the documentation the particular used had not yet accessed (except in the Bang & Olufsen case, where this functionality had not been used at the time of the study).

Weak usability of the authoring functions required recruitment of separate authoring personnel with computing expertise that the available subject matter experts did not possess. But on the other hand, the people recruited were not necessarily experts in the tasks supported.

The end-users of the support systems studied had two key competency dimensions: computer competency and task competency. While most of the users were experts in their tasks but novice computer users, there were also new employees, experienced computer users fresh from training with limited task competency.

While multimedia has been extensively used in various knowledge support systems, its use and influences have not been properly studied. The findings of these cases indicate that both pictures and text are needed in order to support different users. But composition of informative and good quality multimedia material, particularly pictures requires special skills.

Different training needs were also observed. First of all, the users should understand the concept of knowledge support in order to fully benefit from it. In two of the cases it also became evident that the users should have been familiar with the standard software development process. Their impression of the system was heavily influenced by the early prototypes tested in production. Had they known that such prototypes are not even supposed to be very efficient or user-friendly, some initial misunderstandings could have been avoided.

Appropriate computer equipment and optimised software were needed for both the reader and the author users of the support systems. Long response times and technical problems are annoying and soon reduce motivation to use the system. Also compatibility with other computer systems in production was found to be important.

Finally, a successful implementation of a support system seems to require a dedicated change-agent that is responsible for driving the concept in the organisation.

The observed key critical factors can be summarised as follows:
- Comprehensive system perspective.
- Interaction between users and developers.
- Streamlined authoring processes.
- Easy-to-use user interfaces to both reader and author users.
- Encouragement of reader users to provide input and feedback.
- Support for different kinds of readers users.
- Approriate multimedia authoring equipment and training for author users.
- Training on the concept of support and principles of software development.
- Appropriate, reliable and compatible hardware and software.
- A dedicated change-agent.

5.3 Outcomes (RQ3)

Numerous **outcomes of knowledge support systems in operative manufacturing organisations** were observed. The most important and interesting particularly in relation to the requirements for knowledge support in assembly-line work have been collected to this chapter. The full list of the observed outcomes of the cases studied can be found from Enclosure 4.

Flexibility of assembly lines and quality of their operation can be improved with a support system. A significant quality concern can be solved when paper and associated static electricity and dust can completely be eliminated from production, even with a relatively simple computer system. What is more, when the support system malfunctioned in the ABB case, the automatic testing system of the assembly line rejected more faulty products.

Content management was improved in many of the cases, and quality and level of detail of the support material improved (*table 19).* But as noted earlier, keeping the material up-to-minute was a challenge. What is more, authoring and upkeep of the detailed support material required more effort, but changes could be made faster than before. On the other hand, it was possible to ease the author users' work load in the B&O case, as reader users were able to actively participate in content authoring and work method development.

It was observed that a support system can be used for training of new employees, and need for traditional task training can be reduced.

One of the author's original concerns with support systems was their impact on mental workload. The results from two of the cases indicate that Knowledge support has little or positive impact on mental workload of the people supported.

Table 19. Maintaining support material has become more efficient in the ISS case with the introduction of new technologies (Koskinen & al. 2000a, page 246).

Early 1990s	Mid 1990s (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 colour 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 onto the server.

The observed key results and outcomes can be summarised as follows:
- Improved flexibility.
- Removal of paper from production.
- Improved product quality.
- Improved, and more timely content management.
- More effort required for content management.
- People supported can participate in content authoring.
- Reduced need for traditional task training.
- Little or positive impact on mental workload.

5.4 Continuous improvement in learning organisations (RQ4)

Finally, the first and fourth study also provide some suggestions on **using knowledge support to facilitate continuous improvement in learning organisations.** The issues discussed in this chapter are not as concrete as the observations listed in the three previous chapters.

“Change is a stable state”, as they say. Nowhere is this proverb as true as in learning organisations. Situations are examined, possible actions analysed, and the decisions made in a continuous process.

While organisations learn and move rapidly, inflexible information systems are not able to follow the continuous and unpredictable changes. The systems used should allow for the changing, even fuzzy nature of future, but knowledge management systems mostly still rely on rigid codification strategy and neglect the more flexible personalisation strategy. It was surprising to note that contrary to intuition, the codification strategy was not properly implemented in the programmes studied in the MET case. Instead, the programmes relied extensively on personalisation. In this respect, the outcome of both studies is quite similar. The answer is *to leave decision making to the human brain and use information technology as an interactive tool to help the decision making process.*

Information system design should leave parts of the applications unspecified in the detailed logic in order to leave room for human decision-making. This means fewer rules and algorithms and more user involvement. Situations not behaving regularly enough to be handled by information technology will be left for the intelligent user using IT tools to solve the problems and to enter the solution in a common database.

Learning organisations produce and use various kinds of knowledge. Technical and procedural knowledge, concerning the products and their production and use, may be properly managed, but organisational knowledge concerning communication and collaboration in the organisation, the way technical and procedural knowledge has been obtained, is often neglected. This was highlighted by the fact that new inter- and intra-organisational work practices were the main area of new knowledge created in the programmes studied in the MET case. *In addition to technical and procedural knowledge, also organisational knowledge should be systematically managed.*

Lack of knowledge management competences was observed behind many problems. Even competences and resources needed for paper report writing were often lacking. And in the MET case, reports were the primary way of accumulating and storing knowledge. *Particular need for improved KM competences were found in the areas of Knowledge distribution and dissemination, and Knowledge utilisation and productisation.*

Particularly systematic knowledge management is needed, if we want to turn an organisation into a learning organisation, if we want to distil results and lessons from one part of the organisation, for example, a project, and deliver them into another. Some sort of a knowledge repository, organisational memory, and work practices that facilitate the use of this repository are being called for. Phenomena like reduction of middle management and staff dispersion particularly typical to project organisations. But in order to capture and provide knowledge relevant to actual work task performance, *the knowledge management system should deliver and gather knowledge straight to and from employees' workstations.* This was observed in practice in the B&O case, where employees working on the line started actively editing and commenting the information content of the system. The people responsible of the work method design considered the material most useful.

The identified characteristics of knowledge support that can be used to facilitate continuous improvement in learning organisations include:

- Decision making should be left to humans, and information technology used as an interactive tool to help the decision making process.
- In addition to technical and procedural knowledge, also organisational knowledge should be systematically managed.
- Supporting knowledge distribution and dissemination, and knowledge utilisation and productisation should be given particular attention.
- Knowledge should be delivered and gathered directly to and from employees' workstations.

6 Discussion and conclusions

The aim of this chapter is to discuss the results presented in the previous chapter in the context of the literature discussed in chapter 2, Background. What is more, the approach and methods used will be evaluated, further questions and challenges presented, and finally, associated ethical questions discussed.

6.1 Main conclusions

The findings gained from the cases studied are diverse and it is easy to be distracted by the multitude of details. Therefore, the key conclusions and recommendations are presented first before looking into individual findings.

The need for system perspective in knowledge support system development and implementation came up in several situations. In addition, the work systems studied involved complex communication networks that extended well outside the immediate work environment. This leads to three key recommendations:

1) A support system should not be developed as a separate add-on but as a part of the whole work system. The actual work system may have to be re-engineered as well, and the support system is an integral part of that re-engineering effort.
2) In order to address the whole work system, the support system should support not only work task execution but required communication as well.
3) All the interfaces to different user groups and other information systems are important. It is not enough that, for example, reader-users user interface is easy to use, requirements of all the other user groups have to be addressed as well.

