Learning in the process of work - wish or reality? An interdisciplinary approach to designing technology-based learning and assistance systems to promote learning

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ABSTRACT[1]

A high number of variants, small batch sizes, and changing market requirements demand resilient production processes. The employees are increasingly supported in the necessary adaptation processes by digital assistance systems. These provide the necessary content directly in the work situation. The authors present an approach that complements this often mere presentation of information with content preparation and a systematic technology selection and design to facilitate learning in the work process.
The technological basis is formed by virtual and augmented reality, which are selected and designed according to their didactic potential.
The contribution is characterized by an interdisciplinary approach that combines perspectives from technological, pedagogical, psychological, and organizational sciendes. In addition to the participatory design of a digital learning and assistance system, measures to promote organizational integration are described.
The procedure is presented using an example from the automotive industry, which is currently being developed in the research project LeARn4Assembly.

Keywords: assistance systems, learning in the process of work, action orientation, learning activity system.

1. INITIAL SITUATION AND MOTIVATION

More production that is flexible with a high number of variants, decreasing batch sizes and increasing individuality of products require flexible work processes and workflows and thus lead to increasing demands on employees. They constantly have to adapt to current configurations and requirements of the product currently being manufactured. Especially manual activities, such as assembly, are therefore increasingly supported by digital assistance systems [1][2]. The necessary information for the next work step is shown to the assemblers on displays close to the workplace. Previous systems primarily gear towards the error-free execution of the assembly task. The overriding objectives are of high quality and quantity of the manufactured products. However, the worker is usually only supported in the execution of individual operations, e.g. the correct joining of two components. A reference to the superordinate action often is not made so that identification with the activity is made difficult. However, in the sense of the research project presented here, assistance systems should offer support not only in the execution of a work task but also in the integration of the task into the overall working process, in order to make clear to the employee his relevant role in the overall system and thus the sense of his work [3].
The project LeARn4Assembly, funded by the German Federal Ministry of Education and Research, investigates how digital assistance technologies can be designed for manual assembly processes so that they offer the potential

[1] We thank Nils Darwin Abele from the University of Siegen, Department Mechanical Engineering, Chair of Work Science/Ergonomics, for peer-editing the paper what greatly improved its quality.

for learning and understanding and enable the employee to classify his or her own actions within an overall process.

2. THEORETICAL POSITIONING IN THE INTERDISCIPLINARY DISCOURSE

The approach in the project is based on the understanding of the activity theory of the school of cultural history [4], which distinguishes between the three levels of operation, action, and activity (see Figure 1). Each level is subordinated to the higher level. Leontjew also assigns an orientation to each level: corresponding to activities, actions, and operations, he names motives, goals, and instrumental conditions and constraints. Motives thus drive activities. These build on actions that are oriented towards goals. Actions in turn are based on operations that result from instrumental conditions and constraints.

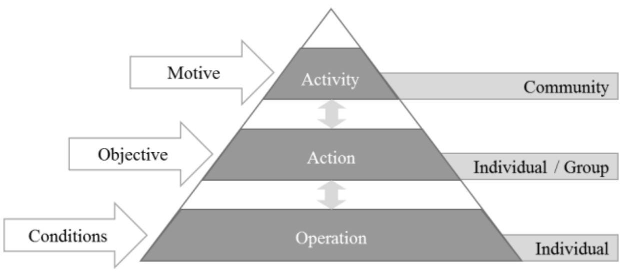

Figure 1: The levels of activity theory, according to [4]

This design process takes place in an interdisciplinary field of tension. From an occupational science perspective, it is clear that a comprehensive consideration of the dimensions of people, technology, and organization is necessary [5]. The learning activity system of industrial and organizational psychology [6] refers to the systemic interaction of learning object, learning medium, learning subject as well as community, rules, and division of labor (see Figure 2).

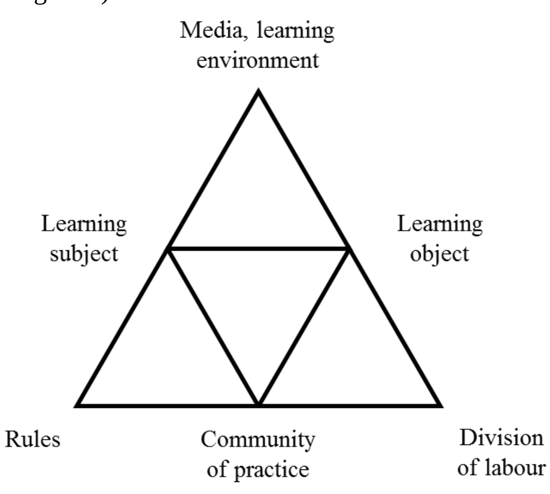

Figure 2: Learning activity system, based on [6][7][8]

