Assistive technologies: companion or controller? Appropriation instead of instruction

Tina HAASE
Fraunhofer Institute for Factory Operation and Automation IFF
Sandtorstr. 22, 39106 Magdeburg, Germany

Wilhelm TERMATH
Otto von Guericke University Magdeburg, Department of Vocational Education and Human Resources Development
Zschokkestr. 32, 39104 Magdeburg, Germany

Dirk BERNDT
Fraunhofer Institute for Factory Operation and Automation IFF
39106 Magdeburg, Germany

Michael DICK
Otto von Guericke University Magdeburg, Department of Vocational Education and Human Resources Development
Zschokkestr. 32, 39104 Magdeburg, Germany

ABSTRACT[1]

Assistive digital technologies support employees in coping with complex activities by providing the necessary information directly related to the work task and according to the individual requirements. On the one hand, they have the potential to relieve people at work, for example by supporting physical assistance systems in physically demanding activities. Cognitive assistance systems can achieve relief by preparing complex data in a way that is comprehensible to the employee and supporting him in carrying out his work and in making decisions. On the other hand, assistance systems can lead to expropriation and alienation by depriving employees of autonomy and room for maneuver. This happens especially when the distribution of roles between the working person and the assistance system only provides the executive role for the human being and all decisions are determined by a technical system that supposedly has the greater stock of knowledge and intelligence.
The question arises as to how a digital cognitive assistance system can help people to experience themselves as self-effective in their work and to develop further.

Keywords: Digital assistive technologies, activity theory, learning activity system, work design.

[1] We thank Prof. Dr. Hartmut Schulze, Head of Institute for Research and Development of Collaborative Processes at the FHNW School of Applied Psychology, for peer-editing the paper what greatly improved its quality.

1. DIGITAL ASSISTIVE TECHNOLOGIES

Digital cognitive assistance systems already support the employee in many areas of work [1]. In the field of maintenance, the employee requests status data of complex technical systems, opens the latest maintenance documents for a malfunctioning component in the work situation, and receives information about the machine and the colleague who conducted the last maintenance [2].
In the commissioning department, the warehouse employees are guided using data glasses and pick-by-light.
In manual assembly, assistance systems are used to support the worker in the assembly of increasingly diversified products. Step-by-step instructions on a display installed close to the workstation are currently the most common [3].
The very heterogeneous applications show the diversity of the required assistance contents as well as the different devices for their display. The use of digital assistance systems is accompanied by various challenges:

1) *Ironies of Automation*
Because of the increasing interconnection, automation and digitalization of machines and systems, the human task in the work system is changing more and more towards a monitoring and controlling function. Experiences that the employee used to be able to make when dealing with minor malfunctions are rarely used today. Nevertheless, it is necessary and expected of the employee to react quickly, efficiently and correctly to the failure situation. The dilemma of the "Ironies of automation" [4] makes clear that the support

on the one hand leads to a relief for the employee, but on the other hand generates the need for new learning opportunities.

2) *Dequalification*
Particularly in standardized processes and activities, the use of digital assistance systems is associated with the risk of employee dequalification. The technical system reliably provides necessary information for processing the next step and the employee executes it. It is often not necessary to understand why the execution has to be done in a certain way or which alternative procedures would be possible. In this scenario, the employee has taken over the executing role in the cooperation between human and machine. There are operational scenarios in which this scenario has its justification, e.g. in the case of high employee turnover or in the case of vacation replacements. In order to enable the employee to safely act in changing and complex work systems and to be able to generate new problem solutions from existing experiences, a holistic work design is required that prevents dequalification.

In this respect, the project aims to expand the workplace-integrated support described in the current examples to include the possibility of learning in the work process.

For this purpose, the authors develop a methodological and technological approach for the design of assistance systems that promote learning. They show which influencing parameters are relevant for this design objective and how a participatory design process can support the achievement of this objective.

2. ACTIVITY SYSTEM AND EXPANDING LEARNING

The realization of the claim of a holistic, participatory work design, also in the design of the assistance system, requires a correspondingly broad theoretical framework in order to connect the individual learning of the working person with the organization's framework and its development dynamics.

