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ABSTRACT

High tech systems not only generate new structures in the production process, but also involve profound changes in job organization, which in turn imply that job qualifications must be modified. In view of the changes within engineering systems and the relevant technologies, it seems expedient to choose a curricular approach based on the concepts of key qualifications and key contents. A model production system serves as a teaching plant at which students would develop company-specific key qualifications. The teaching plant is an assembly plant composed of six self-reliant, but networked learner subsections. A material flow is determined by the structure of production cells (micro view), and the plant represents the product-related production of a model car. To simulate the sequence of the production steps, beginning with the vehicle as ordered by the customer, the production planning system follows the normal company practice and includes elements of the forecasting phase and of production planning. The course provides for a training program in which faults within automated systems must be eliminated. The course covers three major categories of competencies: expert, methodological, and social. Instructional methods include team conferences, self-study of manuals, and group or cooperative learning. Production statistics serve as evidence of the performance in the learning process. (Contains 10 references.) (YLB)

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Theuerkauf, Walter E.

Development of High-Tech Skills

1. Introduction

The development of technical artefacts involves in nearly any field logic operations within data processing systems, with the microprocessor technology assuming a special role when it comes to automatic technological functions. Implementation proper is, however, not restricted to production processes in industry, but extends far into an individual's immediate sphere of life, and thus concerns not least of all her or his leisure activities. We encounter elements of automation both when handling a washing machine or a video recorder. Logic operations, automation, and rationalization are the factors that dominate technological change.

Automated process systems do not only achieve a high level of complexity in realizing, for instance, electronic functions; within the overall system they are equally interlinked with the full range of pneumatic, hydraulic etc. functions (sensor/actor). A closer analytical look at a specific process thus always reveals an interlinked system of the categories matter, energy, information. The system hence appears in the shape of a multi-dimensional competency-related structure. It is defined by functions (which may also comprise a set of sub-functions) and their behaviour, the logic between the functional units being characterized at their interfaces by input and output variables. How interdisciplinary interfaces within technological systems may be illustrated is shown in Fig. 1.

Fig. 1: Components of the technical processes (Blandow)

The technological development of computer-integrated systems, which have to be referred to as high-tech systems, did not only generate new structures in production processes. They also involved profound changes in job organisation, which in turn implies that qualification requirements need to be modified. This entails consequences for the teaching processes both at schools of general education and at vocational schools. The reflections made below in connection with how high-tech skills can be imparted will concentrate on on-the-job training and education, but can also be translated to vocational training schemes.

2. Changed system structures in production

Increasingly higher levels of mechanization on the basis of flexible automation technologies is a ubiquitous phenomenon in production, the present structures differing fundamentally from the transfer automation principle of earlier years. The characteristic features of computer-integrated systems can be outlined as follows:

Automated systems integrate a number of different processing steps in production processes, the transformation and automation processes thus automatically proceeding within larger areas of operation, e.g. within production cells or in processing stations.

The systems are controlled on the basis of microelectronic production/automation facilities, which - being programmable - reflect a high level of flexibility. As a result, also the extent and depth of automation and the degree of uniting processing steps has increased by forming functional blocks with the automation facilities.

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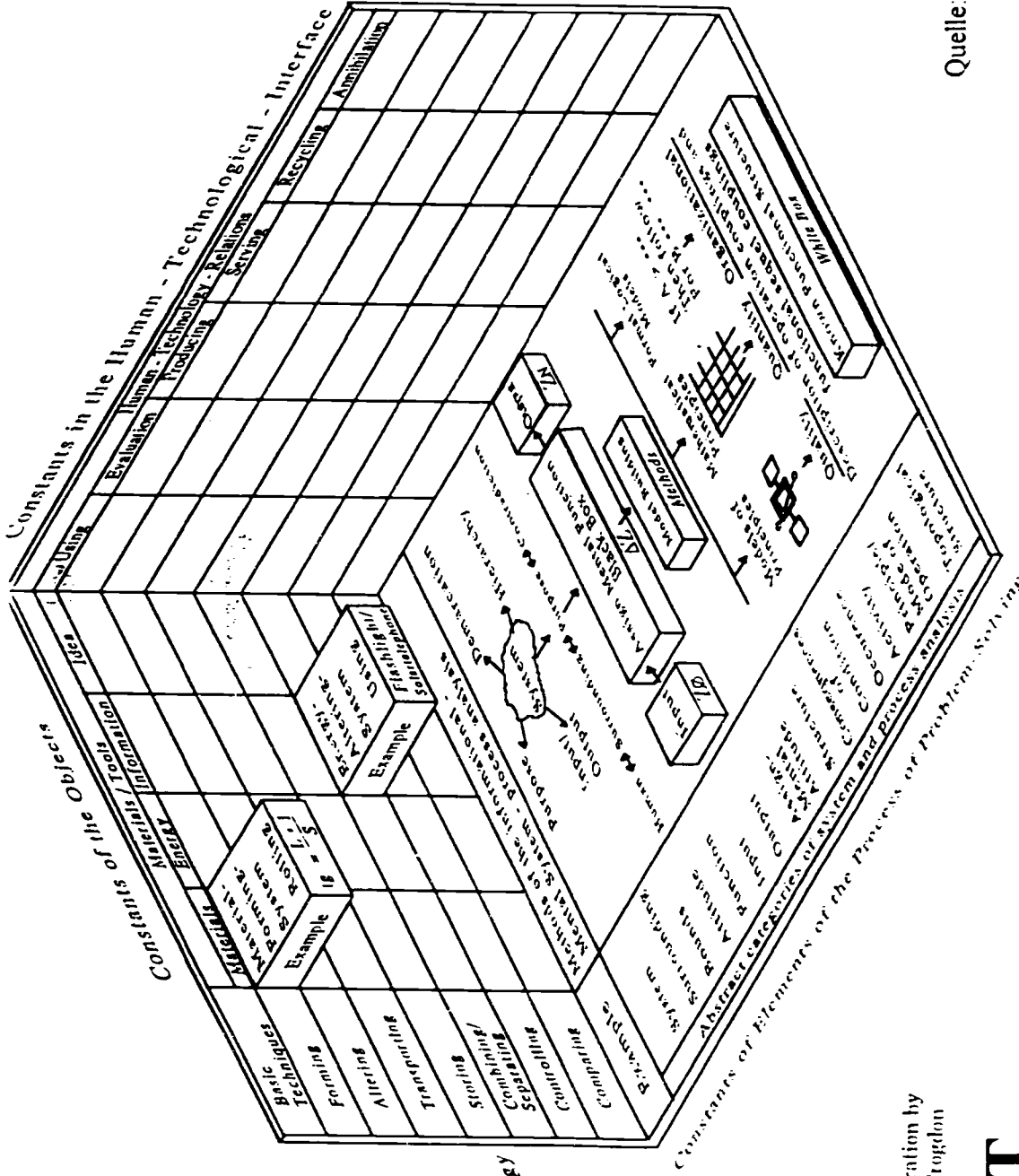
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W. E. Theuerkauf