User-centered design is a key requirement for successful knowledge support systems. But the user-centered approach must not be limited to reader-users as is often the case, but should cover all the user-groups, particularly author-users, whose needs have not been addressed in the reviewed literature at all. What is more, the findings of the cases included to this dissertation indicate that authoring process problems and inadequate usability of the authors' user interfaces may have a detrimental effect on the quality of the support material authored and the work tasks supported with the material. As a recommendation:

4) Particular attention should be given to development of authoring processes and author-user user interfaces.

The tasks observed to need support or being supported were complex, changing and took place in a turbulent environment requiring exceptional flexibility. What is more, improved flexibility was considered to be one of the key outcomes of the knowledge support systems studied. As a result:

5) A knowledge support system should be able to adapt to different users and situations.

6) Changing the support system itself and the knowledge content it provides should be fast and easy.

Implementation seems to be a particularly difficult stage of knowledge support system development and use. Even successful implementations may have caused severe problems like in the AmEx EPSS case (Paul 1999), where half of the employees that were to use the system developed quit their jobs before the system was fully deployed.

7) Particular attention should be given to implementation of knowledge support systems. For example, user-centered development approach may considerably ease the implementation.

Mere distribution of knowledge is not enough, if a knowledge support system is to act as the technological infrastructure of organisational learning. This is stressed by the observation that the support systems studied were used also for training and orientation purposes. Besides, most support systems described in the literature or in the cases included address knowledge and learning only from the codification perspective. The other half of knowledge management, personalisation strategy is usually forgotten.

8) In addition to distributing knowledge, a support system should also facilitate knowledge capture.
9) Learning functionalities should be included to the system in addition to support functions.
10) A comprehensive knowledge support system addresses knowledge from both codification and personalisation perspective.

6.1.1 RQ1: Complex and changing tasks

From the assembly line cases studied it was possible to identify several requirements for knowledge support systems. These requirements and their correspondence with the literature discussed in chapter 2 are addressed below.

The observed requirements are of various depths and definitions. While some of them are clearly defined like the removal of paper from the production, the key requirement, system perspective, actually addresses the very philosophy behind knowledge support development.

System perspective: Maybe the most important observed requirement for knowledge support in manufacturing work was that the knowledge environment of the work site should be addressed from a system perspective as a whole. This corresponds with recommendations of many of the case studied reviewed in subsection 2.5.5.

Complex, changing tasks: Another observed key requirement was that a knowledge support system should be able to support complex, extensive tasks that change often, is also in line with literature. Of the 33 case studies discussed in subsection 2.5.5, almost all involved very complex work tasks. It seems that only complex work tasks warrant the effort required for support system development. Simpler tasks can be supported with simpler methods.

The need to support tasks that change often corresponds with the requirement of **tailorability.** The system should be easily tailorable in order to react or even proact rapidly enough to changes in the environment. Or as one interviewee noted when asked why they had removed a support system from production: “What do we do with a system that takes months to tailor when our production changes on a weekly basis.” It may be impossible to define a general-purpose support system for assembly-line work that would answer to the needs of every assembly line in the world. Developers of industrial information systems and their clients should understand that some tailoring of the system is most likely always required.

Another related requirement is **adaptability:** As noted in many of the case studies reviewed, an adaptive system adapts itself to different users and changing work situations. This agrees with the observed requirement that a support system should adaptively provide appropriate support to different kinds of employees in different situations.

Learning and training: Many of the knowledge support systems reviewed in subsection 2.5.5 included some training and learning functionalities. In spite of the fact that the systems studied for this study did not include any particular training or learning functions, they were used for training purposes in addition to support. So, in spite of the fact that support and training are two separate application domains, a support system should include functions needed for on-the-job and just-in-time training.

Removal of paper: In case the work supported involves sensitive electronic components, a knowledge support system can be used to remove paper from production. This is more a technical than competency issue but static electricity and dust caused by paper is often a considerable problem in modern assembly.

Hardware: In all of the assembly line cases studied, the computers were running not only the support system but other applications as well. Consequently, the computers and the network used in production should be capable of handling all the pieces of software running in the system. If the system is designed to accommodate only one or some of the software, its capacity may not be adequate, and the system will be plagued by delays and long waiting times.

Authors: Author users of the system should be skilled not only in computers but in the tasks supported as well. The concept of content authoring and management seems largely overshadowed by design and development of the support system itself. This issue was raised in critical factors, as well.

6.1.2 RQ2: Forgotten author-users

From the assembly line case studies it was possible to observe several critical factors for knowledge support system implementation and use. These critical factors and their correspondence with the literature discussed in chapter 2 is addressed below. The most interesting observations concern authoring processes and author-users of knowledge support systems. While the literature focuses on reader-users of different support systems, in our cases, also authors and their interaction with the systems studied were found to be of critical importance.

System perspective: The importance of comprehensive system perspective already discussed in the requirements was observed to be a critical factor for knowledge support system implementation and use in operative manufacturing organisations as well. All sources of information, not just the computer system, should be taken into account in comprehensive support system design. This includes support gained through interaction and communication with other people. What is more, introduction of a support system should not be seen as a separate act but as an essential element of a more profound reorganisation of work and organisation.

This finding is well in line with literature and even Senge's (1990) definition of organisational learning. A knowledge support system should not be implemented as an attachment to but as an integral element to a work system.

User orientation: The observed need for more intimate interaction between users and developers during system design is also compatible with findings of the previous studies. This way, the developers could also identify and provide for different kinds of reader users with different sets of competences. But in spite of the weight placed on user orientation and user-centered design, only the reader-users have been discussed in the literature. Author-users have been neglected. The observed need for **reader-user usability** is in line with the literature, but on the other hand, appropriateness and usability of authoring and maintenance functions, **author-user usability**, have not been discussed.

An interesting counterpoint to these usability requirements is offered by the two case studied conducted in the Cranfield University (Fakun 2000). In these studies, the perceived ease-of-use did not have as big an influence as could be expected.

According to our observations, problems in author-user functions and authoring processes may nevertheless cause considerable problems, causing, for example, delays in updating of the content, and lack of trust to the accuracy of the content. What is more, weak usability of authoring functions has required recruitment of separate authoring personnel with computing expertise that the available subject matter experts did not possess.

Easy to use authoring functions would allow task experts, even reader users to participate in content authoring and maintenance. Content authoring and maintenance should be so simple that even minor changes in methods or parts are properly documented. As a result, content could be kept constantly up-to-minute, and support users could trust that the information they receive is always accurate and timely.

But easy to use technology is not enough, if the organisational culture does not allow and encourage all kinds of users to be active contributors of content. In any case, reader users should be given a possibility to spontaneus feedback that would encourage them to point out errors in the support documentation and to provide hints and tips for author users.

As work methods and corresponding documents change regularly, a support system should indicate, when the document has changed, and what parts of the documentation the particular user has not yet accessed.

If a knowledge support system is really to act as a core facilitator of organisational learning, the tools used in various stages of the learning cycle, from knowledge capturing and authoring to knowledge delivery, have to be as uncomplicated as possible. These tools should be so easy to use that they do not complicate the tasks they are supposed to support.

Training or support: While knowledge support systems should be easy-to-use for all user groups, it is not enough. Both author and reader users require training, or support for support system use. User-training and support is not discussed in the literature reviewed, but its necessity was evident in our studies. For example, authoring of multimedia support material requires special skills like work task analysis and photographing. Taking clear, informative and unambiguous pictures is a skill not easily mastered.