The activity theory [6] developed from works of the School of Cultural History [5] distinguishes between activities, actions and operations. In this understanding, activities in their representational character function as a connection between the individual and the organization or society. They represent a material or ideal motive for the individual. The action, on the other hand, is a work action related to a specific objective, which is realized by executing individual operations.
The relevance of this distinction for the design of assistance systems is first of all to enable the working persons to relate to the object of their work as a meaningful and thus motivating element. In the automotive industry, for

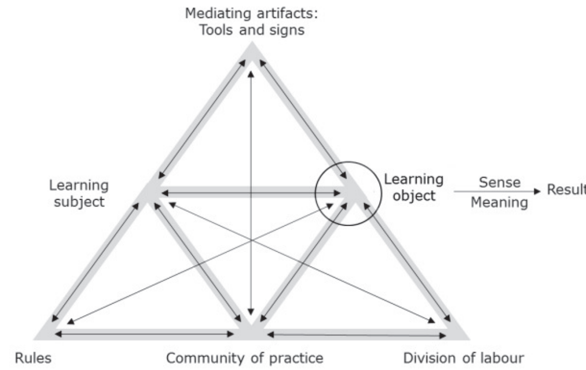

Figure 1: Structure of a human activity system, based on [7]

example, the screwing of a bolt into a certain base plate with a defined torque is an operation, the assembly of a mechatronic system is the objective, and the production of a car is the activity.

In the visualization of Yrjö Engeström, the embedding of the subjects in the dimensions of the environment or organization as the basic structure of an activity system is illustrated (see Figure 1).

The upper triangle formed by subject, tool and object represents the individual who uses tools to process objects. The elements of rules, community and division of labor represent the organizational and social reference of individual action. The combination of these elements forms the system of activity. For the activities of employees in an industrial enterprise, the elements of the activity system can be described as follows:

Subject is the acting person, e.g. as a worker on the shopfloor, development engineer or manager.

Object is the product in its entirety or in parts, e.g. a car or a machine.

Tools are on the one hand material tools such as machines, drills or electrical diagrams, but also methods or expertise.

Rules are both explicit regulations and procedural guidelines as well as implicit acceptance of a certain behavior or taboos.

Community refers to teams, shifts or departments.

The *division of labor* describes the cooperation between the various professions or departments in the company.

After empirical studies in institutions of medical care in the Helsinki area, among others, Engeström [7] developed his research as an extension of the activity-theoretical basic model for understanding and integrating dimensions such as "... dialogue, multiperspectivity and networks..." (ibid. p. 64). The complexity of organizations can therefore only be grasped by analyzing several interactive systems of activity, which include at least one common "collectively significant object" (ibid. p. 65).

Engeström has summarized this updated version of the activity theory based on five principles (see p. 65 f.):

The first principle refers to the embedding of a primary activity system in an interactive network with other activity systems.

The second principle emphasizes the diversity of different opinions, traditions and interests as the origin of problems as well as an impulse for innovation.
The importance of the historical as a third principle does not only mean the immediate local history, but also the long-term history of e.g. a certain industry or branch.

In the fourth principle, Engeström emphasizes the function of contradictions as starting points for change and development. This does not refer to day-to-day political problems, but rather to structurally induced disturbances in one or between several systems of activity, e.g. the introduction of new technologies and, as a result, a changed division of labor with new demands on the qualification profiles of employees.

The fifth principle opens the perspective on the "possibility of expansive transformations in activity systems" (ibid. p. 66). These transformations open up in connection with the escalation of contradictions, in the course of which individuals doubt norms, possibly develop a different common vision and initiate corresponding processes of change. To the extent that the object and motive of an activity system is redefined, Engeström speaks of an expansive transformation.

The behavior of individuals in this system of activity or work in a company understood as a number of interactive systems of activity is therefore always characterized by contradictions between individual elements of the system or between several systems of activity of the company. The perception of such contradictions - e.g. the change of instructions or the restructuring of departments - requires the individuals to adapt their behavior or working methods accordingly. In the understanding of activity theory, these contradictions are important impulses for learning processes.
For the theoretical foundation of learning, Engeström refers to the work of Gregor Bateson [8] with the distinction of three levels of learning. The correct answering of questions or the „correction of mistakes in the selection within a set of alternatives“(ibid. p. 379) dominates the first level. Bateson calls *learning II* an extension of *learning I* in the sense of a corrective change in the set of alternatives. *Learning III* finally means "... a corrective change in the system of the set of alternatives from which the selection is made" (ibid. p. 379).