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

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Constants in the processes of technology

Illustration by Tim Frogdon

IAET

Quelle: Blandow, Eindhoven 1990

The efficiency of sensor and actor technology in conjunction with automation facilities allows the different process parameters to be manipulated and monitored with a higher degree of differentiation, which includes permanent process monitoring (production data acquisition) and optimization. At the same time this goes along with higher levels of mechanization of the systems themselves, which for surface treatment processes involves the use of robotics and, for quality assurance, the use of specific sensors.

Another feature is the networking of automation facilities using process level related bus systems providing for a data transfer from the process through to the planning level. The data transfer/information flow between the levels allows manufacturing requirements planning (MRP) to be employed for material flow control, MRP in some cases also assuming production control and higher-level control functions. As a consequence, changed logistic concepts and production structures (islands of production) are conceivable.

Fig. 2: Networked system in a company

Modern automated plants are characterized by their complex system-based features, their efficiency primarily being determined by their ability to achieve a maximum of machine times, the secondary objective being to avoid and quickly eliminate any faults. From this follow a number of objectives in personnel development:

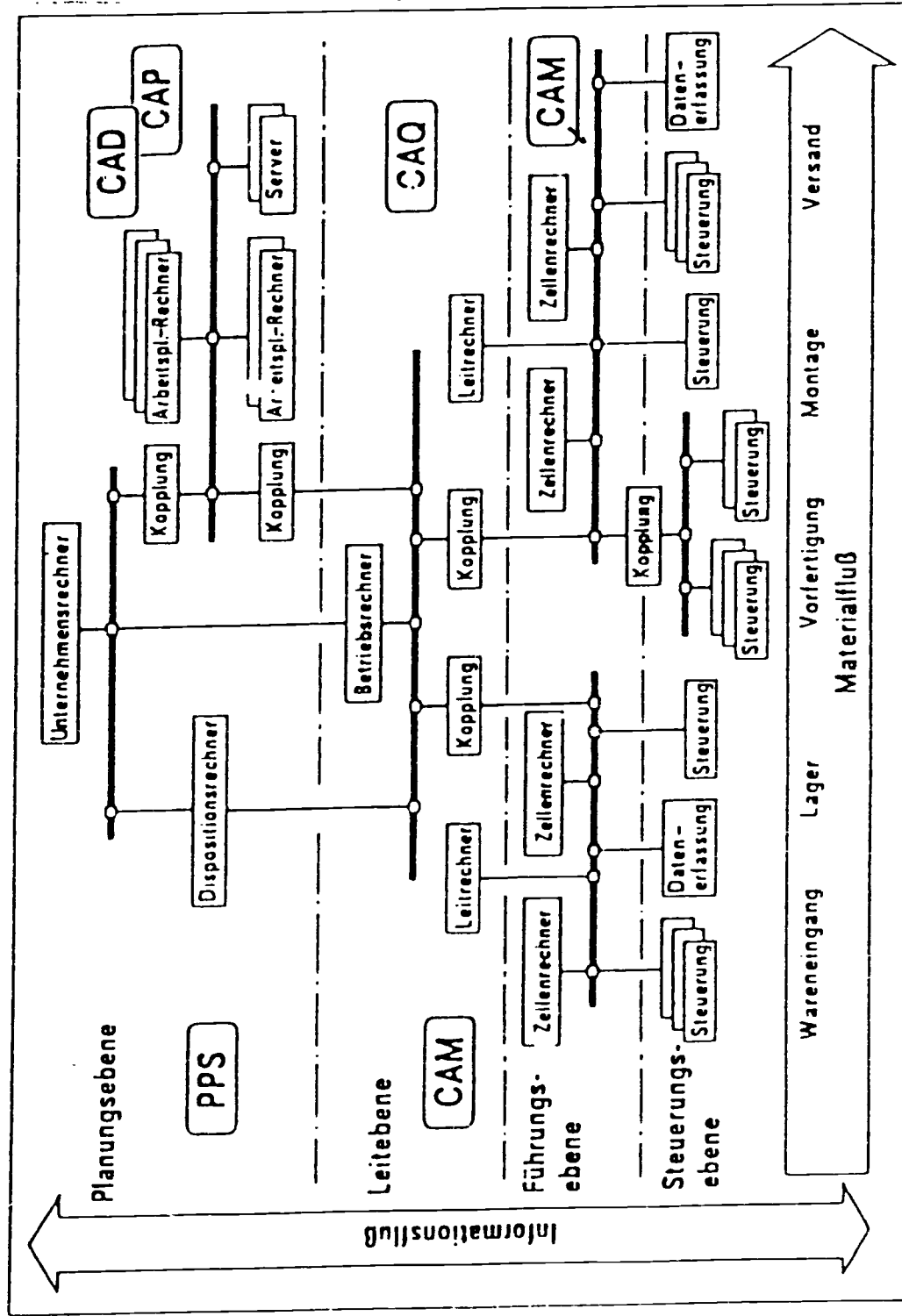
- the development of process competencies, allowing employees to successfully handle complex sequences of operations and place them in the proper perspective within the general context of the company;
- the development of methodological competencies to be able to master networked operations involving directive and optimising functions;
- the development of social competencies and competencies in work and technical organisation allowing employees to arrive at the appropriate task-oriented decisions within the group and to accept, as an individual and as a team, responsibility for the production process (Theuerkauf, Weiner 1991).

