WORKING PAPER

DESIGN OF WORK ORGANIZATION AND
TRAINING DURING THE IMPLEMENTATION
OF ADVANCED INFORMATION TECHNOLOGY

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FOREWORD

It has been commonly recognized that training and education are success factors of advanced production automation systems. There are, however, only few answers to the questions of how to train personnel during implementation and change, how to educate trainers, or how to educate planners and managers.

As a part of the collaborating network of the IIASA CIM-Project, several case studies have been carried out in Finland, where design and training methods were assessed during the real implementation process and new training methods were used and tested as a part of the real design process. This paper presents the results of case studies assessing the training and psycho-sociological impacts of the information systems and it also provides practical guidelines and procedures for training problems. The paper gives a valuable insight into this important topic.

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1. INTRODUCTION

The connections between man and advanced information technology have been studied from several frames of reference. Sociologists have been interested in the development of the qualifications of people during the course of technological development. The effects of advanced information technology on the health and well-being of man have been studied by stress researchers. Organizational psychologists have analyzed the impact of organizational decision-making on the implementation of information technology in work processes, and ergonomists have tried to develop man-computer interaction as much as possible from the viewpoint of productivity and the well-being of man. Also, a more comprehensive orientation of system ergonomics has lately been adopted in studies concerning the connections between man and advanced information technology. The results of these studies have shown that several factors affect the success of the implementation of advanced information technology.

The role of work organization with regard to the consequences of computerized work has been emphasized in several studies. Organizational decisions or strategic choices of management have been shown to affect the success of a newly computerized work process. And some studies (e.g., Buchanan & Boddy, 1984) have demonstrated that these factors can be much more influential than the technology applied.

On the other hand, the success of the design of the man-computer interface has been considered to be an essential characteristic affecting the usability of advanced technology in the work process. The design, and especially the integration of the knowledge of the end users or the knowledge on the work of the end users in the design phase of the technology, determines to a great extent the properties of the man-machine interaction. According to Norman (1986) three kinds of special knowledge are needed to design an interface, namely: knowledge of design, of programming and of technology; knowledge of people, of the principles of mental computation, of communication, and of interaction; and third, expert knowledge of the task to be accomplished. Analogically it can be said that the implementation of advanced technology requires knowledge of the production process to be changed, knowledge on the activities of the workers, including work division and other characteristics of work organization, and knowledge on the technology.

The third important factor affecting the success of the use of advanced technology is training. Wexley (1984) estimated the effects of technology on training requirements. He forecasts that, e.g., office automation causes a need to retrain office workers at least five times in their careers. The need for retraining and continuous training has also been strongly emphasized in the industrialized European countries in the 1980's. For instance, in Finland some of the largest and technologically most advanced organizations have publicly discussed the requirements for retraining or announced the establishment of training programs applying the principles of continuous training for the whole personnel. But the recognition of the importance of training for the development of the work process also gave rise to questions concerning the adequacy of the existing training systems (e.g. Goldstein & Gessner, 1988).

In a research program on "Information Technology and Work Organization", conducted by The Technical Research Centre and the Institute of Occupational Health in Finland and supported by the Finnish Work Environment Fund, the connections of design and implementation of technological change, work organization and well-being of the personnel were studied in the engineering industry, the paper industry and in the banking and insurance business. Technological change consists of at least six critical phases:

a) Predesign of the production system or its change;
b) design of the production system or its renovation;
c) realization of the plans;
d) training of the personnel;
e) start-up of the system; and
f) the steady use of the system.

In the research program on "Information Technology and Work Environment" the predesign and design phases of technological change were studied through interviews of the designers participating in the projects under study. Training systems were studied through observations, interviews and analysis of the training material. The start-up of the systems was not studied as such. The steady use of the system was studied from the viewpoint of its consequences on the well-being of the workers. The aim of the research program was also to develop methods to support a successful implementation of the advanced technology in the work process. Developmental programs or training interventions were conducted in the paper and engineering industries.