With reference to Bateson's understanding of *learning III*, Engeström characterizes the entire system of activity as an object of expansive learning. In relation to the world of work, expansive learning processes change work activities.

3. THE LEARNING ACTIVITY SYSTEM

Development of the learning activity system
In 2005, the increasing integration of information technology into work systems motivated research teams from the universities of Magdeburg, Bremen and Karlsruhe to develop the potential of virtual reality technologies to support individual and organizational learning in the work process [9]. In a first research period, virtual learning media should support individual learning processes, in the second period extended to cooperative and organizational learning. For the third phase, the vision of a "learning space virtual working environment" was developed, in which individuals work and learn in distributed working systems in different domains and at several locations.

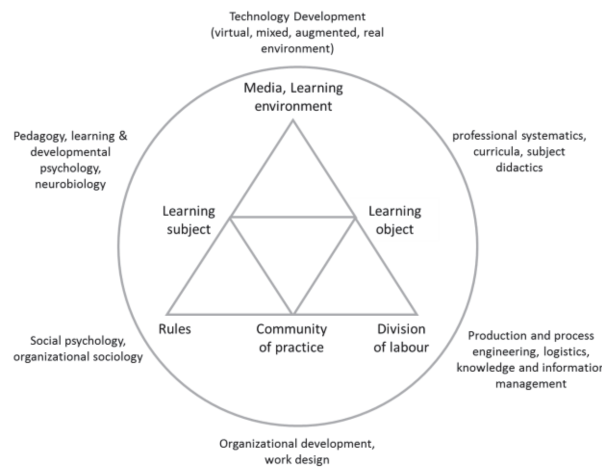

Figure 2: The learning activity system and the main scientific perspectives for its research, based on [10]

Engeström’s activity system provided an analytical framework for designing both individual learning processes in the upper triad and their organizational embedding by including the entire activity system (see above).
On this basis, Michael Dick developed the construct of the "learning activity system as a unit of interrelated elements of the work process" [10].
In the project presented here, these perspectives are scientific references for the design of a conducive to learning assistance system.

Application of the learning activity system
The shown interrelations and dependencies of the learning activity system provide important information on relevant design parameters and influencing variables that have to be considered in the realization and introduction of digital assistance systems.

Figure 3 shows an adapted representation of the learning activity system and four selected examples that illustrate the interaction of the elements of the system in the context of design, introduction and acceptance of assistance systems. We describe these examples in more detail below:

A) *Assistive technology to transfer knowledge about the object, e.g. the product*
Conducive to learning assistance systems have the potential to provide knowledge about the product to be manufactured and to integrate the employee's actions into an overall process. This can include, for example, the functionality of the product or its use in a more complex overall product that is manufactured in the company. In this way, the assistance system contributes to the creation of meaning in the activity and to the identification of the employee with the activity, the product and the overriding motive of the organization.

B) *Assistive technology for the documentation and provision of experience-based knowledge*
In addition to the instructional provision of assistance content for the execution of the activity, the employees acquire expert knowledge in their activities, which enables them to act safely in special situations. This knowledge is usually not documented, but is informally exchanged in discussions. If such an exchange does not take place, e.g. because the opportunity does not present itself or because the knowledge provider has reservations about passing it on, the potential of the individual is not passed on to the organization. Therefore, an increasing number of assistance systems are being developed that enable the documentation and use of experiential knowledge in the work process [11] [12] and thus support an exchange between the employee and the community of practice.

C) *Assistive technology for the transfer of upstream and downstream processes*
The effects and consequences of their own actions are often hidden from the employee. The employee carries out a process in a certain way, but he often does not know about the reasons. An assistance system that makes these interrelationships transparent for the employee can help to increase the quality awareness of the employee, because he can see the consequences of a different approach for the subsequent processes.