Operation of computer-controlled systems necessitates system operators and maintenance staff, whose basic vocational training would have to involve a skilled worker's certificate in metal technology or electrical engineering. When analysing the range of operations to be performed in these systems, it is noted that there has been a shift from qualified manual skills to cognitive skills in process analysis and synthesis, a change which in view of the investment volume of computer-controlled production systems requires a higher readiness to accept responsibility for the process.

3. Key qualifications and key contents as a basis for qualification processes

In view of the changes having taken place or taking place within engineering systems and the relevant technologies, it seems expedient to choose a curricular approach that takes a bearing on the concept of key qualifications and key contents. Where the key qualifications as defined for instance in the Petra model (Klein, Boretti) are mastered, new skills can on this basis be translated to different work situations (Theuerkauf, Weiner 1992).

KEY QUALIFICATIONS AS AN ABILITY OF ORIENTATION FOR A TECHNICAL EDUCATION
 INTERNATIONAL CONFERENCE ON TECHNOLOGY EDUCATION. WEIMAR 1992



IAET

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Company-specific key qualifications can be defined as comprehensive thinking and acting within systems, system/process competency as well as competency in work and technical organisation and team work abilities, which in turn can be classified as follows:

- Comprehensive thinking and acting shall be understood to be product-orientated. Comprehensive understanding will be achieved when workplace related operations form an integral part of an cross-functional perception and a readiness to share responsibility for upstream and downstream processes.
- System/process competency shall be understood to be production-orientated, i.e. individuals have to be able to describe the system/the operating facilities with their complex structures and to functionally associate them with specific workplaces. System competency is measured against the ease with which complex work structures can be handled. Process competency is characterized by the ability to master and assess the dynamic behaviour of plant sections and/or a specific task.
- Competency in work and technical organisation comprises the ability to plan discrete items of job execution. Optimisation can in this context also imply a lowering of production costs by functional and quality improvement..
- Team work ability can be assumed to exist when the group member is in a position to meet tasks with well-aimed problem solving methods in a largely group-based approach, while duly considering given authorities and powers.

Key contents are closely connected with the key technologies that stand out in particular for their cross-sectional function, as is the case for instance with the information technology. The linking elements have to be on the one hand the cybernetic principle of technical systems, e.g. control engineering, and on the other hand the production technologies, as for instance robotics.

4. System configuration for the model production system

To be able to develop company-specific key qualifications, a model production system¹ was developed serving as a teaching plant. This system provides for the production of 54 versions of one model car thus copying the product range of the company for whose training centre the qualification concept had been developed.

From an information theoretical point of view, this model production system can be regarded as a medium being stimulative in nature, while in view of its complexity it at the same time provides an information store of key contents, which is reflected in its networked system/process functions. As the task is comprehensive, it allows, in conjunction with the model system, skills to be developed at the different levels of action and the relevant key qualifications. A model production system thus represents a new educational dimension within the process of learning, which is based on a new and workplace-related relationship between learners and medium.

¹ Responsible for the design and technical realisation of the model production system are VW AG Wolfsburg and FESTO DIDACTIC KG, Esslingen/Germany.

The teaching plant is an assembly plant comprising six self-reliant but networked learner subsections, with on the one hand a material flow that is determined by the structure of production cells (micro view), while on the other hand there is the plant that represents the product-related production of a model car (Fig. 3). The material flow between the sections follows a linear pattern; including buffers. The sections represent different production sectors of the company, as for instance the press or the paint shop.