While the reader-user interface may be self evident, reader users may have to be trained in the very concept of knowledge support so that they understand the purpose of the system and that they are supposed to give input and feedback to the system in addition to utilising the knowledge it provides. If the support system is developed and tested in production, the reader-users should also be informed of the software development process so that they know what to expect.

Feedback: The reader users of the system should be encouraged to provide input and feedback to the system. Such interactivity was a key issue in many of the case studies reviewed in subsection 2.5.5, too. Mere availability of such functions is not enough, because in many organisations, people are still used to the hierarchical information flow. If such tools are not available, easy-to-use, and actually used, information content of the system does not evolve and the organisation the system supports does not learn.

Change-agent: Finally, according to the assembly line cases studied, a dedicated change-agent and clearly defined responsibilities are essential for successful implementation of a knowledge support system. In each of the successful implementations studied, a change-agent was identified. The literature gives attention to change management and roles and responsibilities, but they are not considered to be as critical as our findings suggest.

6.1.3 RQ3: Flexible quality

The observed outcomes of the support systems studied in the assembly line case studies and their relationship with the literature discussed in chapter 2 is addressed below. Of particular interest is the impact on organisational flexibility that was discussed in section 2.2. The observations seem to suggest that knowledge support can really have a positive impact on flexibility of manufacturing organisations. Unfortunately knowledge support (or EPSS) and its impact on organisational flexibility has not been discussed in literature. Another important finding concerns impact on employees' mental workload. At least in the cases studied the impact was found to close to none if not positive.

Flexibility: The most remarkable outcome of knowledge support systems in operative manufacturing organisations was improved flexibility of production in the cases studied. The organisations were able to react to rapid changes in demand and environment.

Quality: On the other hand, findings concerning improved product quality correspond with literature. Regrettably, a before and after comparison of quality and productivity was not possible, as the assembly lines the systems were studied on were brand new and producing new products. One reason behind improved quality was **removal of paper** from production. This was also one of the observed requirements for shop-floor knowledge support in assembly. In the ABB case, paper was completely removed, and in case Task Supporter paper was to be removed as soon as the transition period with parallel paper documentation was over. In the B&O case, papers were not considered a problem, but only two laminated sheets with instructions on support system use were observed. In the ISS case, some papers were involved, but the support system implemented replaced most paper documents from production.

Participative authoring: Another key observation was made in the B&O case, where people supported started spontaneously to participate in content authoring. Such interaction between the system and its users is essential for continuous development of the information content the system and the tasks supported. Such capture and capitalisation of knowledge created in the organisation is also one of the potential key benefits discussed in literature. But the support system and the organisational culture should allow and encourage it.

Content management: Observed improvement in content management corresponds with literature. Particularly when it comes to timely upkeep and delivery of information. On the other hand, in the ABB and Task Supporter cases, delays in content changes were observed, which resulted in outdated information content and lack of trust to the system. The reason behind these problems was insufficient development of author-user functionalities in the systems studied.

It seems that knowledge support systems can potentially improve management of operative knowledge, but if authoring and content management is not properly addressed in system design and implementation, they can also potentially disrupt content management. This is related to the observation that **more effort is required for authoring** and management of knowledge support system information content than for corresponding paper documentation authoring and management. While the authoring side of knowledge support has not usually been addressed in literature, there was one case study (Briggs 1996), where it was observed that obtaining the necessary detail was more difficult than anticipated, as the existing paper based documentation did not supply required level of detail, and it was necessary to actually perform many of the tasks to ensure that the procedures were correct.

Task training: The observed reduction of need for traditional task training supports literature that often uses this issue as a primary justification for development and implementation of knowledge support systems. It should be noted, though, that as discussed in the previous chapter, new kinds of training are also needed for both author and reader users of the knowledge support system, focusing on the system itself.

Mental workload: Little or no work has been done on psychological influences of knowledge support, particularly its impact on mental workload. This has been a source of concern for the author, and it has been a relief to observe that the systems studied have had little or positive impact on employees' mental workload.

The literature identifies two potential problems concerning knowledge support systems: Resistance to change and disruption of interpersonal communication.

– Significant **resistance to change** was not observed in the cases studied. Actually, the resistance was surprisingly low in those cases, where implementation of the system had been successful.
– **Disruptions of interpersonal communication** were not specifically studied, but at least no overt detriment of communication was observed. In addition, the communication network studied in the ABB case was found to be extensive in spite of the presence of the support system. What is more, in the ISS case, one of the reasons for implementation of the support system was that that the new assembly line was disrupting interpersonal communication with its noise and longer distances between employees. The support system was to replace some of the lost communication.

6.1.4 RQ4: Continuous improvement in learning organisations

The most concrete model for using knowledge support to facilitate continuous improvement in learning organisations is offered by Raybould (1995, 2000). The problem with his Organisational Performance/Learning Cycle (see *figure 7*) is that that it does not address organisational knowledge at all, but focuses on technical and procedural knowledge. And, as discussed in subsection 2.4.2, *capture and management of organisational knowledge is essential for organisational learning*. If the organisation fails to manage it, it risks repeating its errors over and over again and failing to repeat its successes.

In addition, Raybould's cycle is based on codification knowledge management strategy, but as discussed in subsection 2.4.2, *both codification and personalisation strategies are needed* in order to successfully manage different kinds of knowledge. Based on the findings of the MET case study, particular attention in knowledge management should be given not only to capture of knowledge but to dissemination and utilisation of knowledge as well.

So, the cycle proposed by Raybould should be expanded to cover both technical and procedural, and organisational knowledge, and to address not only codification but also personalisation knowledge management strategy.

What is more, a knowledge support system used to facilitate continuous improvement in learning organisations should leave actual *decision making to humans* and use technology as a tool that helps the decision making process. Human beings are far more flexible than information technologies, and constantly changing environment requires ability adapt, to make decisions based on fuzzy and incomplete information.

Finally, support should be brought as *close to actual work context* as possible, so that it can be utilised in work task execution without extra effort. For example, in production, supported should be delivered and knowledge gathered directly to and from individual employees' workstations.

6.2 A model on support system development and use

Both support system development and support content development should be addressed in order to develop knowledge support that facilitates continuous learning and organisational development. Both processes should be turned into learning cycles that interact with each other.

The proposed model (*figure 24*) is based on the knowledge support system development cycle discussed in subsection 2.5.7, content authoring process described by Kasvi & al. (2000a) (see subsection 2.5.8) and Raybould's (1995, 2000) Organisational Performance/Learning Cycle (see subsection 2.4.1) that has been revised to include organisational knowledge and personification strategy. In addition, the overlapping parts of the three models have been integrated.

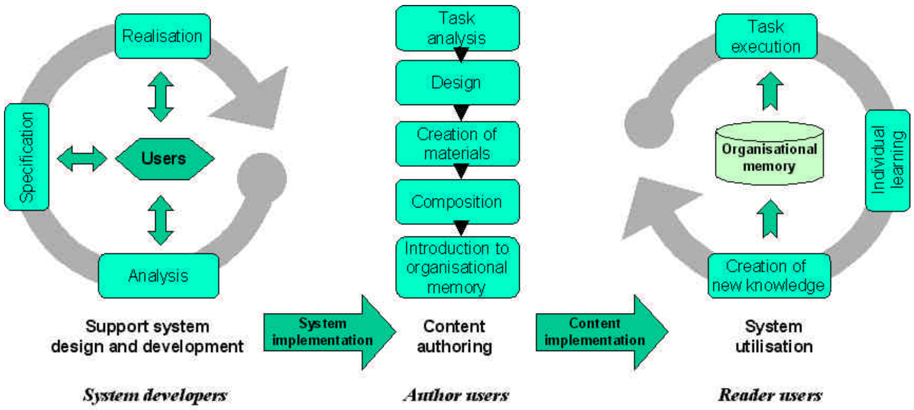

Figure 24. The model of interacting support system and support content development cycles with corresponding main actor groups.