2. DESIGN AND IMPLEMENTATION OF ADVANCED TECHNOLOGY

2.1. Predesign of the Production System

When a new production process or a change in an old production process is planned, the goals and reasons for a new process are given first. In the research program the goals and reasons for the renovation of a paper machine, the production of gear wheels, and the introduction of a micro computer based work station were studied in the "production" of insurances. The basic reason for the renovation of the paper machine studied was the fact that a twenty-year-old paper machine had to be renovated, because its maintenance costs would otherwise have been intolerably high. In this situation also the forecasts of the future markets of paper products were examined. In the mid-1980's the forecasts promised a 2-3 per cent increase in the use of newsprint and a 9-10 per cent rise in the use of fine paper. The marketing forecasts therefore supported the change-over from newsprint to fine paper. The change in the products meant that most of the critical parts of the paper machine had to be renovated, and an automatic controlling system was needed to control more precisely the quality of a more demanding product (Leppänen et al. 1988).

In the production of gear wheels the benefit gained from the installation of FMS was mainly supposed to be connected with the increase in productivity through the increase of capacity, the decrease in lead times, and the increase in volume flexibility. It was also assumed that a more advanced production technology would improve the quality of the products. Also a reduction in the number of workers needed was expected (Norros et al. 1988). In an insurance company the aim of developing a more advanced information system was mainly an improvement of the client service. The realization of this goal also meant changes in work organization. Formerly the work in the life insurance department had been divided so that one clerk executed the input of information into the data base, and the other made the decisions concerning the admission of the insurance or compensation on the basis of an insurance. After the technological change, one clerk was expected to handle both of these tasks (Vitikkala & Huuhtanen, 1988).

In the industrial cases the production goals and technological facts guided the predesign of the renovations. Organizational goals were not planned or even discussed, except for the need to reduce the work force in the metal industry. In the financial services the goal of the change was an improvement in the quality of service. This goal was seen to be reached through the reorganization of work.

The predesign of technological change also includes the decision concerning the realization of change. As is usual in organizational decision-making, both the expenses and the time available for the investment were reduced. Therefore the possibilities to include unforeseen topics, e.g. work organization and training, in the design of the new production system were diminished. According to the legislation in Scandinavian countries it would, however, be necessary to analyze the effects of work on the health and the well-being of the personnel already during the design of the technical system. Some cases (e.g. Daniellou, 1988) have also shown that at least the goals for the work characteristics can be set in this phase of the design process.

2.2. Design of the Technological System

The time needed to realize technological systems or their changes in all production branches studied is relatively long. E.g., the modernization of a paper machine will take from twelve to fifteen months. This means that there is enough time to make decisions concerning the division of work and the training of the personnel. The long duration of the design period also reflects the possibility to use participatory design methods in order to utilize the knowledge of the production personnel in modelling the production process for the so-called "driving practice" discussions, or for the examination of the usability of the system during its design. In the cases studied the change was, however, regarded as a technological phenomenon. According to the analysis, the design of the implementation of technological change was characterized by:

1) Haste. As both time and money available for the investment were reduced after the predesign, the technical design was done in a hurry, which meant that the decisions were not always very carefully considered. Tight schedules in the design also meant that all technical resources were bound to the technical design, and it was not possible to analyze various decisions from the viewpoint of the whole production system.

2) Lack of co-operation between the design and production personnel. Participation of the production personnel in the design of a new production system varied greatly in the three branches studied. In the paper mill the production personnel kept the old process during the design of the new system, and did not participate in decision-making with regard to the system. As a result, the automation system producer made the decisions concerning the interface. Thus, after it had been put into use, several corrections and renovations had to be made to the interface. The differentiation between design and production also diminished the learning possibilities of the production personnel. Participation in the analysis of the developmental needs of the work process, and their realization, has been considered to be one of the most effective ways of learning or, at least, of arousing interest in the new production system.

Also in the engineering industry the realization of the design of FMS was quite conventional. The participation of the users was representational, which means that the representatives of the labor union were in the project group (Norros et al. 1988).