Dick describes the learning activity system as follows [6]: The triadic interrelation between the subject, the object, and the medium of learning state that a medium or a tool mediates every human activity and its influence on the environment. The subject of learning describes a gap between requirements and competence. This gap can be formulated as a task to be solved by learning activities with the help of media, learning methods, and tools [9]. This triad is embedded in the work process, which can be described by the other structural elements. The community represents different individuals or groups, which are connected with each other in a cooperating or competing way. The division of labor is understood as the horizontal distribution of tasks as well as the vertical structures of power and prestige, status and hierarchy in a learning activity system. The rules refer to explicit and implicit norms, values, and laws that promote or limit interactions within the learning activity system. Such a system of learning activities carries contradictions between its structural elements or between different learning systems and thereby causes or inhibits development, innovation, expansion, and change of knowledge.

Concepts for learning in the process of work describe how work systems should be designed to enable learning in the workplace and to enable an immediate transfer of what has been learned into action [10][11]. The seven criteria of learning facilitation described by Frieling are reflected in terms of their suitability for the design of digitally supported activities: autonomy, participation (involvement), complexity/variability, communication/ cooperation, feedback, and information.

The engineering sciences and information technology disciplines provide technological methods for designing digital assistance systems that meet the described requirements. At present, VR and AR technologies in particular offer the potential to promote understanding directly in the work process, e.g. by overcoming visibility limitations and avoiding real existing dangers [12]. Other corresponding disciplines that deal with these and related issues and must be considered for conceptual design, technical implementation, participatory introduction, and sustainable use are business education, psychology, sociology, and economics.
In the project described, the authors develop an interdisciplinary approach for the design of workplace-integrated technology-based assistance systems and their organizational integration to promote learning. The procedure is developed and presented in the following using an example from the automotive industry.

3. INDUSTRIAL USE CASE

In the “LeARn4Assembly” project (duration: 05/2019 - 04/2022), the research and business partners design and develop assistance systems for three different workplaces that promote learning. We describe our approach using an example from the automotive industry. In the field of mechatronics processing, we investigate the employees needs for learning and assistance in the performance of their jobs, which digital technologies are suitable to support them in the performance of this activity, and how the system can also offer them adaptive learning content in a suitable way. Figure 3 illustrates the selected procedure. Within the scope of a detailed work and requirement analysis [13] [14] [15], we first approached the entire work area of mechatronics processing. By means of observations the different workstations (B) were examined with regard to the operations to be performed, complexity and learning content (A). In interviews, the different target groups in the company, which could be influenced directly or indirectly by the introduction of a new assistance solution, were questioned regarding their experiences, goals, and expectations about an assistance system.

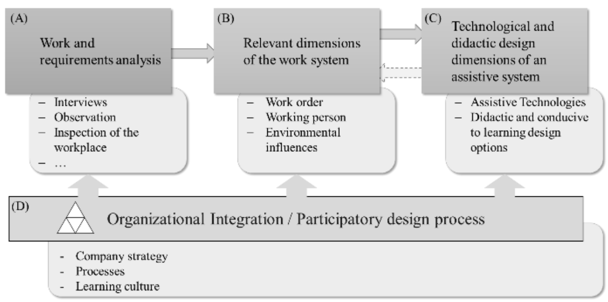

Figure 3: Procedure for the design and integration of a digital learning and assistance system

The interviews addressed representatives of management, training and further education as well as employees of the mechatronics preparation area. In order to be able to design a tailor-made solution, the workplace was also analyzed with regard to its general conditions. The focus lay on aspects such as brightness and volume, existing digital support systems and possible interfaces to our solutions, and other environmental influences. For example, working with oil-smeared hands precludes interaction by means of touch gestures.

In parallel, suitable technologies are selected and didactically based design options are developed (C). This is done in a participatory negotiation process that takes into account the individual requirements of the working person as well as the didactic potential of the technologies. The sustainable use of the developed solutions requires the organizational embedding (D) along with the corporate strategy, established processes, and the learning culture.

In the field of mechatronics processing, the reworking workplace was identified as particularly relevant in the work and requirements analysis. While most other activities in the work area are largely standardized and already supported by assistance systems, reworking requires a greater degree of experiential knowledge and problem-solving competencies. For this reason, mainly female employees with a higher level of experience use this workplace. For the design and implementation of a digital assistance system, the research partners have developed objectives on two levels in close cooperation with the operational partners:

1) Assistance during the operational execution of the activity for efficient task management
2) Advanced learning modules to promote process understanding

In the following chapter, we describe the didactic-methodological concept that is being developed for these two objectives and for which a technical solution will be selected and implemented in the further course of the project. Figure 4 illustrates the activity system for the use case.

4. DIDACTIC-METHODICAL CONCEPT

Basic design principles

Learning in the seminar no longer meets today's production requirements. The decoupling of learning from a real work task leads to the development of abstract, so-called inert knowledge [16]. Besides, the knowledge imparted is often not up-to-date and its transfer into the work process is difficult.