One should keep in mind that the models have been considerably simplified in order to fit them into a single figure. One should refer to the corresponding subsections 2.6.7, 2.6.8, and 2.5.2 of this dissertation for details. The point is that both the system design and development, and its utilisation are iterative, learning processes. The linear content authoring process is just an intermediate step, necessary for implementation. What is more, it should be noted that the roles of the author users and the reader users are interconnected as discussed in subsection 2.5.3.

6.3 Evaluation of approach and methods

Ensuring reliability and validity is one of the key problems of qualitative research approach. And how far reaching generalisations can one made from a few constructivist, action research based case studies? Even the literature constituting the background of this dissertation is mostly based on a few case studies, far from random examples of the phenomenon studied. And case studies by their very nature focus on understanding the phenomenon under study within a single setting.

The basic distinction between reliability and validity, the two key requirements for good research, is simple: while **reliability** stands for accuracy and consistency of the research methods used, **validity** concerns the focus of these methods, do they measure the right thing?

Reliability of case studies relies on the theoretical reasoning behind the research methods used and the implementation of these methods. While the case studies included may have a slightly different focus, that is, reliability over the cases is not as good as it could, they should also be judged by their internal characteristics. How reliable the methods and their implementation were in each particular case? (*figure 25*)

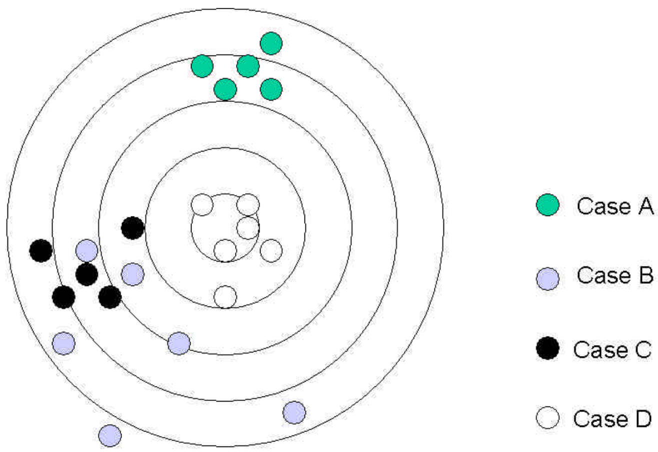

Figure 25. The often used target metaphor for reliability and validity can be used to illustrate the problem of a multiple case study setting. While the results of the D case are both valid and reliable, results of the A and C cases are reliable but not valid and in the B case, the results are neither valid nor reliable. And what should one think about overall reliability and validity?

Yin (1983) lists the four tests for research design quality and the case-study tactics for dealing with them. *Table 20* lists these tactics and what factors improve or weaken quality of this study in each test.

Table 20. The four design tests, Yin's (1983) case study tactics and this study.

Test	Case-study tactic	This study
Construct validity	– Use multiple sources of evidence – Establish chain of evidence – Have key informants review draft case study report	+ Multiple sources and methods were used. + Specific subjects were defined for the studies. + Semi-structured interviews were used to focus subjects on the phenomenon studied. + Results were reviewed with key informants.
Internal validity	– Do pattern matching – Do explanation-building – Do time-series analysis	+ Many types of methods were used to triangulate the results. + Results and experiences from previous cases were utilised. – Causality was important in RQ3. – A lot of inferences have been required.
External validity	– Use replication logic in multiple case studies	+ Results were compared to the results of corresponding case studies and literature. + The assembly line cases had several similarities.
Reliability	– Use case study protocol – Develop case study data base	+ Same methods were repeatedly used but new perspectives were added, based on previous experiences. + Subjects were carefully selected and the sample of reader users was 100% – In the earlier cases the researcher was inexperienced.

Unfortunately, while Yin's (1983) four tests are well suited for studies that aim to understand characteristics of real world phenomena, they are not ideal for studies striving to understand problems associated with construction of artefacts, for example, knowledge support systems. The difference can be illustrated by comparing quality of potential answers to two questions: How are knowledge support systems used? How to develop a good knowledge support system? Thus, while the tests are useful for evaluation of the results of Research Question Three, and maybe One, their usefulness is limited for Research Questions Two and Four.

Due to the long history of this work, the material used comes from several related, but separate research projects. Besides, as their funding came from different sources, they also had differences in their goals and emphasis. As a result, the methods used have not been as uniform as they could have been for the purposes of a summative dissertation like this one.

Also the author of this dissertation has changed over the years. This can be observed from the methods used in the case studies, how they have evolved as the author has gained more experience on the field. It would have been very beneficial, if the first case studies could have been studied with the same experience as the last ones. Even the documentation of the methods and data used in the first case studies was not as detailed as it should have been, and considerable effort was required to reconstruct some of the information presented in this dissertation.

While the semi-structured nature of the interviews may violate the principles of qualitative research, the semi-structured approach was chosen in order to focus the findings on a particular issue, namely knowledge support. But within this field, the purpose was to answer even such questions the authors of the interviews did not know yet, when the studies started. Nevertheless, the questions were based on extensive background work, particularly in the Task Supporter, ISS and MET cases that benefited greatly from the previous cases. The setting can actually be described as a chain of case studies.

This dissertation summarises many years of work on knowledge support systems and organisational learning. While this long history has allowed observation of the development of the concepts, it may also have made some of the findings and recommendations outdated as well. One should carefully consider, how valid observations made on support systems based on Intel 80386 processors and early 1990s organisations are in present day work environments.

One can criticise the selection of the cases studied and the number of subjects. The cases were not by any means selected examples but dictated by the funding and access. First, ABB industry ltd was approached because they had previously provided researcher access to their production, and things had worked out fine for both parties. Second, Bang & Olufsen A/S approached the author and his colleagues as they had heard of the first case and offered to fund a research and development project. Only in the Task Supporter case, the selection of subject can be considered random, as all the companies that had purchased the system were included into the study. In the ISS case, the assembly line studied belonged to a client of a company that was partly funding the work, and finally, in the MET case, the organisation studied funded the study itself.

On the other hand, within these cases, the subjects were carefully selected to include all the people involved. Besides, in all the assembly line cases, all the available reader users were included. The sample was 100% of the population.

Careful selection of subjects within the cases became particularly important when it was observed that some of the key findings focused around system perspective and author-users. Had the selection of subjects not included not only reader-users, but, for example, author-users and line-managers, a lot of essential information would have been lost. This was due to the sociotechnical tradition of the Laboratory of Work Psychology and Leadership, stressing the importance of a more comprehensive perspective.

Generalisability of case studies can be observed from two perspectives (Yin 1983). **Analytical generalisation** or generalisation to theory means that the findings support the original theoretical propositions. Multiple case studies supporting the given theory enhance analytical generalisability. **Statistical generalisation**, on the other hand, is typical of surveys. While the number of cases and subjects was too small for statistical gerenalisation, the generalisation is based on the analytical approach, which was realised through comparing the results with former empirical studies and existing literature.

While findings from a single case can be considered valid within that case and a set of cases can provide more generalisable insights, one should be careful when applying these insights into practice outside the cases studied. Fortunately, all the assembly line cases studied were relatively similar in several respects like the work environment, the nature of the tasks performed and the products manufactured, the basic structure of the knowledge support systems and the employees background.