D) *Assistive technology to promote a learning and failure culture*
The design of assistance systems is also an expression of the learning and error culture that is practiced in the organization. A system that sees itself as an exchange platform for employees, in which they document their experiences, tips and tricks beyond formal rules and exchange them with the community of practice, for example.

4. DERIVATIONS FOR THE DESIGN AND IMPLEMENTATION PROCESS

Based on the considerations of the activity system, expansive learning and the development of the learning activity system, we will now develop practical derivations for the design and implementation process of conducive to learning and workplace integrated assistance systems (see Figure 4). At first, important influencing variables are identified, which determine the later technology selection and design.

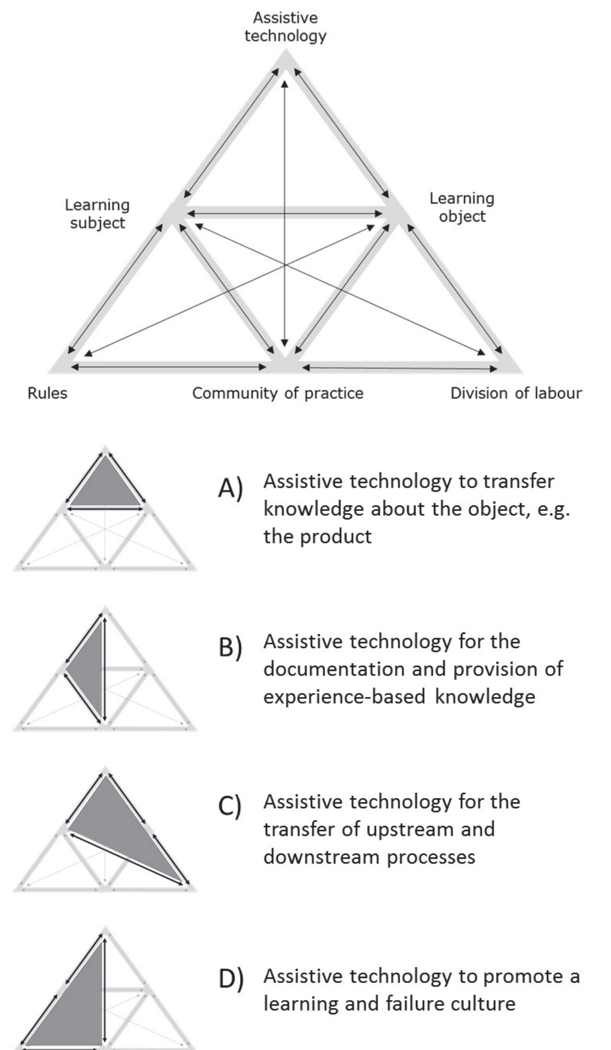

Figure 3: Application of the learning activity system for the design of conducive to learning assistance systems

For this purpose, different methods of work and requirements analysis are applied. An interdisciplinary design process, resulting in an assistance system that takes into account the interrelationships and effects within the associated learning activity system, follows this.

Parameters that influence the effectiveness of the assistance system

In further development of the often technology-centered development processes, the effective use of assistance systems requires the consideration of various influencing factors. The learner as a direct user of the system should be considered in his individuality in order to meet his personal requirements and needs. These factors are e.g. age, competence level and experience in performing the activity, as well as the willingness to learn, which can be derived from the personal motive.

The learning object includes the activity, its embedding in the overall process and knowledge about the object that is the purpose of the activity. Relevant content should be identified that promotes the identification of the learner with the product and the activity and thus contributes to the creation of meaning.

In addition, the integration of the learner into the Community of Practice should be analyzed in order to obtain information about the members of the Community of Practice and existing possibilities for the exchange of experiences among them, which must be taken into account when designing exchange processes using the assistance system. This is closely related to the rules, norms and values that are practiced in the organization and are reflected, for example, in the learning and error culture. Information on these parameters usually requires a strong relationship of trust and can be obtained mainly in informal processes, e.g. through participant observation.

The conditions at the workplace have a decisive influence on the selection and design of the technology. Therefore, the determination of factors such as volume, brightness, spatial conditions and existing IT systems are essential parts of the analysis process.