In an insurance company the responsibility of the project aiming at the renovation of the life insurance system was with the user organization (Vitikkala & Huuhtanen, 1988). The design project, however, took place at a high level in the organization, although the management of the organization assessed that the end users participated in the design of the new system more than in other projects related to the implementation of advanced information technology in the organization. These results reveal that, although participatory or user-oriented technical design has been recommended in several articles and textbooks, it is not very widely utilized. There are several reasons which may hinder the use of participatory approaches in the design and implementation of advanced technology. These are:

a) Lack of knowledge. The end users or the production personnel are not specialists in the terminology of information technology, and cannot participate adequately if the language of the designers is not translated into their language. On the other hand, the organization and the designers of advanced technology are not specialists in the methods of participatory work design.

b) Attitudes. To a certain extent changes in work life always include the question of power. Participatory work design methods can be seen as a threat to the existing hierarchy of power in the organization as has been shown by Klein (1984). According to her study, especially the first-line managers resisted employee involvement. They felt that employee involvement programs are good for the employees, and even for the companies, but they did not consider them to be good for themselves. The reasons for this attitude were different for different groups of first-line supervisors. According to Klein the status seekers resisted employee involvement, because they enjoyed the prestige of being the boss, and felt that they lost something while participating in, e.g., quality circles with workers. The skeptics thought that worker participation means only talking, and not real action. They also felt that participatory work orientation is some kind of a trick of the upper managers, who do not, however, support the whole idea. Equality seekers resisted worker participation, because they felt that it happened at their expense, and they wanted more involvement for themselves. The deal-makers who were accustomed to base their power on making one-on-one deals with the workers according to the rules of "divide et impera" felt that they did not have any mechanisms of influence after the worker participation came to use. One group of supervisors resisted employee participation on the grounds of the known X and Y theory by McGregor, which roughly says that there are two kinds of people: those who can think, and those who cannot think, and must therefore be programmed in detail.

The attitudes of technical designers and supervisors towards employee participation in Finnish organizations under technological change were not studied in detail during "The Information Technology Project". But the interviews and observations of the designers and some supervisors revealed that resistance towards worker participation existed also among Finnish technicians and engineers. It was also an interesting to find that the higher the status of the manager, the less he expressed resistance towards worker participation. On the contrary, the high-level managers tend to think that the activation of workers to develop production processes is a very important goal. The lessons from Japanese quality circles have achieved their goal everywhere!

c) Laboriousness of the participatory design methods. It has been assumed that participatory design methods would be easy and quick to use. But in reality participatory methods, such as modelling of the work process, mock-ups and simulations of the work process, are laborious and time-consuming methods, at least where information technology is applied to large production systems.

3) Decisions on organizational structure, work division, and the contents of work are not considered as a part of the planning process in the implementation of advanced information technology. Therefore the organizational structure is handled as given, partly because work division, manning of the production process, and task descriptions are subjects requiring negotiations between

the employer and the employees. The conclusion of an agreement on these subjects is sometimes troublesome and sluggish, and therefore the decisions are postponed.

The organizational decisions made in connection with technological change have often only meant reductions in labor force. Therefore the attitudes towards organizational decisions are not very positive, and there is a tendency to maintain the old organizational structure. But the adequacy of traditional organizations ought to be always revised in new situations. E.g., in the chemical wood processing industry, the organizational structure dates back to the times of craftsmanship. Workers start from those tasks which are considered to require very humble or no professional skills, and they proceed from task to task until they reach, at the age of fifty, the job considered to be "the most qualified". This kind of career development was necessary when the basic education was poor and professional training did not exist. Nowadays the workers coming to the pulp and paper industry have a nine-years' basic education and a two-years' professional training in paper making. But the organizations in which they work are traditionally organized. This situation is frustrating, because the workers cannot use their knowledge, and when it is not utilized, one may ask how much of it will be left when they reach the "highest level".

The rapid changes both in the products and in the technology used would also require such organizations which utilize and increase the professional qualifications of the personnel. Complex systems require the cooperation of several workers, and therefore also a comprehensive conceptual understanding of the production process. In order to update and maintain this knowledge, systems are needed in which the workers have the opportunity to use their skills and to acquire new ones. This means flexible organizations, change of tasks and continuous training of the personnel. In complex production systems the strict boundaries between design, production and maintenance personnel are also an obstacle to the continuous development of the process.

2.3. Training of the Personnel

A problem which often arises in connection with the implementation of advanced information technology concerns training. Especially the experiences with training in the use of office automation have been poor (see, e.g., Kalimo & Leppänen 1987). In the industry the attitudes towards training are nowadays mostly positive, but training is not always adequately organized. In the research program "Information Technology and Work Environment" the training of the personnel in projects aiming at the use of advanced technology was studied by interviewing the designers, analyzing the training programs, and observing the training process. These methods revealed several problems in the training related to the implementation of advanced information technology in the chemical wood processing industry.