Circumspect generalisations concerning similar settings can be made. But should significant characteristics like nationality of the subjects or the nature of the tasks supported change, one should carefully check the validity of the findings in that particular setting before taking action.

When it comes to issues concerning knowledge support and learning organisations one should be even more careful. Only one case (MET) was studied with focused interest in organisational learning, and the organisation studied (a framework program) was far from typical, and very different from the other organisations (assembly lines and plants) it was compared with. On the other hand, the findings were fascinating. Literature searches failed to provide corresponding prior studies and the observed lack of systematic management, not to mention development of organisational knowledge was a surprise. There has been a lot of discussion on learning organisations and knowledge management, but this discussion has not always turned into action.

One can conclude that while the findings concerning knowledge support in assembly line environments may be considered mostly valid and reliable in that particular setting, the findings concerning knowledge support and organisational learning should be treated as pointers for future research.

6.4 Questions and challenges

6.4.1 Further questions

Possibly the most important "new" observation made in this dissertation is the neglect of author users in knowledge support (or EPSS) literature. More work is definitely needed in order to properly address author-users' needs in support system design. This is particularly important in learning organisations, where a support system should act as the technological basis of the organisational memory. If it is too difficult or cumbersome to create and maintain the contents of that memory, the organisation risks losing lessons it has learned.

Another interesting issue is the impact on organisational flexibility. While the theory discussed in section 2.2 justifies knowledge support with improved organisational flexibility, and the findings of the assembly lines studied support that theory, the issue has not been properly studied. What comprises organisational flexibility in practice and how can a support system facilitate it?

Both literature and our findings stress the importance of systems thinking in knowledge support system design. But how should that be done in practice? What is the relationship between a work system and a knowledge support system? And when it comes to knowledge support system development. How should one integrate organisational re-engineering and support system design?

Finally, the issue of organisational learning and knowledge support is still open. While the findings of the included cases provide some insights, they are based on limited material. The questions raised are nevertheless very interesting, even disconcerting, and deserve further study.

6.4.2 Applicability on other fields

The findings discussed in this dissertation come from five case studies, four of which come from manufacturing industry, particularly light-weight assembly. The ideas of knowledge support can be applied to many other fields too, as demonstrated in the case studies reviewed in subsection 2.5.5. Actually, knowledge support systems are usually developed to support other kinds of jobs than assembly work tasks.

Most of the findings discussed in this dissertation are general in nature. Actually, only success in elimination of paper is specific to manufacturing industry. But for example system perspective, recognition of author-users importance, importance of organisational in additional to technical and procedural knowledge, all could be discussed on other application areas, for example, health care or office work tasks too.

But, as discussed above, it is important to test the validity of the findings if they are to be used as a basis for any further work, particularly on other application areas. They are, after all, based on a few case studies and literature based on case studies.

6.4.3 Ethical questions

Implementation of new technologies always involves ethical value questions. Knowledge support is no exception. For example, shared databases and communication networks may enhance knowledge sharing in distributed organisations, but does this enhancement mean tightened control or democratisation of knowledge?

There are at least three important groups of value questions that developers and implementers of knowledge support systems should consider (Kasvi & al. 2000d):

- Does knowledge support influence users’ mental wellbeing?
- How does knowledge support influence work community?
- How does knowledge support influence users’ competences and creativity?

While one of the goals of knowledge support systems is to ease negative mental workload caused by work task performance through satisfying knowledge needs present in work situation, they can also have adverse effects. A support system may be so cumbersome to use that it actually increases instead of decreases mental workload. Poor usability and functionalities not properly reflecting the tasks supported or their performers, are to blame. It has been observed that elder employees are often replaced with younger ones when new computer systems are implemented. This is absurd. If an information system is too unusable for more experienced employees, the problem is in the system, not in the employees. The system should be changed, not the employees.

Knowledge support can be designed not only to expand employees' competences and autonomy, but also to reduce freedom of action and possibilities for spontaneous creativity. While paper based documentation is often somewhat vague and general, multimedia based task instructions can easily be so detailed they control task performance to the least detail. But work tasks with a forced rhythm and carefully defined execution strains task performers more than tasks where performer can control his or her work (Karasek & Theorell 1990). The very same information can also support creative problem solving if organised for that purpose. It is a question of will and system design.

A knowledge support system can not only control but also track task performance, even without the employee knowing it. How often the employee needs support? How fast he or she progresses from a task to another? In many cases tracking may be fully justified, but it should always be wilfully deliberated, what is tracked and why. Where does employees' privacy end?

Knowledge is power and prestige also in work units, and knowledge support systems influence these social structures. Does knowledge support limit social interaction as indicated by most earlier definitions of electronic performance support systems or does it lower social barriers and open new communication channels like peer help provided by the PHelpS system discussed in subsection 2.5.5. In many early definitions, minimising human interaction, that is, support from other people, was not only considered characteristic to EPSS but also one of their key goals (see, for example, Raybould 1995).

Not all value questions are threats. Knowledge support also opens new possibilities. For example, Longman (1997) observes in his article "Janitor stole my job" how easy access to knowledge democratises decision-making in workplaces and decreases both the amount of training and the mental skills needed to perform many white-collar jobs. As more people are able to access and process information needed for decision-making, they can present their opinion and have an influence. This empowerment may improve operative employees' chances to progress in their career into managerial positions. But it may also weaken management's control over the organisation.

From a learning organisation perspective the most interesting feature of knowledge support systems is the possibility to not only distribute but also collect information. But do we have the right to collect people's ideas and to collectivise their individual competences? What are employee's intellectual property rights to his or her personal, experience based expertise? A system that systematically collects and distributes people's tricks and tips may also crumble the competency based professional pride of the most experienced employees. How does it feel when nobody asks for you advice any more?

Who do create, communicate, and consume knowledge provided by the support system? Do operative work units become polarised into knowledge intensive work tasks and routine support tasks? Or does knowledge support democratise knowledge, bringing effective knowledge management within everybody's reach?

A knowledge support system can be designed to support competency and learning, but it can also be used to deskill employees, to minimise the need for competency and learning at work: When all the information needed is available on-demand, you do not need too learn it. Competency is replaced by just-in-time knowledge that is available only when it is needed. Performance without learning is actually often mentioned as one of the key goals and characteristics of electronic performance support systems, particularly in literature written in the early 1990s (for example Geber & al. 1995 and Rosenberg 1995).

As Carr (1992) points out, instead of replacing employees' skills with technology, we should preserve their core competences, reduce the time and attention that employees have to pay to their inessential duties. Technologies like knowledge support should be used to take over the inessential tasks and to preserve (and support) core competences.