Fig. 3: Layout of the model production system

The different production stations are interconnected by the flow of information using a control centre. The material flow inputs and outputs of the different stations are at the same time defined as the points of acquisition for production control. They are thus in conformity with the actual production structure of the company. The system is, moreover, equipped with mobile data memories in the workpiece fixtures contributing to the flow of information such that the current job status can be read into and out of the data memories in the different station.

Production planning and production control proceed from the control centre². To be able to simulate the sequence of the production steps, commencing with the vehicle as ordered by the customer, the production planning system depicted in the control centre followed the normal company practice and included elements of the forecasting phase and of production planning. The company's very complex programme packages with the associated tasks were reduced to the essential actions for a TOP DOWN method.

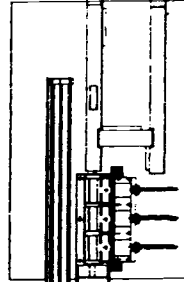
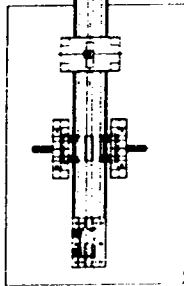
Information flow linkage within the stations - between the sensors and actors of the mechanical installations and the operating and monitoring units - is achieved by the Siemens SPS-S5 programmable controller. The data exchange between the programmable controllers of the stations and the HP master computer was realized by the Siemens H1 bus, connected to which are the PG 750 programmers (Fig. x). Within the plant, the programmers assume the operating and monitoring functions and also provide for programme interference. The data acquired through production data acquisition are stored in the data blocks of programmable controllers at station level on the one hand, and in the data files on the other. This is where the production data are analysed statistically for evaluation of the production processes performed and are displayed on the monitor. The figures they furnish include those on productivity, capacity utilization, efficiency and downtimes in the model production plant.

Fig 4: Information flow structure of the model production scheme

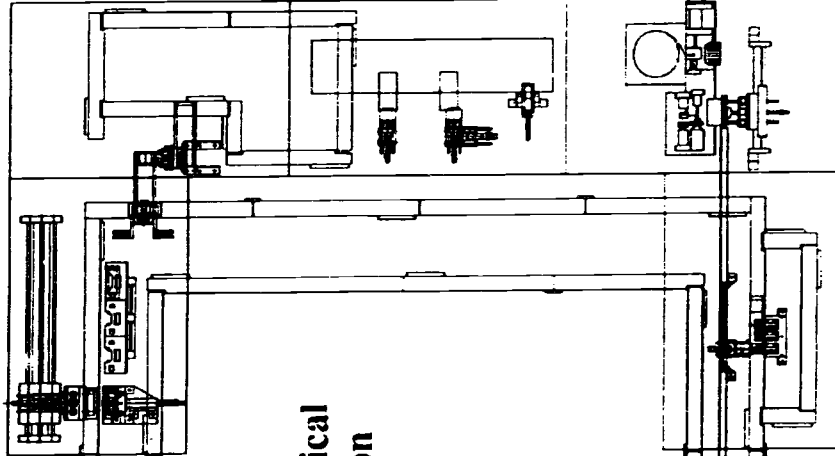
The interfaces between man and production equipment are tied to the actions operating, running and supervising the sections. The operating panels and the electric control circuitry were designed with due regard to company standards and safety regulations. With the aid of monitors the material flow can be followed and watched, actuators can be manipulated, and signal conditions of sensors can be interrogated. Course participants responsible for operation of the sections are left with a number of possibilities of how to manipulate the function of the sections in the modes "adjusting", "individual operation", "individual movement", and to follow the process within the networked system.

² The control centre software was developed on the basis of the Simflex simulation software by the department "Produktionssysteme" at Gesamthochschule/Universität Kassel, Germany, under the supervision of Prof. Dipl.-Ing. A. Reinhardt.