1) A comprehensive conceptual understanding of the complex system is needed to be able to work adequately. Training should create a comprehensive conceptual model of the production system. Usually, however, the training programs were simply piles of paper and the representatives of the producers of the different parts of the technical system spoke about the characteristics of their devices. The trainers were unable to integrate the phases of the production process, and this led to a fragmented picture of the production system and the overall functioning of the work process.

2) The training of the workers for the automatic operating system was cursory and inefficient. The technical aspects of the system were overemphasized. Instead of teaching people how to use the automatic system as a tool in their work, various technical details, with which the users had nothing to do, were discussed. Theoretical knowledge about the equipment or the process was not given. For instance, rules of thumb were given for the control of the automatic operating system instead of the logic of its functioning. Theoretical knowledge on the functioning and interrelations of complex systems is, however, a prerequisite to mastering the process in every situation, including rare disturbance situations.

3) The training methods were inappropriate. Lectures were used as the main teaching method. Although simulations have proven to be effective in teaching people to use all kinds of devices including computers, the simulations in the projects studied were not adequate, nor were they adequately applied.

4) The expertise of the original organization was not utilized in training.

5) The trainers were inexperienced and they were not acquainted with the methods of adult education. This proved to be a weakness which led to the above-mentioned problems. As the trainers were unaware of the principles of learning and adult education, they were unable to plan training programs that could function.

The pulp and paper industry is not the only industrial branch having problems with training. In another Finnish study on work in flexible manufacturing industry (Vartiainen 1986) the FMS operators assessed their training as being too narrow. They found that the training did not give them enough skills in work planning, programming and understanding the structure of the system. The operators estimated that a suitable training period would be between two and six months. Also, the training program ought to include programming, maintenance, measurements, pre-setting, operating the system and machines, and manufacturing bodies according to technical drawings. The operators also found that in addition to vocational school education, specific FMS training as well as training with the equipment used in practice was needed.

3. ALTERNATIVE TRAINING CONCEPT

The training problems arose mainly from the conceptual and methodological problems of adult education. The only effective training method has been considered to be either direct class room lecturing or, at the other extreme, transmission of attitudes, misunderstandings and rules of thumb from one person to another. Both methods are roughly speaking based on the concept that there are different kinds of people. Some people can think and teach others. The others are not capable of theoretical thinking, but need continuous guidance from those who can think. It has also been assumed that the latter type of people are not at all interested in "boring theory", and need only transmission of the practices and tricks developed by some theoretician somewhere. McGregor (1960) has described this concept about the characteristics of human beings in his well-known X & Y theory.

Alternative approaches to professional training have been developed lately. In the project on "Information Technology and Work Environment" a training concept based on Vygotsky's theory of the development of the behavior of adults was adopted. This training concept has been developed by Finnish researchers (Toikka et al. 1985, Engeström 1987). This concept, called "developmental work research", determines the formation of new kinds of (work) activities, from the analysis of the historical development of today's activities to the analysis of the actual activities. The next phase of development is the formation of new instruments for the activity. This means the formation of both abstract instruments, such as mental models of the work process, and concrete instruments, such as the interface of the man-machine system. In the third phase these new instruments are applied to the activity through strategic tasks. In the fourth phase a new type of activity is again evaluated to continue the development.

It is essential in this kind of training that the trainees are the source of activity. Learning through analysis and modelling of a work process requires the participants to construct a functional model of their work process consciously through discussions. The function of the trainers is to create tasks that proceed logically, so that the analysis and models created in the previous phases of training can be used during the creation of more complex functional models. The trainers must also ensure that the most advanced theoretical knowledge on the phenomena essential in the work process under study is available during training. Otherwise possible misunderstandings may prevent the creation of a theoretically correct, knowledge-based model of the system. As a result of the creation of the models, a more developed work process will be shaped. This, however, requires that the developmental needs of the work process are analyzed and that solutions are created for them. The new ideas created for work development must yet be realized.

This concept was applied in the training of the operators of FMS during the design of the system, and in a paper mill after the start-up of the system.