Interdisciplinary design and integration process

Based on the analysis phase, decisions are made on appropriate technologies that are appropriate for the activity to be supported. Working with oil-smeared hands, for example, provides an indication that especially devices that can be controlled by non-contact interaction should be considered. In practice, the use of virtual or augmented reality technologies depends not only on didactic principles but also on the availability of 3D construction data.

Technology design addresses primarily didactic and work design decisions, e.g. for the selection and preparation of learning and assistant content.

The introduction of new technical systems is often accompanied by necessary adaptations to the work organization, e.g. by the creation of new work tasks. The exchange of experience knowledge via a digital assistance system requires the experienced user to insert his knowledge into the system and binds corresponding time resources. To prevent this task from becoming a burden, the documentation must become part of the activity.

In order to promote the organizational integration and acceptance of a new technical system, new virtual and/or real formats for the exchange and reflection of employees

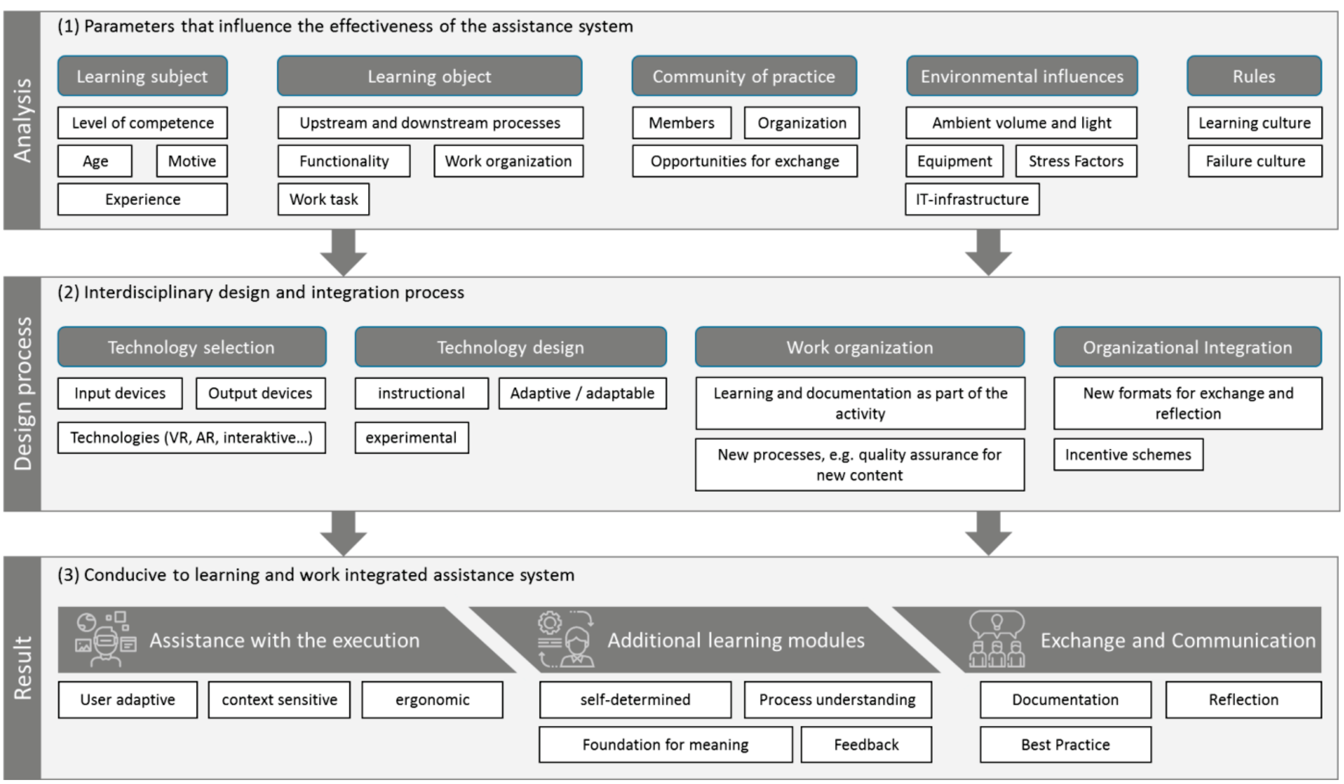

Figure 4: Analysis – Design process – Assistance system

among each other are needed. In addition, methods of motivational psychology are required to create incentive systems for the use of learning and assistance content.