Pressing Work

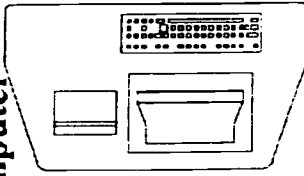


Car Body

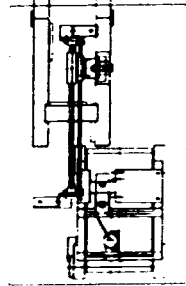


Mechanical
Production

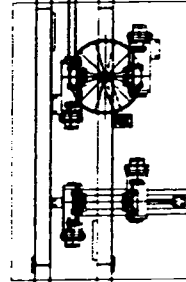
Master
Computer



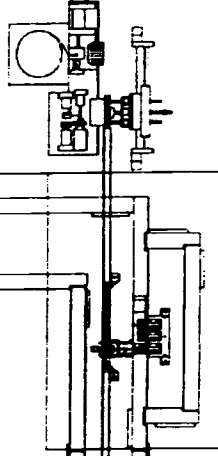
Final Instruction



Axel and Wheel
Assembly

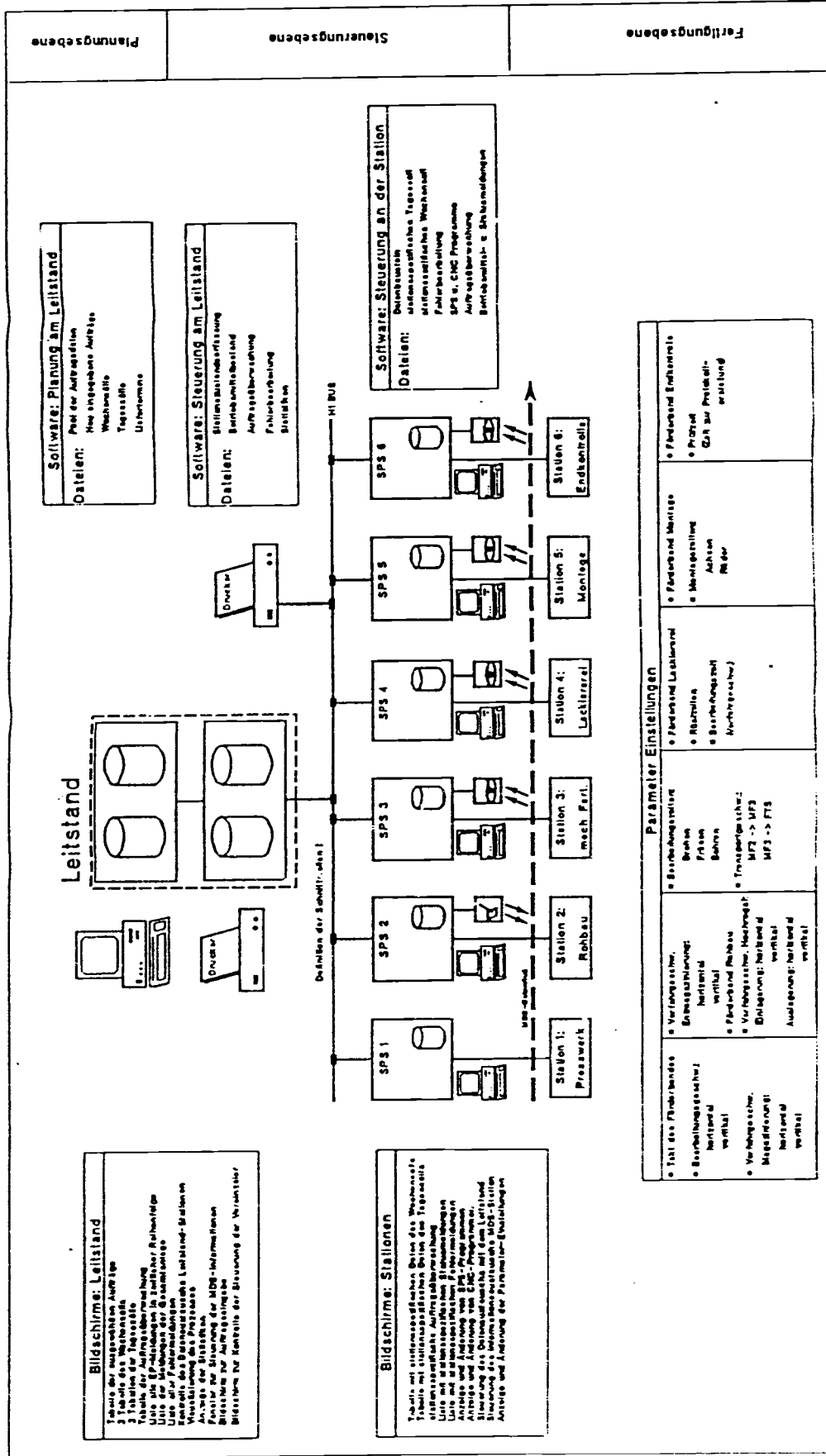


Paint Shop



I A E T

Informationsstruktur im GRIF-Modell



Bildschirme: Leitstand
Tabelle der ausgehenden Aufträge
3 Tabelle des Werkbestands
Tabelle der Auftragsübernahme
Tabelle der SP-Planungen in zeitlicher Reihenfolge
Liste der Stationen der Gesamtanlage
Kontrolltabelle des Leitstandes
Kontrolltabelle des Prozents
Anzeige der Stationen
Anzeige der Stationen mit MFG-Informationen
Bildschirm zur Anzeige der MFG-Informationen
Bildschirm zur Kontrolle der Steuerung der Werkstatt

Bildschirme: Stationen
Tabelle mit stationenspezifischen Daten des Werkbestands
stationenspezifische Auftragsübernahme
Liste mit stationenspezifischen Informationen
Liste der stationenspezifischen Parameterdaten
Anzeige und Änderung von EDC-Programmen
Steuerung des Onlinezustands mit dem Leitstand
Steuerung des stationenspezifischen MFG-Informationen
Anzeige und Änderung der Parameter-Einstellungen

Parameter-Einstellungen	
<ul style="list-style-type: none"> • Fertigungstyp • Bearbeitungszeit • Fertigungszeitpunkt • Fertigungszeitpunkt • Fertigungszeitpunkt 	<ul style="list-style-type: none"> • Bearbeitungszeit • Fertigungszeitpunkt • Fertigungszeitpunkt • Fertigungszeitpunkt • Fertigungszeitpunkt
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The operator's ability to respond quickly and adequately to faults within automated systems is an essential productivity factor for real production systems. The course therefore provides for a training programme where under an interlinked operation scheme faults have to be eliminated. To this effect, different fault configurations can be combined or faults can immediately be triggered in the control centre. The master computer initiates mechanical, pneumatical, electrical or EDP-related faults, which is either a random or an immediate, but always a section-related process.