3.1. The Case of the FMS Operators

In an engineering plant producing gear wheels training was started in the design phase of the system. The researchers assessed that training based on the concept of developmental work research would contribute both to forming user qualifications, and to FMS design (Norros et al. 1988). To form qualifications for mastering both normal work situations and disturbances, as well as optimizing the system, a three level model hierarchy was developed. The first level comprised performance models, i.e. algorithms for different operative situations. It was considered very important that the models be consciously formed in order to create and change procedures during different situations. System level models therefore became necessary. This means that the system elements and their interactions were analyzed. But there were no system models corresponding to the users' needs. The aim of the training was, however, to teach the users to create the models they need in the operations. Consequently, a third level model was constructed. Through analyzing the essential changes in the economy, technology and social organization of work during the development of work activity, the elements of FMS and the complex interactions between them were clarified.

As a result of this training, for instance a critical design error was revealed during a simulation task in which the optimal operating strategy was tried to be established for a rather typical production situation. The simulation was made using the lay-out model of the system and the model of the central control. The users had had their first contact with the central control in operating the system the previous day. This task revealed that the three groups of operators weighted optimality criteria differently or did not always consider all the criteria. During the discussion it turned out that the strategy that appeared optimal (maximizing system load, minimizing transportation of pallets, minimizing settings) caused a system disturbance due to a particular specification in the central control regarding the handling of empty pallets in the system.

The reason for this problem was that in an earlier design phase the question was considered as a technical detail among others, and the system engineer did not see the significance of this detail for the system functionality.

Two solutions were suggested. The problem could have been eliminated by changing major principles of handling the pallets. Another possibility was a partial solution that would leave some restrictions to be taken into account in operation.

The researchers assessed that the partial solution was more likely to be put into effect, because it required less resources. The case demonstrated that considering the design solutions from the operational viewpoint reveals solutions that have to be reconsidered. The case also showed that the later the interaction between design and operation is established, the more restricted are the solutions that can be adopted.

3.2. The Case of the Personnel of the Paper Machine

In the paper mill a training intervention was started to improve both the work and the workers' qualifications after the start-up had been a failure, partly due to inadequate and insufficient training.

The training program organized by the research group was realized in the winter of 1986-1987. The program consisted of 100 hours, which were distributed over six two-day periods. The trainees were the workers and foremen of all five crews. Also the operating engineer and the department supervisor participated in the training program. Two or three crews participated in the training at a time, which meant 14-20 participants per session. The training program included five main topics, namely: principal model of work activity; historical phases of paper making; model of newsprint production; model of fine paper production; and construction of an improved work process. In this case a model of newsprint production was necessary, to point out the differences in materials and machinery in newsprint and fine paper production.

The models of both newspaper and fine paper production were very detailed. The characteristics of products, raw materials and additives, and their interrelations were analyzed. A detailed model of the paper machine was constructed, and the functions of the main parts of the machine and the methods to control and operate the whole system were analyzed. The model concerning the work process also included a detailed analysis of work organization, division of work, and the tasks and professional qualifications of the posts of the personnel on the fine paper machine.

An essential part of the training process was the creation of proposals for the development of the work process. During the training program several problems and developmental needs in the work process had come up. The creation of proposals for developmental actions was started from these ideas. It was necessary to specify the reasons for the proposals. Therefore a special form was filled out, in which the specifications of a proposal were documented. In this document the following topics were also discussed:

- positive and negative consequences of the proposed action
- prerequisites for the realization of the proposed action
- who will decide the realization of the proposed action
- who will execute the proposed action
- timetable for the actions.

During the training sessions 63 developmental actions were planned. The majority of them dealt with five topics: tools, communication, division of work, work activity, and professional qualifications. Five proposals dealt with topics which do not belong to the groups mentioned above.

The extent of the proposals for the development of tools (N=20) varied greatly. The possibility to construct a hierarchical display system, starting from factors affecting usability and ending with factors important for the financial outcome of the process, was discussed. But also the possibility of maintaining the position of a single valve in the memory of the automatic operating system was seen as an important developmental goal. The latter developmental goal also represents those problems which result from the design of the automatic operating system. Altogether eight proposals concerning the development of the functioning of the automatic operating system were due to design errors. Three developmental needs referred to problems in the interface design. Five developmental proposals concerned technical characteristics of the paper machine, and four proposals represented totally new ideas, which came up during the analysis of the existing work process. These proposals aimed at developing an automation for product change in the process, the construction of a hierarchical display for quality and development of the foremen's job with the help of personal computers and other tools.