Conducive to learning and work integrated assistance system

An assistance system that supports the employee in the correct and safe performance of his or her work that is conducive to learning and accepted by the employees requires at least the components that are listed in Figure 4 under (3):

- Context-sensitive and user-adaptive assistance during the execution of the activity
- Further learning modules to support the understanding of the process and strengthen the identification with the activity, the product and the overall motive of the organization
- Opportunities to exchange and communicate in order to reflect, adapt and, if necessary, improve one's own approaches with those of the community of practice.

The procedure described in Figure 4 provides guidance for the necessary analysis, implementation and introduction processes. They are to be adapted to the specific activity systems of the companies and their components.

5. REFERENCES

[1] Niehaus, J. (2017). Mobile Assistenzsysteme für Industrie 4.0: Gestaltungsoptionen zwischen Autonomie und Kontrolle.

[2] Keller, A., & Haase, T. (2019). Kognitive Assistenzsysteme in der Prozessindustrie. Ergebnisse eines partizipativen Gestaltungsansatzes.

[3] Haase, T., Radde, J., Keller, A., Berndt, D., & Dick, M. (2020, July). Integrated Learning and Assistive Systems for Manual Work in Production-Proposal for a Systematic Approach to Technology Selection and Design. In International Conference on Applied Human Factors and Ergonomics (pp. 853-859). Springer, Cham.

[4] Bainbridge, L. (1983). Ironies of automation. In Analysis, design and evaluation of man–machine systems (pp. 129-135). Pergamon.

[5] Kölbl, C. (2010). Kulturhistorische Schule. In G. Mey & K. Mruck (Hrsg.), Handbuch Qualitative Forschung in der Psychologie (1. Aufl., S. 182–194). Wiesbaden: VS Verlag für Sozialwissenschaften.

[6] Leontjew, A. (1979). Tätigkeit, Bewußtsein, Persönlichkeit (Beiträge zur Psychologie, Bd. 1, 1. Aufl., 1 Band). Berlin: Volk und Wissen Volkseigener Verlag.

[7] Engeström, Y. (2008). Expansives Lernen in der Arbeitswelt. Für eine Neukonzeptionierung der Tätigkeitstheorie. In L. Rosa (Hrsg.), Entwickelnde Arbeitsforschung. Die Tätigkeitstheorie in der Praxis (International cultural-historical human sciences, Bd. 25, 1. Aufl., S. 61–89). Berlin: lehmanns media.

[8] Bateson, G. (1983). Ökologie des Geistes (3. Aufl.). Frankfurt am Main: Suhrkamp.

[9] Universität Bremen; Universität Karlsruhe; Universität Magdeburg (2007, 1. August). OLIVA - Organisationales Lernen in virtuellen Arbeitssystemen. Konzeptpapier zur Beantragung eines Sonderforschungsbereiches/Transregios bei der Deutschen Forschungsgemeinschaft (1. Aufl.) (Schenk, M., Spöttl, G., Zülch, G. & Jenewein, K., Hrsg.). Bremen.

[10] Dick, M. (2007). Das Lerntätigkeitssystem als Rahmenkonzept für die Gestaltung, Implementierung und Nutzung von VR im Arbeitsprozess. In M. Schäper & M. Schütte (Hrsg.), Kompetenzentwicklung in realen und virtuellen Arbeitssystemen. Bericht zum 53. Kongress der Gesellschaft für Arbeitswissenschaft vom 28. Februar - 2. März 2007 (S. 29–34). Dortmund: GFA-Press.

[11] Haase, T., Termath, W., & Martsch, M. (2013, January). How to Save Expert Knowledge for the Organization: Methods for Collecting and Documenting Expert Knowledge Using Virtual Reality based Learning Environments. In VARE (pp. 236-246).

[12] Gerhardt, M., Haase, T., & Dick, M. (2020, July). Reflections on an Interdisciplinary Approach: Integrating Assistive Technologies and Experience-Based Knowledge in Maintenance. In International Conference on Applied Human Factors and Ergonomics (pp. 787-793). Springer, eCham.