When considering the different levels of the company structure, model production suggests the following actions on the different levels:

Planning level:	production planning, time scheduling, etc.;
Cell level:	production control, progress control, SPC;
Process level:	resource control.

The model production system is thus available in the form of a group-based laboratory, which on the one hand simulates the actions within the company structure and on the other hand serves as an educational system. But only by cross-linking the individual learner sections can the development of key qualifications actually be achieved.

With a view to information theory, the model production system is a medium that possesses a stimulative character and is because of its complexity at the same time an information store as reflected by its complex system/process functions. The model production system thus represents a novel educational dimension for the learning process, which is based on a new learner/medium relationship. The complexity of the task allows - in conjunction with the model plant - to acquire the capacity to act on the different action and control levels.

2 Realisation of the curricular objectives

Adequate qualification analyses are an indispensable prerequisite when establishing a catalogue of educational objectives for a course. But two general objectives can be named irrespective of such analyses.

- In the course, the group is to aim at an optimised production performance within the model production system. To achieve this, special emphasis is placed on the demonstration and the use of restarting, run-up and continuous-operation strategies (cf. Millberg et al, 1992).
- To maintain a smooth material flow within the production process of a model car, operators have to be able to act competently and reliably. As the model plant comprises six networked sub-sections, optimisation of the production process cannot be realised by actions of the individual, but only by the group becoming active in the learning process (Bühner, Pharao, 1993). The linear structure implies a retroactive effect between group and individual, thus also necessitating individual commitment.

The objective of trouble-free continuous operation providing at the same time for acceptable productivity standards can only be achieved when strategies of thinking within networked systems are available.

To acquire the required expert competency, the course concept concentrates on the key issues listed in Table 1.

Production strategies	Knowledge of the systems and the structures of logistics in the automobile production sector. Drawing a comparison between the company production system and the model production system. Realising and identifying evaluation criteria for production and assessing same.
Programmable controllers	Knowledge of the configuration and programme of programmable controllers and the way they are linked with EDP systems. Knowledge of the mechanical, electrical and pneumatic elements of the system. Identify functional structures of the controllers, i.e. analyse the logic circuits between the mechanical, electrical and the automation units. Identify and eliminate faults.
Communication/Interlinking of resources	Knowledge of the in-company networks and thenetwork available in the system, including data acquisition, data transfer, data manipulation, data evaluation. Describe the structure and function of the information flow and identify their effects on the energy and material flow.
Optimisation. of matererial and information flows	Knowledge of the strategic, operative objectives of the company. Ways and means of optimising the material flow within the model production system. Bring measures of organisation, qualification etc. into a relationship with the model production process and translate same to actual working conditions in the company.

Table 1: Factors of the expert competency as part of the course concept

As a methodological competency, the ability to act competently and reliably necessitates the ability to inform, think, decide and react independently. The key qualifications this requires are listed in Table 2.

Analytic, step-by-step thinking	Split up the functions of the different sections of the entire production process into logic sequences with the aid of the system analysis, which is then represented and discussed within the group.
Synthetic/conceptive thinking	Develop production and qualification schedules. Influence the daily production.

Acquiring and processing information	Analyse and evaluate process information furnished by section monitors. Analyse production results. Develop alternative production strategies. Consult circuit diagrams and manuals for fault analysis and elimination.
Methodical approach and selection of information	Working with the Leittext (or key material) method. Selection of the necessary elements of knowledge providing for better production process handling.
Problem solving	Identify malfunctions within the production process, i.e. bottlenecks, and develop solutions for process optimisation. Employ problem solution strategies also as trouble shooting strategies and eliminate faults.
Transfer	Contribute industrial experience and newly acquired knowledge to the learning process and translate same into practical action in start-up and control procedures within the model production process.

Table 2: Factors of the methodological competency as part of the course concept

Commitment and successful action within the group presupposes an adequate social competency. The relationship between this competency and the actions within the production process is demonstrated in Table 3.

Flexibility	Assume different tasks in the production process and adjust to new situations (e.g. disturbances) and functions within the learning process.
Capacity for teamwork	Master the model production process and the course situation as a production team/group of learners both by dividing the work and by a common approach. This also presupposes that the role of the trainer/moderator is that of a partner.
Ability to communicate and negotiate	Come to an agreement between the sub-teams responsible for the different sections. Maintain communication with the trainer. State and evaluate facts. Oral and written presentation of problems.
Initiative	Develop solutions to problems occurring in the production process without having been asked to do so by the trainer; discuss possible solutions with the group and translate them into action as

agreed with the trainer. Suggest learning processes on the basis of an analysis of individual qualification deficits and initiate same individually.

Responsibility

The production plant represents an asset demanding careful handling. Improper handling has consequences for the work/the learning process of the present and of future groups.

Table 3: Factors of the social competency as part of the course concept

3 Methodological features of the course concept

If learning is to have the effect of developing professional competencies, a course trying to communicate such competencies should aim at aspects that will be of significance for the target group in its real job situation.

Starting from this consideration, the course for system supervisors was conceived such that the model production plant was to be put into operation and run in at steps of 25%, 50% and 100% of its maximum performance (Fig. 5). The course thus follows normal run-up procedures in real plants (cf. Wiendahl, Garlich, 1992) and hence has immediate reference to the responsibilities of system supervisors.