Communication is always a problem in continuous shift-work. Proposals for the development of communication (N=9) concerned both the improvement of the use of communication means already in use, such as various reports and notice boards, and the development of new ways and means of communication.

Eleven proposals concerned the development of work as an activity. The following developmental proposals were made: improvement of the technical development of the paper machine, rationalization and systematization of the development of the chemistry of the production process, improvement of cooperation between the production and maintenance personnel, and systematization in the clarification of production disturbances and errors.

Two developmental proposals concerning division of work were made. Seven proposals dealt with the improvement of professional qualifications through additional training. Ways to improve the organizational climate, and various other topics were discussed as well.

The results of this training intervention support the idea of participatory work design. The personnel of the paper machine made several developmental proposals concerning the paper production machinery. If adequate methods, like simulations, had been available during the design of the production process, the design errors could have probably been realized earlier. At least a careful follow-up system ought to be established after a start-up of complex production systems, as some of the problems cannot be noticed without the help of the real-life experience either in a full-scale simulator or in the actual activity.

The developmental proposals also revealed that a systematic analysis of the work process led to questions about the functioning of the process. These questions about the functioning of the raw materials and the machinery call for a discussion of their theoretical base. When the questions are elicited by the personnel and answered by the experts in chemistry, automation technology and machine construction, the theoretical knowledge about the work process increases. Also, proposals for the development of the whole work process as an activity are created. In this case the personnel of the paper machine made proposals concerning developments such as the experimentation of paper chemistry on the machine, developments in training during changes, as well as some other proposals which could not have be made if the production system had not been comprehensively understood.

4. CONSEQUENCES OF THE IMPLEMENTATION OF TECHNOLOGICAL CHANGE ON WORK ORGANIZATION AND CONTENT

The effects of technical change on the essential work characteristics have been studied in the "Information Technology and Work Environment" project during the different phases of the implementation of technological change. Work characteristics were studied through questionnaires and interviews of the personnel in the work processes under change.

4.1. The Case of the Paper Machine

In the paper mill the foremen and the workers of the paper machine assessed the work characteristics before and after the implementation of technological change and after the training intervention.

Work content

The variability of the work content and the possibility to utilize one's knowledge and skills at work are essential features from the viewpoint of the workers' well-being. The personnel of the paper mill stated at every phase of the technological change that they could really utilize their knowledge and skills at work. They also felt that their work demanded much thinking and decision-making. The work was also experienced as variable. After the training intervention the personnel of the paper mill felt that the work allowed them to use their knowledge and skills even to a greater extent than one year after the change (Leppänen & Auvinen 1988).

Autonomy

No statistically significant changes in the psychological autonomy of work occurred during the change processes. The state of the machines and the whole production process determine the work pace, especially during production disturbances. Work on a paper machine requires moving over a wide area, and the workers on a paper machine are not bound to their work site. After the intervention the respondents felt that they could move even more freely around the working area.

Social contacts and management

Social contacts between co-workers were assessed as being good, and no changes in these relations were seen during the training intervention. Also, the assessment of the managerial competence and other characteristics of the actions of the closest superiors was quite positive. But this varied during the technological change. Before the change and after the training intervention the personnel assessed their superiors as being more competent to organize and lead work and as being less supportive and helpful than one year after the change and before the intervention. It must, however, be noted that the opinions had merely returned to the same level as before the production change (Leppänen & Auvinen 1988).

Quantitative work load

Quantitative work load has been shown to be a stress factor in any work. In this study both the experienced sufficiency of the breaks as well as the clear overload situations were analyzed. The amount of overload experienced during the phases of technological change was also investigated. Quantitative overload was assessed to be more common one year after the change. Two years after the change (and after the training intervention) quantitative overload had diminished, and the number of breaks had become more sufficient (Leppänen & Auvinen, 1988).

Changes experienced in work characteristics in the course of the technical change

The personnel of the paper machine also assessed the changes in the work characteristics in the course of the technical change. Before the technical change they were asked to predict the changes in the work characteristics. After the technical change as well as after the training intervention they assessed the effects of the change on the work characteristics (Table 1).

Some changes occurred in all of the essential work characteristics during the technological change. The assessment of the changes in work characteristics before the change revealed fewer or smaller changes than the assessment of the effects of the realized change. The work characteristics dealing with the work content changed considerably during the technological change. The difficulty of tasks, the challenges of work, and the opportunity to use one's abilities had increased. These changes can be considered to be positive as regards the well-being of the personnel.