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Enclosures

Enclosure 1: Key features of the case studies analysed
Enclosure 2: Requirements in the cases studied
Enclosure 3: Critical factors in the cases studied
Enclosure 4: Outcomes of the cases studied

Enclosure 1: Key features of the case studies analysed

Case	Task type	Support type	Study type	Key methods	Key findings
ADAPTS	Complex maintenance	Adaptive hypermedia	Proof of concept	NA	Concept was proofed
AmEx EPSS	Complex office work task	Automated letter-writing system	Development story with anecdotal observations	NA	Implementation caused severe resistance to change
APPLE A	Assembly planning	Adaptive intranet web-pages	Feasibility and impact	Observation, questionnaire, audio recordings	Most of the analysis not yet done. System is easy to use.
ASSIST	Astrophysics data analysis	Interactive, collective memory	Usability, usefulness	Interviews, Questionnaire	Usability and usefulness OK
BOPS	Learning management	Learning management system	Impact, implementation	Interviews, questionnaires, log-files	Key success factors identified
CLASS	Teaching, Learning, Administration	Distributed support	Impact, attitudes	Learning result tests, Questionnaires	Only CLASS scored positively in all attributes
Ericsson hypermedia MI	Relatively simple end-assembly	Hypermedia	Feasibility, usability	Usability trials	Assumptions questioned. For example, user participation did not have effect on usability or ease-of-use or usefulness.
Ford Digital Manual	Machine tool use and maintenance	Hypermedia	Impact and usability	Usability trials in two factories	Assumptions questioned. For example, effects of computer anxiety, user participation, ease-of-use and usefulness were mixed.
Hymatic hypertext	Complex assembly and testing	Hypertext	Impact	Questionnaire	Efficiency improved. Reduced user frustration, which had a positive effect on use.
IMMS	Maintenance Management	Automated maintenance scheduling	Impact, usability, evaluation	Statistical analysis, case tests, observation, questionnaires	Performance improved, no errors in case tests, easy to use, evaluation positive

Insurance agent EPSS	Insurance agents	Information and advice	Impact	Interviews, observations, sales results, questionnaires	Paper was preferred over EPSS, Classroom was preferred over CBT, Computer did not impact support outcomes, CBT did not impact learning outcomes, Training or support did not influence selling, EPSS is cheaper than traditional training
Interactive Volleyball	Volleyball practice planning	Information and planning tool	Feasibility	Questionnaires	The concept is feasible
Internet Kiosk	Machine tool use and maintenance	Hypermedia kiosk	Field test	Initial field notes	Some advantages over existing methods.
Johnston Boiler project	Cutter Boiler use and maintenance	IETM	Assessment of use	Evaluation of 20% of the cutters of the fleet with boilers.	Test scores and task performance improved greatly.
KERMIT EPSS	Software use	Text based or audio prompting	Impact	Performance time measurement, Post-test	Performance time and retention were improved.
KWS	Army action officers group work	groupware	Methodology	Literature study	Feasibility methods identified
LPS	Lesson planning	Instruction and tools	Impact	Observation, performance evaluation	Novices performed and learned the task
Manufacturing on-line help	Planning engineer, coordinator, warehouse worker	On-line help	Impact	Observation Performance evaluation	Scores were low, system had no impact, learning did occur.
Multimodal support	Assembly	Multimedia instructions	Laboratory test Field test	Laboratory: Performance evaluation (time and accuracy), Questionnaires Field: Observation, interviews	Media selection influences assembly time and quality. Assembly line workers preferred support system over paper
NECST	Contracting	Hypertext, contract generator	Feasibility	Observation, usability testing, expert review, implementation log, interviews, questionnaires.	The concept was found feasible. Subject matter experts are important.

NNAble	Technical troubleshooting	Case library, collaboration, reference, training	Development story with anecdotal observations	NA	Key factors to skill and work development and EPSS development identified.
PHelpS	Offender Management	Context specific support, case-based help, peer help	Usability study	Observation trickle files	5/7 help requests were successful.
Retail banking Support System	Retail banking advisory and sales	Information source	Problem solving	Action research	Support system development methodology.
Software configuration management	Software configuration management	CBT, help, reference	Development story with anecdotal observations	NA	Recommendations for development and implementation.
STAR-ASI	Aviation Safety inspection	On-the-job training aid	Development story with anecdotal observations	NA	Recommendations for development.
TA	Software use	Proactive task-oriented information.	Impact	Performance evaluation.	EPSS supported outperformed classroom trainees on conceptual tasks.
Testing of face shovel hydraulics	Complex technical testing	Multimedia information	Development story with anecdotal observations	NA	System is useful and in use.
THEO EPSS	Customer phone service	Information source	ROI	Observation, Questionnaire, ROI analysis	Cost-benefit break-even point is likely to occur in 4 years but can range from 1 to 18 years.
TSS and PSS	Complex technical testing	Hypertext, hypermedia	Feasibility	Task-Technology Fit analysis for hypertext. NA for hypermedia.	Mixed findings on hypertext. Hypermedia well received by managers.
U.S. Navy DSS	Complex planning task	Lessons learned delivery with a plan authoring tool	Impact	Simulation with simulated users.	Substantial improved plan quality
Wearable origami support	Origami making	Wearable support	Laboratory test	Performance evaluation, questionnaires	Difference was minimal.

Wearable QALive and WaRP	Quality assurance	Wearable support	Field test	NA	System worked flawlessly. Guidelines for wearable system developers.
WRCC	Learning and support system development	Discussion forum, link manager, resource construction system	Impact	Questionnaires, log-in information	Use dwindled when facilitation ended. Hundreds of outsiders used the system in addition to subjects.

Enclosure 2: Requirements in the cases studied

Case ABB	
Observations	**Requirements**
Complex complete-build end-assembly task with a phase time of 30-45 minutes.	–
A new product family with several models and thousands of variants.	– Correct support materials should be easy to locate. – Content management should be easy and efficient. – An advanced data base system is required.
A new production line.	–
Products, parts and work methods changed rapidly.	– Support has to be delivered directly to work context. – Support content should be easy to maintain. – A support system should inform its users of topical content changes.
High fluctuation in number of orders of different models.	– Both regular and temporary staff should be supported.
There were disruptions and delays in the communication between organisational units and actors.	– A support system could support organisational communication in addition to task execution.
Required paper-based instructions were often not yet available when needed	– Information content of the system has to be kept up-to-minute.
Static electricity caused by paper documentation could have damaged sensitive electronic components	– Support should not use paper.
The reader users were a heterogeneous group. Some were used to computers while some had not touched one before.	– A support system should be very easy to use. – The user interface should take both experienced users (e.g. shortcut keys) and novices (e.g. context sensitive help) into account. – Training in computer use and the concept of knowledge support is needed.
Author users were technicians not familiar with the tasks supported.	– Author users need support to understand the tasks supported.
Employees were used to using bar code readers present at work sites.	– The system could utilise the bar code readers.
Employees were using self-made unofficial documentation in addition to official task methods documents. In addition, a complex social network was used as a source of information.	– Conversing existing documentation into electronic format is not enough. The diverse information environment of the work task to be supported needs to be understood from a system perspective.
Global organisation with similar products produced in several places around the world	– The system should support easy mantenance of identical documentation in different languages. – The system should address the variety of competences, for example, literacy, of employees available in differenct countries. – The system should take into account different cultural backgrounds of employees from different countries.
Planned application areas included training, orientation and support	– Learning oriented functionality is needed in addition to support functions.
Case B&O	
Observations	**Requirements**
A very complex and difficult new product, involving new materials, tools and methods.	–