A prerequisite of qualified group work on the job is the core task (Gohde, Kötter 1990). The core task of this qualification concept and hence a point of reference for the group is the achievement of the optimum model plant performance or output. Derived from this core task are sub-tasks determining the individual learning steps to be acquired. They are developed with the group in team conferences and geared to the given objectives of the qualification plan. Such an approach demands from the learning group not only creativity and innovative abilities for the work to be accomplished, but also for the individual leaning process.

Collateral course objectives are trouble shooting and fault elimination during different production phases. To be able to successfully practise trouble shooting procedures, the strategies employed start from the theory of problem solution and correspond to the diagnosis procedures taught in in-company training programmes (cf. Genath 1984). They were included in the course in order to reduce to a minimum plant stoppages and downtimes during the running-up phase.

Familiarisation of the participants with the start-up procedure in the different plant sections is not an instruction item. From their work as system supervisors, most participants already know the configuration of the operator's panel as well as the algorithms to be able to start the plant from the panel. What they do normally not know is the structure of the monitors of the programming unit and the way how the monitors are linked with the different operating conditions of the production system. The participants acquire this knowledge autonomously from manuals studied in parallel with the practical approach.

A significant aspect is that in this way the more selective or specific knowledge participants have acquired through experience is linked with newly acquired knowledge. The experience and abilities of the participants is used to develop a dynamic working team where group-

Exercise	Method/ Media	Teaching Operations
<p>Phase 1:</p> <ul style="list-style-type: none"> - Capabilty for individuel learning - Stragies for starting the plant - Strategies for Problemsolving 	<ul style="list-style-type: none"> - Combined instruction - Lecture by the coach - Guide Text - CBT/ Video 	<ul style="list-style-type: none"> -Working with guide text to develop key qualification
<p>Phase 2:</p> <ul style="list-style-type: none"> - Planing the initial and the starting operation - Initial operation of some fundametal units 	<ul style="list-style-type: none"> - Grif- plant - Self learning with starting algorithm and documents of the plant 	<ul style="list-style-type: none"> - Initial operation under the guidance of the coach - Analysing the defects during the starting run
<p>Phase 3:</p> <ul style="list-style-type: none"> - Job Order manufacturing with the capacity of 25 % - Training at the different stations 	<ul style="list-style-type: none"> - Master control - Grif- plant 	<ul style="list-style-type: none"> - Starting the networked stations - Production control -Analysing the results of the production - Discussing the statistics of the production
<p>Phase 4:</p> <ul style="list-style-type: none"> - Job Order manufacturing with the capacity of 50 % - Recognizing and eleminating defects - Improving the production flow 	<ul style="list-style-type: none"> - Master control - Grif- plant - Fault- generator 	<ul style="list-style-type: none"> - Production control -Analysing the results of the production - Discussing the statistics of the production
<p>Phase 5:</p> <ul style="list-style-type: none"> - Job Order manufacturing with the capacity of 100 % - Improving the production flow 	<ul style="list-style-type: none"> - Master control - Grif- plant - DV assisted analyse of the weak points 	<ul style="list-style-type: none"> - Production control -Analysing the results of the production - Discussing the statistics of the production - Pursueing the targets of the production
<p>Phase 6:</p> <ul style="list-style-type: none"> - Individual und collective Analyse of the sequence of the course 	<ul style="list-style-type: none"> - Analyse of the weak points of the plant 	<ul style="list-style-type: none"> - Individual planing of further education

oriented problem solutions are given priority. The course structure will hence not be the same for other target groups.

The qualification concept making use of the model production system provides in a very special way for the development of an individual behaviour (Bunk, Kaiser, Zedler 1991, p. 369). For the development and furtherance of a social behaviour, such as the ability to cooperate and communicate, the course employs social patterns permitting the individual to work and learn with his or her colleague or within the group as a whole.

Fig. 5: Typical course structure

Another form of cooperation is the team conference, the main issue of this conference being the starting of the production process, increase in production and the productivity of the model production system. The team conference encourages

- the shaping of the action pattern required for plant start-up by describing concrete objectives and sub-steps, as well as the accepting of a shared responsibility for the learning process:
- arrangements on the functions to be performed by the participants for plant operation,

to name but two aspects.

In the team conference, participants do not only accept responsibility for the production process, but also for the learning process. Before commencing with each item to be acquired, the participants discuss all the tasks that have to be completed or that have already been solved. The trainer is in this context assigned the role of a moderator.

4 Productivity considerations as a benchmark for progress

If the aim of the course is to arrive at an optimum plant performance and output, and if the production statistics represent the result (controlling) of this process, they can also serve as an evidence of the performance in the learning process. They comprise in a comprehensive way the practical abilities as well as the theoretical standard of knowledge. The advantage of this progress monitoring lies in the objectivity of the evaluation method. Since each course covers at least three production cycles, the production statistics they produce are direct indicators of the knowledge gained (Fig. 6).

The statistical characteristics are interpreted as follows:

Capacity utilisation	shows the level of the production performance of the group as compared with the plant rating,
Running time factor	shows the downtimes for the plant sections,
Degree of utilisation	shows in how far the objectives of the group (intended car output) have been achieved,
Error statistics	show the nature, instances, significance and times of trouble shooting/elimination processes.

Statistical data can also be compared with the results of earlier courses and used as a basis to discuss improvements.