The teaching/learning concept developed in the project brings together the approaches of learning in the work process [11], action orientation [17] and design that promotes learning [10].

In a first step, the learning and assistance contents were selected that are relevant for the processing of the task at the reworking workplace. The considerations for the selection of the learning content were characterized by the understanding of the interaction between man and machine in an increasingly digitalized work system. The authors continue to attribute a leading role to humans, in which they make decisions and are ultimately responsible for them. The learning and assistance system enhances skills by providing more detailed information, demonstrating interrelationships, and preparing complex data in a comprehensible way. The practitioners understanding of the assistance system corresponds rather to that of a "valuable companion" than to a compensation for human deficits.

To ensure that an assistance system is not perceived as a threat but as a valuable companion, the following didactic design principles are formulated:

1) The use of learning and assistance content is voluntary.
2) Users shall be able to explore and appropriate the system actively.
3) The selection and preparation of the content are adapted to the individual requirements of the user.
4) The provision of the content is context-sensitive, i.e. depending on the current work step.
5) The contents must be relevant and represent organizational context and motives.
6) Insights from motivational psychology are taken into account to create incentives for the use of the learning modules.

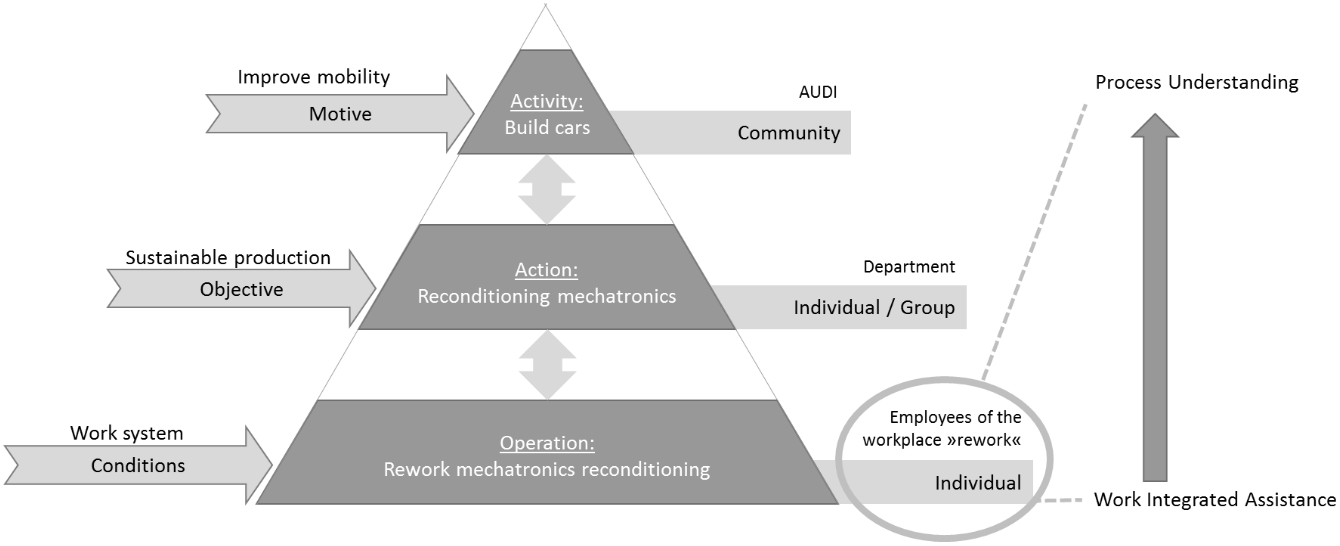

Figure 4: Activity system for the Use Case

The design and development process usually takes place in various areas of tension in business practice: Time to learn vs. time pressure in the work process, taking responsibility vs. limited room for maneuver due to security, assistance for self-determined work vs. assistance as a knowledge management system. A balance is required that takes these individual requirements and organizational objectives into account. In the following, the procedure of the project partners in the Use Case is described.

Use Case specific design decisions

Based on the consideration that the employees at the workplace "rework" are qualified for their job and that the focus is not on ad hoc qualification, e.g. in case of illness or as a vacation replacement, the assistance should not be implemented in the sense of step-by-step instructions, but rather offer adapted assistance content in critical situations. This decision supports the described attitude of the authors regarding the distribution of roles between man and machine and contributes to the fact that the employee is perceived as competent and does not receive supposedly trivial support (e.g. marking the next screw to be loosened). Instead, the focus is on work situations in which experienced employees have acquired certain procedures that have proven to be time- and resource-saving or to which special attention should be paid due to increased error-proneness.