Also the number of working instructions had increased and the work pace had speeded up. An increase in work pace would be considered as a negative consequence had the study been made in piece production. But in an automatically controlled paper mill work pace is not a problem. On the contrary, lack of concrete work has been considered a problem in the process industry. Therefore the change in work pace is not a risk factor, but can, instead, help to maintain a satisfactory level.

Table 1. Assessment of the changes in work characteristics due to technological change before and after the change and after the training intervention. The left column describes the psycho-sociological characteristics for the work and the assessment is the subjective assessment by the operator. The numbers are percentages of the whole set of respondees.

		Decreases/ decreased	No change	Increases increased
Working instructions	I	5	27	59
	II	6	11	80
	III	6	10	82
Autonomous decision-making	I	2	73	18
	II	6	42	47
	III	5	44	44
Freedom to control one's work pace	I	9	91	-
	II	42	33	21
	III	29	53	14
Opportunities to use one's abilities	I	-	36	60
	II	6	31	60
	III	3	21	68
Difficulty of tasks	I	-	18	77
	II	-	19	78
	III	-	13	82
Work pace	I	-	14	82
	II	-	25	75
	III	5	15	77
Status of work	I	-	50	50
	II	3	56	33
	III	11	33	52
Challenge of work	I	-	36	60
	II	3	25	67
	III	3	24	71
Monotony of work	I	50	50	-
	II	39	44	10
	III	66	21	13
Pleasantness of work	I	5	41	50
	II	17	44	34
	III	8	36	54
Responsibility	I	-	36	64
	II	3	31	64
	III	3	41	51
Contacts with co-workers	I	-	73	23
	II	6	42	47
	III	3	46	44
	N	22	45	44

I = before change, II = after change, III = after training

The positive changes in the assessed pleasantness of work (increased) and monotony of work (decreased) are also a factor in support of the positive consequences of technological change on the essential work characteristics.

The changes in work characteristics were dependent on the total production change, which included changes in products, machinery and the control system. The impact of the automatic control system on work characteristics was therefore studied through direct questions. The attitudes of the paper machine personnel towards the use of advanced information technology in the paper production were very positive. The implementation of the automatic control system was considered to be a challenge.

Although the final results show that technological changes have had a positive impact on the work characteristics, the results also reveal that problems in design and training during the implementation phase caused problems regarding the quantitative work load and, according to the assessments of support and managerial competence, the work of the first line supervisors. The assessments of these work characteristics returned to a positive level after the training intervention, which shows that a comprehensive conceptual model of the work process decreases "trial and error" orientation and redundant work. A better understanding of the functioning of the work process decreases the pressure towards the first line supervisors in two ways. First, the supervisors are more competent in doing their work and there is no reason for complaints. And secondly, when the workers have a comprehensive mental model of the work process, they do not need the supervisors' help in minor details.

4.2. The Case of FMS

The assessment of work characteristics among FMS operators was studied by Seppälä et al. (1988). According to the authors, most of the operators of the old single-purpose machines were skilled metal workers who had a vocational education and an average work experience of more than ten years. Their jobs were rather independent, including machine set-up, measuring and inspection of the processed parts, daily maintenance of the machines and, to some extent, planning the succession of their own work. Although professional skills and experience were needed for doing the job independently, making a batch and operating the machine was a very repetitive and short-cycled task.

The jobs in the new production system consist of different and partly contradictory tasks from the viewpoint of skills and work demand. In general, operating a computerized flexible machining system consists of manual, repetitive loading/unloading tasks as well as of professional, more demanding tasks, such as planning, programming, tool presetting, disturbance removal, measurements, quality inspection and maintenance of the machines. In addition to the traditional knowledge of blueprints, materials, tools and metal cutting, new knowledge and skills related to programming and operating CNC machines and industrial robots must be acquired. Sc, in principle, the new technology offers good opportunities for a horizontal and vertical extension of the job. The question arises how the tasks of different skill levels are allocated or combined when the jobs are designed. In the case described here an operator or a group of operators is responsible for all the main tasks needed to run the system.

The FMS operators were also asked to assess the effects of technological change on their work characteristics (Table 2).

Table 2. Operators' opinions of the changes in job characteristics related to the new technology (n=8).