A new production line.	–
The company has a very democratic work community.	– A support system should facilitate end-user feedback. – The system could be used to collect ideas and recommendations directly from production.
There is high seasonal fluctuation in number of orders for the product.	– Both regular and temporary staff should be supported.
The company has a design-focused approach to production.	–
The company has a need for improved documentation of task execution methods.	– Authoring and changing content has to be easy.
The system was to be used for task documentation, training and support.	– Learning oriented functionality is needed in addition to support functions.
Computers in work sites were running other pieces of software with several operating systems.	– Work site computers have to have sufficient computing power. – The software used has to be compatible.
The reader users were not experienced computer uesrs.	– A support system should be very easy to use. – Training in computer use and the concept of knowledge support is needed.
The author users were production planners and experienced computer users.	–
Case Task Supporter	
Observations	**Requirements**
The system was mainly purchased to support complex lightweight assembly tasks	– Characteristics of these tasks should be taken in account in system design.
The tasks, the system was purchased to support were subject to frequent revisions.	– Content should be easy to maintain and update.
The task supported in the case studied mor closely was very complex and demanding complete-build end-assembly task with a phase time of 30-45 minutes.	–
Information environment of the task supported was complex with three corresponding sources of supportive knowledge.	– A system perspective is needed and all the sources of information should be addressed in addition to the computer based support system.
Details of task execution methods were constantly changing	– Support has to be delivered directly to work context. – Content should be easy to maintain and update. – A support system should inform its users of topical content changes.
Upkeep of paper-based documentation had proven cumbersome and slow.	– Content should be easy to maintain and update. – Information content should be kept up-to-minute.
Static electricity caused by paper documents had caused problems with electronic components.	– No paper should be used in work sites.
Official work method documentation had been supplemented with personal notebooks containing keypress-level instructions on computer system use.	– Usability of all the computer systems used in production is important. – Actual information needs of the shop-floor employees shouls be identified and addressed by a knowledge support system.
Reader users were mostly middle-aged women with basic education only and some experience in using computers.	– A support system should be very easy to use. – Training in computer use and the concept of knowledge support is needed.
Author users were production engineers and experienced computer users.	–

Computers in the work sites had also other pieces of software running. Disturbances in these systems complicated work tasks considerably and influenced employees perception of all shop-floor computer systems.	– Work site computers have to have sufficient computing power. – The software used has to be compatible. – The computer system environment should be addressed as a whole.
Case ISS	
Observations	**Requirements**
Complete-build end-assembly of an existing product family of complex products with several variants.	–
Production was transferred from an assembly cell into a totally new assembly line.	–
The new line severed the natural communication channels of the assembly cell.	– The system should support communication in addition to task execution.
Assembly-line employees were communicating both with their colleagues and people from	– The system should support group and organisational communication in addition to task execution.
The company had very low turnover of personnel.	–
The information environment was very complex, consisting of 12 major sources of task related information	– A system perspective is needed and all the sources of information should be addressed in addition to the computer based support system.
New employees were recruited on a regular basis.	– Training of new employees could be supported by the system.
Most employees were brought in through a half year training course.	– The system could be used in the training course.
Employees' tasks were not limited to end-assembly, but included also pre-assembly and repairs.	–
Paper-based documentation was causing several kinds of problems, they were often out-of-date, easily lost, on the way or too far. (see, for example, Hailikari & al. 2000)	–
	–

Enclosure 3: Critical factors in the cases studied

Case ABB	
Results and observations regarding implementation	**Recommendations**
Navigation arrows had to be redirected to reflect assembly line workers' perception of the structure of the task supported.	– User interface and knowledge structure should be compatible with users' mental models of the task supported.
Timely authoring and upkeep of the information content caused problems. The tasks changed rapidly and the authors were not experts in tasks supported.	– Knowledge content authoring and upkeeping procedures and functions should be easy to apply. – Enough appropriate resources with authoring and subject matter expertise are needed.
Resistance to change was very low, possibly partly due to Hawthorne effect (see Mayo 1945) and an unexceptionally participatory development process.	– Participatory development methods should be used in knowledge support system development.
Only some 20-30 minutes of training was needed even for totally inexperienced computer users.	– Careful design of user interfaces and usage processes in needed.
All users preferred using the ITSS prototype instead of paper-based instructions, assuming that the information in the system is up-to-date.	– Content has to be kept up-to-date.
Results and observations regarding use	**Recommendations**
Both novices and old hands used the system but in a different way and with different intensity.	– A support system should provide appropriate support for both novices and experts. – User interface design should take both novices' and experts' competences into account.
Only those parts of the documents were used that focused directly to users' tasks and goals.	– The primary content of a support system should address the tasks and goals of the users.
Detailed instructions were used the most, as people checked details they were uncertain of.	– The system should provide the level of detail required (often deeper than in traditional paper based task documentation). – User interface should allow users to locate required detailed information with minimum effort.
While pictures were the primary information source, but some preferred starting from text.	– Both pictures and text are needed in order to support different users.
Composition of pictures affects understanding of information. If, for example, the colour of a part on the screen was different than the part at hand, people often thought that they had made a mistake and the work was halted. What is more, pictures were to be carefully cropped to include only essential material and taken from the same direction the employee sees his or her work.	– Composition and upkeep of pictures requires special attention. – Uniformity of the real (work site) and virtual (support system) environment is essential.
Younger men felt they knew how to do their job and did not use the system as much as the rest but made more mistakes than the women using the system.	– Gender differences should be taken into account in support system design and user training. – Employees should be allowed access to the system without losing their "coolness" in front of their peers.

Most of the information needed still came directly from the supervisors and product designers, not from the support system.	– All sources of information, not just the computer system, should be taken into account in comprehensive support system design (systems thinking). – The information needs of the tasks supported have to be identified and included into the system.
All users needed additional information and help from other people during first assembly of a product.	– A comprehensive support system should facilitate interaction and communication in addition to task execution.
There were inaccuracies in the textual or visual information content.	– Quality assurance practices should be included into the authoring process. – A spontaneous feedback system is needed.
With the first prototype versions of the system users got easily "lost in cyberspace".	– Content should be organised to reflect users' mental models.
Pages describing main work phases confused users if they contained detailed pictures.	– Picture and text should be equally detailed.
People mostly followed the pre-defined routes through the material even when they were free to browse the material at will.	– Defining pre-defined routes for hypermedia documents is a serviceable practice.
Information content of the system was not always up-to-date.	– Content maintenance processes have to be streamlined to make them as timely and practical as possible
Case B&O	
Results and observations regarding implementation	**Recommendations**
A support system can be used as a training tool and to document production methods.	– Requirements of potential secondary application areas like task training should be taken into account in system design.
Production testing is the best time to author the first version of the support materials. Before the task is still changing too much, but soon after production testing the system is already needed for task training.	– Optimal timing of authoring of the first version of support content should be given consideration.
A support system can facilitate assembly line workers' participation in production method development. Assembly line workers can author very useful support material.	– Authoring tools should be easy to use and available to end-users. They are the experts in the tasks supported, after all. – Reader users require authoring tools and editing rights to the knowledge content.
The quality of the still-video pictures was considered to be poor.	– Good quality still-video equipment is to be used. – Author users should be trained in basics of photography. – Sufficient lightning needs to be arranged when pictures are taken.
There were no connections to other software systems, but they would have been useful.	– Information systems used should be open and interoperable
Mouse was not fast or easy enough, and a food pedal was considered.	– Other control devices need to be considered. – User interface should be designed to minimise complicated mouse operations like double-clicking.
The first testing versions of the software were not stable, which had an impact on the initial attitudes of the staff.	– End-users have to be aware of the phases of the software development process.
Experienced users have to familiarise newcomers to computer systems used in production, including the support system.	– Experienced employees could be given basic training. – A special training work site with all the computer systems used in production could be useful.
Results and observations regarding use	**Recommendations**