Therefore, the two generally described objectives are represented in the Use Case as follows:

1) *Assistance during the operational execution of the activity for efficient task management*

   During the execution of the assembly and disassembly steps of the reworking the worker is supported by the provision of experiential knowledge. This knowledge guides the action by providing explanations of important points to be observed and the procedures that have proven effective in similar situations. The support is offered directly in the work situation and contributes to the efficient and qualitative execution of the work.

2) *Advanced learning modules to promote the understanding of the process*

   In order to make sure that the learning and assistance system can have a capability enhancing effect and to enable the employee to transfer procedures to similar situations, he or she must understand the interrelationships and decisions that form the basis of a recommended course of action. Therefore, a learning module is developed for selected episodes of experience, making the functional relationships comprehensible.

However, the learning and assistance content should not be limited to the ability to correctly process the work task, but should also support the process of creating meaning and thus the identification with one's own activity and the manufactured product. For this purpose, it is necessary to explain the relevance of the task in the overall system to the employee. In the example described, therefore, contents that extend beyond the operative activity should also be provided, e.g. on the role of mechatronics in the vehicle, costs saved as a result of successful preparation of mechatronics, etc.

The objective is to commuicate the tasks and activities of the individual as an important contribution to the realization of the motive of the organization.

5. TECHNOLOGY SELECTION AND -DESIGN

Virtual and augmented reality technologies form the basis for the implementation of assistance systems. VR technologies are mainly used in semi-nar settings so far. However, if we also include desktop applications under the term VR, their integration into the work process is possible without any problems and the didactic potentials of this technology, which have been proven many times, can be exploited. (Zender et al. 2019)

AR-technologies are mostly associated with the use of Smart Glasses. But here, there are also a number of design options for the integration into the work process: e.g. in a stationary workstation, mobile via tablet or smartphone or directly into the work area with the help of projection systems.
The two objectives of the learning and assistance system described above (operational support in carrying out the activity and learning modules to promote understanding of the process) offer different didactic potentials for the technologies in the described use case and must be selected carefully so that they can develop these potentials.
For the operative support of the employee in the execution of his activity the following requirements to the technology are in the focus:

- The correct information must be provided at the right time.
- It must be possible to quickly understand the assistance content presented and to transfer it to the real work situation.
- The execution of the activity should not take longer with the use of the assistance system than without.
- The work organization is adapted in such a way that the employees have the necessary ressources to work on the learning sequences.

In the selection and design of the technology, the focus will be on the context-sensitive provision of information due to the requirements described above. Technologies of activity recognition [17] allow the identification of the current assembly step by capturing and combining different sensor information, so that the contents required for this step can be offered in a precisely fitting manner. The research partners are currently investigating various types of augmented reality for the delivery of assistance content. The decision will mainly depend on the conditions at the existing workplace, e.g. already existing displays, and on the ergonomic requirements of the working person. Future users will be able to choose between different output devices to meet their individual requirements.
For the realization of advanced learning modules to promote process understanding, the following requirements are specified for technology selection and design:

- Learning should be possible in the process of work and not require a changing to another location, e.g. to a learning station.
- A learning module may take a maximum of two minutes. The learning content therefore has to be divided into modular sequences.
- Learning should be action-oriented, i.e. based on concrete practical situations.
- The use of the learning modules should be self-determined, according to the individual interest in knowledge.

Desktop-based Virtual Reality applications offer the potential to meet the described requirements, even experimental learning can be implemented through interactive design. Actions and their consequences can thus be tested and experienced without danger. The partners in the project are also planning the integration of multimedia-based learning content.

6. ORGANIZATIONAL INTEGRATION

The sustainable use of assistance solutions requires not only acceptance by employees and the provision of up-to-date assistance content, but also an organizational integration. The learning activity system [6] [20] offers a systematic framework for designing the requirements along the dimensions of individuals, technology and organization and for selecting the required methods of work and requirements analysis.
In the use case described, a number of concrete measures for the organizational integration were selected and implemented.
In all phases of the project, the focus is on a common understanding among the project partners from different disciplines, but also with the prospective users. In order to accomplish this, we first identified the company stakeholders who will be affected by the introduction of the learning and assistance system or who have an interest in its introduction. Within these very heterogeneous target groups the individual expectations and objectives were determined in a moderated setting. While representatives of the management formulate their goals more on the basis of productivity indicators, the operative employees, who will use the system directly, are more interested in good usability. These different expectations were communicated transparently. These expectations, serving as success criteria and objectives, also form an important basis for the evaluation process and finally for a targeted design.

In the further course of the project, a technology roadshow was also organized. The employees could experience the latest technologies with selected sample applications. Various VR and AR applications from other operational usage contexts were shown. This gave employees who do not naturally deal with these technologies in their daily work the opportunity to get to know them. This event also served to inform the participants about the current development steps. The authors see transparent communication and integration of all participants as a key to the organizational integration and acceptance of the developed solution.

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