Fig. 6: Status of the Job Orders

Such an approach in assaying progress provides course members with an economical and practicable instrument of self-control without having to force the trainer into a role of a critic or judge.

5 Final remarks

The concept presented here was subjected to a summative evaluation in a number of pilot course. It was proved that the intended objectives can be met with the model production system.

The model production system provides for active non-simulative learning by doing for the actual job. For the learner it proves to be an experience- and perception-based method of presenting and activating existing knowledge. It was found to be important to develop the ability to act reliably in systems characterised by a high degree of automation. The fact that the learners did often not achieve the intended production result within the given time demonstrates the very high demands complex networked systems make on them. The concern especially system supervisors showed when failing to achieve the maximum output, which could be explained by their professional self-image, proved to be an encouragement for a yet increased commitment. The controlling proved to be conducive as statistics demonstrated quite clearly whether or not the production cycle concerned provided for a real net output.

For the company, the "model production" laboratory with its synergistic approach will offer a new dimension of experiencing the computer-integrated and networked production process, as in a "learning" company it can serve as a tool for a learning process where experimenting and discovering figure large. Networked systems assume integrative functions as they call for a coordination of competencies, as well as a group-forming behaviour to allow capabilities to be fully developed. The concept of networked systems is based on a discursive group consensus and it would hence be expedient to jointly qualify persons on the plant who perform different tasks and who come from different levels within the company hierarchy. This would facilitate not only an exchange of expert knowledge, but also the development of the communicative competence. With such a communication- and relation-based discourse, networked systems comply with an essential quality feature of the learning organisation (Grosse, 1994).

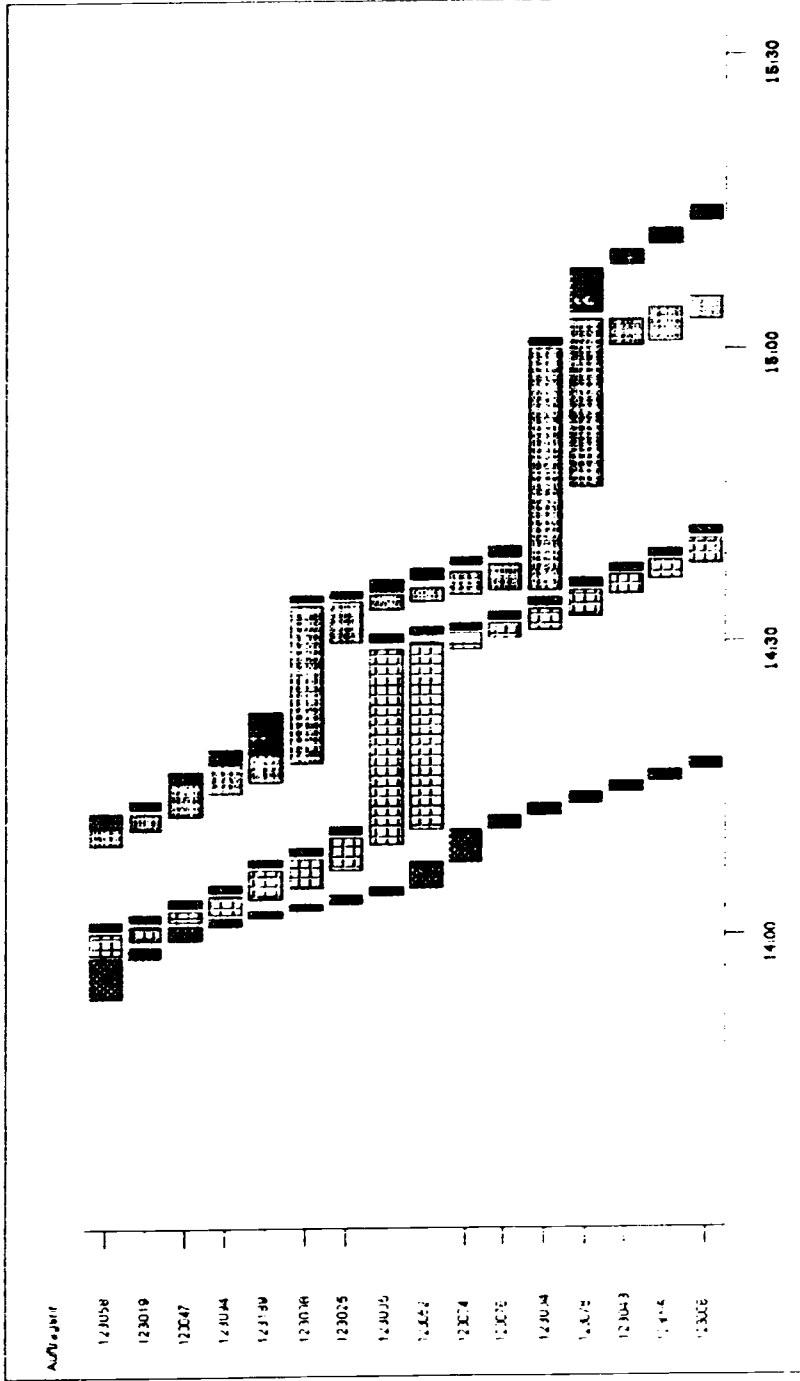
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Course: "grif 3" 1
 Date : 05. 11. 94
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Status of the Job Orders



Station 1 Station 2 Station 4 Station 5 Station 6

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