Both novices and old hands used the system but in a different way.	– A support system should provide appropriate support for both novices and experts. – User interface design should take both novices' and experts' competences into account.
About half of the staff likes to keep the system on while working. The other half feels that they know the tasks so well that they do not normally need support. Some experienced employees used the system to remind them of problematic task details.	– Potential different ways to use a support system should be identified and taken into account in design.
Workers with reading disabilities were employed and supported with the system.	– Needs of disabled workers should be taken into account in user interface design. – Sound should be available in all work site computers so that people feel that everyone is treated equally.
The system was used particularly, when task descriptions had been changed or the user was uncertain of correct work method.	– The system should indicate when documents have been changed. – Locating needed pieces of information should be easy and fast.
Users would have wanted a function that would have correlated users and content revisions, indicating, which pieces of documentation had changed since the user last had used the system.	– The system should indicate when documents have been changed. – The user needs to be tracked when he or she uses the system.
Authoring required about twice as much time as writing corresponding paper documentation	– Authors need more time.
Document maintenance increased as the documents contained more material.	– Enough appropriate resources with authoring and subject matter expertise are needed for authoring and content maintenance.
Updating of digitised speech was sometimes neglected.	– Different media elements should be used only when needed. – All media elements have to be maintained.
Finding the correct piece of information was easy and fast.	–
The system was considered slow in authoring use.	– Appropriate computer equipment should be used. – Time-critical components of software should be identified and optimised.
The system was considered superior to paper-based support arrangements.	
Users would have liked to zoom into some of the pictures.	
Use of still-video-camera (Canon ION) and graphics software was considered cumbersome.	– Tools to be used in authoring should be selected carefully.
Case Task Supporter	
Results and observations regarding implementation	**Recommendations**

Most implementation of the system had failed due to various reasons: – Responsibilities not defined. – Lack of a dedicated change agent. – Failure to understand shop-floor information support needs. – Lack of proper authoring personnel resources. – Incompatible computer technologies. – Unsatisfactory usability. – Turbulent business environment. – Slow tailoring of the product. – Lack of cooperation between end-users and developers.	– Responsibilities need to be defined and a change-agent chosen. – A change agent is needed to actively drive the concept forward. – Enough appropriate resources with authoring and subject matter expertise are needed. – Information systems used should be open and interoperable. – Usability of all the user interfaces of a support system should be stressed. – A support system should be easily tailorable to the evolving needs of client organisations. – Interaction between end-users and developers in order to understand actual needs.
Results and observations regarding use	**Recommendations**
The system was not trusted, as the information content was often out-of-date. Other sources of information were better kept up.	– Content has to be kept up-to-date.
The expected content updating procedures required some paper-based bureaucracy which slowed down the process.	– Content maintenance processes have to be streamlined to make them as timely and practical as possible.
The system did not provide all the information needed.	– The information needs of the tasks supported have to be identified and included into the system.
The system was not used by all employees in expected levels, and some preferred paper-based documents that were more up-to-date.	– Content has to be kept up-to-date.
The other components of software running in the work site computers caused often disturbances.	– The components of software used should be compatible and reliable.
The reader users considered the system easy to learn but boring and rigid.	–
Usability of the authoring functions was bad.	– Usability of all the user interfaces of a support system should be stressed.
Case IIS	
Results and observations regarding implementation	**Recommendations**
Not all the employees trusted computers	– End-users need to understand, how information systems work and why they sometimes fail. – Transparency and reliability of the system need to be emphasised in its design.
Some users showed signs of "computer phobia".	– End-users should understand, how information systems work and why they sometimes cause emotional reactions in users.
People were afraid that the support system would automate task performance too much or reduce employees' ability to remember important things by themselves.	– Design of the system and its use should facilitate learning. This focus should be communicated to the users.
Looking at the screen was found to be laborious	– Screen quality should be good. – User interface layout; clarity and usability require particular attention.
ISS was often down during the implementation phase, causing distrust.	– End-users have to be aware of the phases of the software development process.

Some of the end-users felt that they would have required more training. Some of the employees did not even know how to turn the computer on! On the other hand, some felt that time should not be wasted on training.	– Training is needed. – End-users' capabilities to use the new information system should be evaluated.
Results and observations regarding use	**Recommendations**
Combination of voice and picture were considered easier to use than the instructions with text and picture. None found the combination of text and picture uncomfortable to use. (Repokari & al. 1999)	– A support system should facilitate flexible combination of different media in support material.
All users preferred the support system over the paper-based system due to easier use and access to right information.	–
Some essential information was missing from the system, and the employees had to turn to the old documents to find the information.	– The information needs of the tasks supported have to be identified and included into the system.
Computer-based work method documents were considered easier to maintain and manage than paper-based documents.	–
The system was considered easy to use and learn. (Repokari & al. 2000b)	–
After some experience using the system, the users considered it somewhat slow. (Repokari & al. 2000b)	– Appropriate computer equipment should be used. – Time-critical components of the software should be identified and optimised.
Introduction of a knowledge support system does not have negative effects to the reader users' mental workload. Particularly tiredness was moderately reduced. (Koskinen & al. 2000b)	–
The system has allowed expansion of the employees tasks. (Koskinen & al. 2000b)	– Introduction of support system should not be seen as a separate act but as an essential element of a more profound reorganisation of work and organisation.
Time required for changes in knowledge content of support material was considerably reduced by the introduction of the support system.	

Enclosure 4: Outcomes of the cases studied

Case ABB
– No paper documentation was needed in production. – The system was used to replace paper-based ISO 9001 documents. – Quality declined when the system was off-line. – Centralised management and upkeep of work method documentation became easier. – It became possible to transfer people from one task to another in a moment's notice. – The support system eased moving the whole line and the work practices to Germany.
Case B&O
– The employees working on the line started actively editing and commenting the information content of the system. The people responsible of the work method design considered the material most useful. – The system suited well for training of new employees, who were able to practice without stress and embarrassment. – Time needed for traditional training during ramp-up 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. – 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. – The support documents were more detailed and up-to-date than traditional paper-based documents had been. – Authoring of support documents took more preparation and task analysis and twice the time than making of paper-based documents. – Computer based support documents needed more upkeeping, as there was more material to maintain. – An obstinate quality problem was solved partly through systematic use of the support system. – The system eased task and task phase time analysis. The production planners responsible for the analysis did not have to trouble actual production as much as the information needed was available in the system. – The quality (consistency and timeliness) of the documentation improved.
Case Task Supporter
– Reader users became more willing to use computers than before and felt that their computing competences had improved. – Influences to mental workload were mainly positive, but the observed improvements (employees felt that tasks had become easier and more variable, and that they were more brisk and enthusiastic) may have been caused by other changes in the work environment.
Case IIS
– The authors considered the multimedia documents easier and faster to update and maintain than paper based documents. – In the early 90s, updating the support material took an average of 235 minutes. In the mid 90s 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 (Koskinen & al. 2000a) – Multimedia-based support was easier to use and needed information was found faster than the paper-based support system. – The support system solved many practical problems related to paper documents. Papers had often been either in the way or too far or even lost. – Effects on mental workload were slightly positive, but not remarkable. The tiredness dimension had improved moderately. Employees felt that the system had made the tasks easy to carry and considered the system to be comfortable (Koskinen & al. 2000b)

Study 1

Eloranta E., Mankki J. & Kasvi J.J.J. (1995) Multimedia and Production Management Systems. Production Planning and Control, 6(1), 2-12.

Study 2

Kasvi J.J.J., Vartiainen M., Pulkkis A. & Nieminen M. (1997) Information tools for the shop-floor. AI & Society, 10(1), 26-38.

Study 3

Kasvi J.J.J., Vartiainen M., Pulkkis A. & Nieminen M. (2000) The Role of Information Support Systems in the Joint Optimisation of Work Systems. Human Factors and Ergonomics in Manufacturing, 10(2), 193-221.

Study 4

Kasvi J.J.J., Vartiainen M. & Hailikari M. (2003) Managing Knowledge and Knowledge Competences in Projects and Project Organisations. International Journal of Project Management, Accepted for publication.