	Decreased	No Change	Increased
Qualification demands			
-Professional skills	-	-	8
-Decision-making	2	-	6
-Responsibility	-	1	7
-Difficulty of work	-	-	8
Autonomy			
-Choice of tools and methods	2	1	5
-Control of work pace	5	3	-
-Working instructions	1	2	5
Social contacts	3	5	-

All respondents shared the opinion that the demand for professional skills has increased. The majority of the operators felt that the qualifications associated with independent decision-making, planning and responsibility had increased. The challenges offered by the work, such as difficult tasks and opportunities for using one's abilities in work, were seen as being unchanged or having increased by all persons. Furthermore, a positive feature from the point of view of the psychological well-being was the fact that most of the operators experienced their work as more interesting, pleasant, and still offering opportunities for contacts with their fellow workers.

In parallel to these psychologically desirable characteristics, the introduction of new production methods has also brought forth some negative aspects. Even though the operators felt that the opportunities for choosing their tools and work methods had increased, some restrictions in the autonomy of the work were experienced. The opportunities for controlling one's work rhythm had decreased, there were also more rules to be followed, and the pace of work had increased.

The researchers (Seppälä et al. 1988) concluded that the results of their study supported the findings of other studies in the Finnish engineering industry as well as of other European studies. The deterministic predictions of a "collapse of work" or the de-skilling of work have not materialized, at least as long as the systems are rather new and still under development. On the contrary, the results confirm a conditional view. Job content, work demand and skills required are dependent on the job design and the management philosophy. The computerized technology enables the management to transfer the control and qualified tasks from operators to specialists and thus to create de-skilled and polarized jobs. However, there is an alternative model called "human-centered" or "skill-based" automation, which is not only more human, but also economically more profitable in the modern era of competitive, flexible and customized production.

5. DISCUSSION

Implementation of advanced technology into a work process is a complex act, the final results of which depend on the success of every phase of planning and realization of the plans. In the research program "Information Technology and Work Environment" both the design and the implementation of advanced technology and its consequences on work characteristics were studied in three branches of industry and business.

The results supported the idea that the design practice determines to a great extent the characteristics of complex man-machine systems. Rouse and Cody (1988) have stated that traditional design orientations have not been very successful from the viewpoint of man-machine interaction. The traditional design orientations have tried to enforce the design of man-machine systems to the matrix of engineering design (academic view) or have at least argued that the design of man-machine systems should utilize the same types of tools and methods as, e.g., aerodynamics (parity view).

The study on the renovation of the paper machine revealed that the design approach used was purely academic. According to Rouse and Code (1988) a central premise of the academic view is that there is a particular way to pursue design. Usually this means top-down orientation, both in the design organization and in the design of the man-machine system. In the design organization the individual designers take their portion of the problem, and are unaware of most of the goals of the whole project. After finishing their work, they bring the solution back to be integrated into the overall system. The goals of the whole process are given in technical and economic terms which have been later decomposed into functional requirements, and further into task descriptions. But, as a consequence, the parts designed can frequently not be integrated, and the allocation of tasks is not feasible as regards usability, reliability and the well-being of man. On the paper machine under study, both production and work characteristics took a negative direction after the unsuccessful integration of the parts of the design of the renovation. A training intervention, intended to bring the bottom-up orientation to the system through the development proposals made by the personnel, improved the situation, but one year too late.

In the design of a flexible manufacturing system in an engineering plant the knowledge and ideas of the end users were applied to some extent during the training of the personnel (Norros et al. 1988). The workers encountered problems in the plans and made corrections to them. They also assessed the consequences of the technological change on the work characteristics to be positive.

These two examples support the idea of participatory work design. A complex system must be analyzed from the viewpoint of work activity to ensure its functioning as a tool. Both, in the case of the paper machine and in the case of the FMS, the production personnel made several corrections to the technical production system. They also developed their work process as an activity by creating new systems for several critical production phases. But this kind of development requires the personnel to have a comprehensive mental model concerning the production process. And this means that the theoretical concepts must be learned consciously and in activity.

Positive results from these developmental or training interventions also support the idea that a multi-disciplinary orientation is needed to assure the adequacy of the technological change for the work process. In addition to technological expertise, knowledge is required on the work process and its related work activities, expert knowledge on the development of the work activity, as well as a human learning process.

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